Central Asian Carpet Production:
An Ethnoarchaeological Study for Defining and Attributing Traditional Technologies

by

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A dissertation submitted in partial fulfillment of
the requirements for the degree of

Doctor of Philosophy

(Anthropology)

at the

UNIVERSITY OF WISCONSIN-MADISON

2026

Date of final oral examination: March 12, 2026

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Dedicated to Mom for teaching me to weave,
to Dad for building the looms,
and to Luke for letting me fill the house with carpets.

Acknowledgements

I would like to thank the following University of Wisconsin faculty for their integral roles in the completion of this research. First, Dr. J. Mark Kenoyer for providing helpful and insightful guidance and feedback throughout the entire process, and particularly for his patience and encouragement during the COVID-19 pandemic. I also appreciate the help of Drs. Sissel Schroeder, Nam Kim, Marina Moskowitz, and Jennifer Pruitt for answering questions, giving suggestions, and sitting on my committee. I am indebted to Professor Marianne Fairbanks for helping me experiment with historic textiles and looms, to Professor Cecile Ane for her assistance with data processing and statistics, and to Professor Gulnara Glowacki for not only teaching me Kazakh, but tailoring her lessons to textiles, art, and history to better support my work.

I am also thankful for the helpful discussions, connections, and resources provided by faculty at University College of London, including Professors Tim Williams, Stephen Shennan, Marco Nebbia, Ulrike Sommer, and Paul Wordsworth.

I am deeply grateful to Dr. Gaigysyz Jorayev for over a decade of friendship, encouragement, and opportunities in Central Asian archaeology. He is responsible for showing me that handicraft research in Central Asia was not only possible, but accessible and welcoming.

Many people assisted with my overseas fieldwork in various roles. I would like to thank Novruz Makhumudos, Marzhona Aminova, Nurseit Nomanuly, Murodbek Jumaniyazov, Juma Han, and Sandugash Orynbay for acting as translators in Uzbekistan and Kazakhstan, and for their assistance with on-the-ground logistics. I appreciate the assistance of Khodji Soat Durdi, Faridun Niyazov, Madrim Matkarimov, and Balatbek Beicbekov for granting me gracious access to their workshops, and for their enthusiasm in sharing carpet history with me. I am very grateful for the welcome and assistance provided in Turkmenistan by Sabir Nurmommayeva, Maksat Hudayberdiyev, and the staff at Turkmenhaly and the National Carpet Museum. I would like to thank the Samarkand Silk Carpet Workshop, the Khiva Silk Carpet Workshop, Altyn Orda, and the Otrar Museum for letting me access their space and collections.

Several institutions and their staff granted me access to their collections and were very useful in answering questions and providing background information. These include Archie Williams at Christie's, Frankie Keyworth at Sotheby's, Mutlaq al-Juraid at the Al Sabah Collection, Laura Camerlengo and Randy Dodson at the de Young Museum, and staff at the Victoria & Albert Museum, the Indianapolis Museum of Art, and the Petrie Museum.

I am resoundingly thankful to the weavers who participated in this study for welcoming me into their homes and workplaces, answering my questions patiently, and allowing me to explore carpet weaving through their eyes. Thank you very much to Bashorat, Dilbar Omonova, Durdiposhsha Omonova, Halima Matyaqubova, Kulyash Aidarbekova, Madina Ahmetova, Maftuna Narzulloeva, Maloxat Qurbonova, Mehribon Haitova, Nazokat Aminova, Nigora, Sholpan Zhycinbek, and those weavers who elected to remain anonymous.

I would also like to thank the women who leant their names to the weavers throughout the data analysis process: Alyx Kopie-Miecznikowski, Anna Sluka, Barbara Glas, Carol Miecznikowski, Christina Sluka, Dorothy Sluka, Eleanora Miecznikowski, Ginny Miecznikowski, Janina Miecznikowski, Jean DiBattista, Jennifer Sluka, Kate Sluka, Kathleen Sluka, Mairead Sluka, Margaret Sluka, Monica Miecznikowski, Stephanie Channings, and Teri McConell.

I can never thank my family and friends enough for their support, throughout this degree and my whole life. I appreciate my parents, Jim & Anna Sluka, for their emphasis on the importance of both science and art throughout my childhood, and for supporting me financially and emotionally through over a decade of higher education. I thank my siblings, Justin Sluka-Miecznikowski, Christina Sluka, Alyx Kopie-Miecznikowski, and Bud Denega for laughter and encouragement and commiseration, and for reliably pretending to care and understand when I talked about my research. I thank my extended family for their financial support in helping me to get the education I wanted and for picking me up from airports at all hours of the day, including Jan Miecznikowski, Carol Miecznikowski, and Mitch Ross. I especially appreciate Ginny Miecznikowski and Christina Sluka for their hands-on contributions to the data collection and analysis in this project. Thank you to Ted Levermore, Hannah Thielmeyer, Ali Deatsch, Steve Godfrey, Hannah Gibbs, and Elise Middelton for helping to relieve stress and provide endless encouragement. I am blessed to have had the emotional support of Mafalda, Montoya, and Fez, who love carpets as much as I do.

Finally, from the bottom of my heart, I would like to thank my husband, Luke Channings. Thank you for supporting me in every sense of the word, for encouraging me, for letting me bounce ideas off you, for letting me spend our money on carpets and flights to Turkmenistan and bags of wool. Thank you for doing the dishes while I worked and cooking for me when I was too jet-lagged to do it myself, thank you for setting up VPNs and SIM chips and midnight taxis when I was overseas. Thank you for letting me drag you to Uzbek madrassas and French castles and Anglo-Saxon hillforts. Thank you for everything you've done to build us a beautiful life: I can't wait to put this project aside and share it with you.



Abstract

Due to a very small and widely distributed sample, the technological history of knotted pile textiles is mostly unknown. Disparate fragments, usually of carpets, give reasonable evidence for both technological transmission and multiple independent innovations. This lack of clarity, coupled with modern textiles whose provenance is established by merchants and dealers rather than by historians or weavers, produces a textile sample that is both limited in scope and badly described. To strengthen attribution accuracy and increase potential for intensive research into carpet technical evolution, several goals were addressed. First, a more detailed typological scheme of production characteristics was developed. These typological traits included more than 70 technological and social factors. This classification scheme provides more acute differentiation of similar objects and elucidates differences that are usually overlooked. The traits were categorized through interviews and observation of weavers in six Central Asian communities.

The second goal was to understand if and how these documented traits affect the physical form of the finished carpet. Eighteen modern weavers produced thirty sample carpets which were analyzed with a new method towards this goal. Carpets were photographed from the back, where knots are individually visible. Each knot is recorded by marking its four corners in a geospatial coordinate plane, and the knot's square area and its precise shape were calculated from the coordinate points. Knot sizes were plotted in both the x- and y-axes, representing change in average knot size across the width or length of the carpets. These data were compared to the production characteristics and several correlations identified. The presence of these correlations suggests that some production characteristics create regular, patterned distortion in the knots.

The shape data were analyzed separately using a generalized Procrustes analysis and a principal components analysis. By comparing the clustering of the shapes in eigenvector space, correlative patterns were identified linking different shapes to various production characteristics.

The correlations derived from the modern sample were then used to reverse-engineer production characteristics historic carpets and fragments. Knot size and shape data were measured from fifty-two historic Asian carpets and fragments groups following the same procedure as the modern materials. By plotting the historic data over the modern data, points of similarity in distribution and variance were identified and used to make estimates about the production characteristics that best describe the ancient carpets. For some characteristics, it was possible to compare the confirmed qualities of the historic fragments to the experimentally-derived estimates. Several links to the production characteristics in the modern sample have better-than-random predictive success in describing the historic sample. By evaluating the accuracy of the estimations, the relative value of different correlative patterns was determined.

This work suggests that it is possible to derive normally-invisible production data from historic carpet and fragments, and to identify small-scale differences in structure. This has enormous potential for expanding our limited understanding of archaeological weaving practices, and tracing changes, innovations, and transmissions in carpet technology across time and space. Particularly, it is possible to identify fragment groups which do not appear to have been woven under the same circumstances, and to clearly cluster carpets by their community of production. It also shows early promise in contradicting long-held beliefs about carpet production.

1. Introduction

The research presented in this dissertation is the first step in reaching a long-term goal to better understand the technological history of knotted pile textiles, particularly before c. 1000 CE. Despite dating to at least 1500 BCE in Asia and possibly reaching as far back as the early 3rd millennium BCE (see Hirsch 1991; Riefstahl 1944; Woolley 1934), there is no clear origin point for the technique, nor are there obvious linear links between groups across space or time. These textiles, often referred to as carpets regardless of direct evidence of function, spring up in the Bronze Age without a clear prototyping or bootstrapping trajectory, and with nearly the same structure that is still used by weavers today (Khlopin 1982; Rudenko 1968, 1970). Subsequent artifacts appear separated by enormous distances with no clear transmission link between the two groups, and often with distinct structural and aesthetic styles (see Fujii & Sakomoto 1990; Pfister & Bellinger 1945; Riefstahl 1944; Rudenko 1968, 1970; Woolley 1934; Zhang 2019). This would seem to imply that the technique was innovated several times independently, building off local invention, resources, pressures, and aesthetics. However, the different groups seem to be on precisely the same timelines, with one-off finds of similar quality appearing thousands of kilometers apart but within a century or two of each other. In my opinion, this suggests a concurrent evolutionary trajectory based on shared development or technological transmission, and not multiple wholly independent innovations.

Although many modern scholars and enthusiasts place the origin of knotted pile in Mesopotamia or (slightly less popularly) among Turko-Iranic nomads in the central Eurasian steppe (Böhmer & Thompson 199:30; Dalley 1991:118; Eiland 1973:3; Erdmann 1960:15; Reifstahl 1944:45; Thompson 1993:65), the archaeological and scientific justifications for preferencing those theories above many others are weak (Baker 1995:364; Khlopin 1982:117; Spooner 1986:204). As carpets are an iconic and widespread cultural commodity of many groups across Eurasia, a better understanding of carpets' history could provide insight into aspects of ancient and historic communities at every scale, from their personal mythologies and aesthetic preferences to the wider influence of trade networks and migration.

This question of origin point and the subsequent web of inventions and transmission events that lead carpets to solidify on a common structural style around 1000 CE were my original points of interest in this topic. However, carpet studies do not currently have the data, in either quantity or quality, needed for this type of complex network analysis (see examples of what *is* available in Bidder 1964; Aslanapa & Edmonds (ed) 1988; Edwards 1953; Eiland Jr. 1976, 1979; Eiland III 1993, 2004; Erdmann (ed) 1970; Helfgott 1994; Moshkova 1996; Thompson 1993; Tsareva 1984, 2016). This data limitation can be attributed to three main factors:

1. exceptionally few carpets or carpet fragments survive from before c. 1400 CE;
2. those that survive from the last half-millennium are attributed vaguely, poorly, or not at all; and
3. surviving pieces of all ages are usually described and classified by only a very small subset of their characteristics, primarily aesthetic.

Carpets, and textiles more generally, have been understudied in technological archaeology because of their poor preservation rate and low sample size, as well as a common tendency to discount them as ubiquitous, unspecialized, or "women's work" (Costin 2013:180). This issue is compounded by the fact that many modern researchers have little or no concept of how much time or skill is required to produce textiles, which in turn leads to inaccurate and reductive explanations of textile technology, design, and cultural value (Schiffer & Skibo 1987:598). While this is changing and textile studies are getting ever more popular and enjoying more rigorous theorizing and analysis, it is still very difficult to perform the large-scale comparative tests of standardization, technology, and innovation that more stable media can produce. However, it is specifically because textiles are so ubiquitous, time consuming, and skilled, and because they embody an immense amount of socio-cultural data, that their study is so important. The more people who are involved in a technology, the more refined our hypotheses can become, the better we can understand processes and pressures like invention, transmission, consumerism, novelty, fashion, experimentation, creativity, and identity signaling, and the better we can understand the development of tradition, heritage, and cultural identity (Jolie 2004:313).

With tens of common extant and historic structural and technical variations (see Moshkova 1996 for a thorough overview), carpet-weaving should be an excellent candidate for studies of technological evolution, innovation, and blending across time and space. The structural, technological, and idiosyncratic features of carpets can mostly be swapped at will without significant impact on the structure, function, longevity, or physical appearance of the

finished piece. This means that the pressures acting on carpet technology are not overtly functional or efficient, but instead may be better understood as representations of subtler influences of community identity, superstition, creativity, personal preference, inattention, conformity, conservatism, etc.

Despite carpets' apparent wealth of potential information, the three factors listed above work together to create a historic sample that is not easily studied through technological lenses. The research presented in this dissertation is a step towards removing some of those limitations. This work develops a new system for diversifying carpet classification schemes and tests a new methodology for defining the production characteristics of individual carpets. The diversified classification scheme incorporates far more dimensions of variation than are included in any system I know of in the field today, correspondingly increasing the number of dimensions along which similarity and difference in carpets can be measured and articulated. This expanded typology is joined by a new method for reverse-engineering some of these dimensions from historic carpets, where direct information on production traits is normally lost.

By expanding the available data available on a specific carpets' production, I believe it will be possible to A) better understand the carpet, its production, its weaver, and its social context as an individual, B) to identify new points of similarity and difference among carpet artifacts that were previously unknown or overlooked, and C) to use that new comparative information to confirm, refute, or refine attributions and network connections over time and space. These improvements in carpet data can together act as a framework for more robust and detailed study of carpet technological evolution. Although these network insights were my original goal,

incremental improvement must be made in carpet data first, and so those evolutionary studies are beyond the scope of this work. This dissertation instead focused on testing only the new descriptive methodology. However, this long-term over-arching goal of developing evolutionary network analyses should be kept in mind, as it is useful for contextualizing frameworks and methodological choices in the wider holistic project, and not purely on the explicit experiment described here.

The primary research questions addressed in this dissertation are therefore as follows. First, to determine if technological, idiosyncratic, or social characteristics present during modern carpet production leave a consistent, measurable trace in the finished carpet, as measured by variation in knot size and shape. This question was answered through analysis of small-scale changes in knot size and shape across a sample of modern hand-woven carpets. I anticipated that technological, social, and idiosyncratic factors present during production would cause displacements in the carpet warp and weft, which in turn create tiny distortions in the knots built upon them. When quantified, I suspected that these small differences could be associated, through scale, direction, or distribution, with specific production characteristics.

Second, I wanted to know whether these associations between knot distortion and production characteristics in modern carpets could be used to backwards-engineer the production contexts of historic carpets through measurement of similar knot distortions. Where similar knot distortions are measured in an ancient or historic piece, I suggest that a similar (if not identical) trait was used in the historic production. Where successful, I anticipated that these

connections could provide a wealth of new information on production technologies and pressures which are normally not “visible” in historic carpets.

Through the analysis presented in later chapters, I determined first that there do seem to be some consistent distortions of knot size/shape created by specific technological, social, and idiosyncratic characteristics. Although not every tested characteristic resulted in a measurable change, several (including the use of supplemental rods to tension the warp, reference to pre-drawn designs, and the personal flair of the individual weavers themselves) did create distinct changes in knot size/shape. These changes represent both distributed and random variation, suggesting a larger relationship between the micro-scale knots and the macro-scale loom and social setting.

Once I identified these correlative changes in knot size/shape, I used them to backwards-engineer the production settings of historic carpets and fragments. Based on a testable subset of measurable structural traits, where the reverse-engineering predictions could be directly confirmed or refuted, I identified several knot patterns that resulted in a better-than-random predictive outcome. Not all the production characteristics with a correlative knot change generated accurate predictions; only a smaller subset which represent specific kinds of knot variation did that. Namely, characteristics with variation in the carpet’s x-axis and variation showing a statistically significant change in variance were more successful than traits with variation in the y-axis, or ones with a change in mean size. These results and conclusions are discussed in more detail in Chapters 8-10.

Basic Theorizing

Technology underpins every object that we interact with, both today and in the past. It is entirely pervasive, influencing and receiving reciprocal feedback from nearly every aspect of human life (Dobres 1999:130; Hayden 1998:3). Because of this, study of technological systems can provide insight into social, cultural, religious, linguistic, mythological, and even biological organizations, worldviews, and structures (Dobres & Hoffman 1994:213; Fitzhugh 2001:128). It is inherently multi-dimensional, with avenues for the study of materials, economics, function, design, and fashion; and multi-scalar, providing insight into large-scale processes like migration and warfare, but also individual processes of invention, creativity, skill, and personal aesthetics (Dobres & Hoffman 1994:213; Lemonnier 1986:154; Roux 2010:217). In order to meaningfully contribute to wider understanding of life in the past, technological studies themselves must be multi-focal, multi-dimensional, and multi-scalar (Bentley 2015:124; Dobres & Hoffman 1994:212-213; Dorland 2018:893; O'Brien & Shennan 2010:5).

Most of us have a general intuition for what technology is, and we do not initially think we need to define the word. A succinct definition provided by archaeologist Edward Jolie seems to sum up the popular understanding: "techniques and raw materials used to manufacture a product" (Jolie 2004:307). At first glance, this seems to cover it. But it can rapidly get out of control when we consider where exactly the edges of a technology, technological system, or technological network fall. Whether a technological study should include aspects of raw-material processing, material transportation, tool construction/maintenance, post-production processing,

or use-life repairs and reuse is not universally agreed, nor is the amount of similarity or difference required to define a separate technological system.

A community-of-practice (CoP) approach is therefore one foundational paradigm of this dissertation. One of the theory's most useful features is it focus on boundaries. Boundary drawing, boundary maintenance, boundary jumping, boundary decay, peripheral participation both just inside and just outside the boundary, and the measurement and evaluation of variation both within and without the boundary are all considered within the framework (Gandon et al. 2018; Harush 2020; Lave 1991:64; Lave & Wenger 2001:112; Nicklin 1972; Roux & Krasik 2018, Roux 2020; Wenger 2000:232). The framework does not presuppose where boundaries should fall in relation to a specific technology based on modern or ethnographic parallels, but rather attempts to identify and define the boundaries, wherever they measurably exist in the archaeological record. This creates an almost "nesting doll" approach where communities are situated and defined by increasingly narrow characteristics of relatedness, ultimately reaching down to even a single person in some cases (Gandon et al. 2018; Roux & Krasik 2018). A community-of-practice, as a unit of analysis, can therefore be very focused and exclusive, or very open and inclusive. By focusing on the boundaries and where and when the group maintains and replicates those boundaries at different scales, some insight can be drawn for where to bound archaeological technology studies. Rather than trying to define the boundaries of a technology or system from a modern or even ethnographic point of view, a CoP approach can provide guidance on how inclusive or exclusive a particular technological sequence or web should be, using lateral references to factors like spatial or temporal distribution of similar and dissimilar

artifacts. This is one of the basic goals of this research: to identify similarities and differences in ancient carpets that may indicate social-cultural boundaries, shared context, or a technological lineage.

This attribution of different techniques and pressures to distinct communities-of-practice could, I believe, have extended application in a technological evolution framework. Cultural and technological evolutionary research benefits greatly from multi-point comparisons, just as biological evolutionary research does (Boyd et al. 1997:2; Tehrani & Collard 2009:12). The more traits that can be compared between groups and across time, the more robust models and predicted relationships will be. Working from a CoP mindset of practitioners sharing more traits with those within their community than outside it, an evolutionary study can determine which traits to include in a comparative phylogeny based on which best represent community membership, vs. which seem to be distributed more randomly.

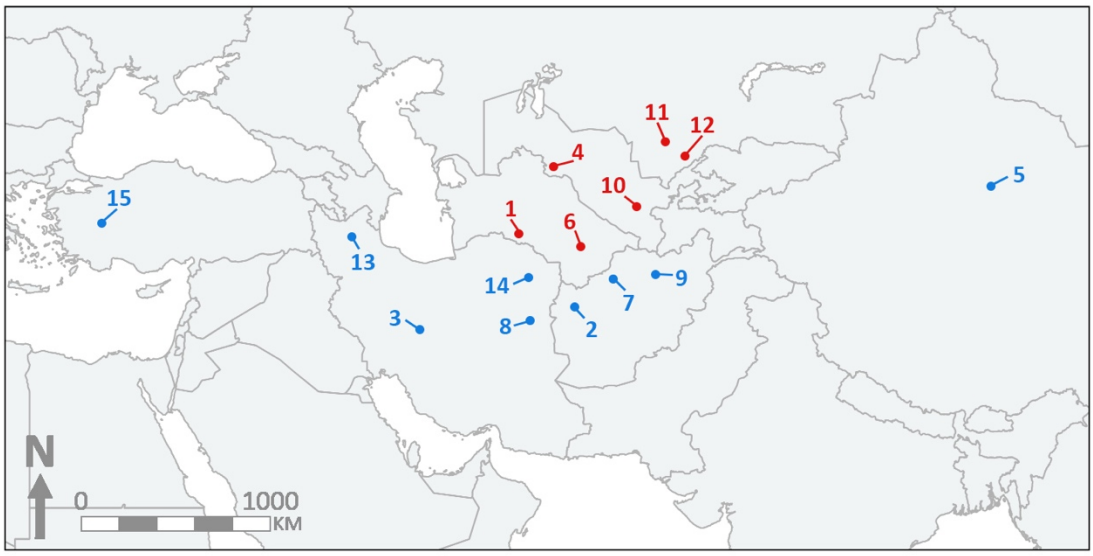
These two frameworks therefore work well as the foundation for this research. The techniques presented here have the potential to increase information on communities of artisans working in the past, and in turn to provide useful boundaries for defining trait complexes which might survive, transmit, or die out as a group. It is on this assumption of in-group similarity and both independent and multi-point transmission of traits across time and space that the themes of this dissertation are built.

Answering the Research Questions

The foundational step in answering the questions listed above was to build and measure a modern carpet sample. Despite nearly three thousand years of history (at least) and a native range across much of Asia, carpet technology appears to have changed very little since the 2nd millennium BC, with most if not all the extant techniques appearing in ancient contexts. The combination, quality, and distribution of techniques change, but there isn't much evidence for the structures themselves changing in meaningful or permanent ways. In fact, a modern weaver probably wouldn't have any difficulty recreating an ancient textile, because it would not require any special skills or tools that she does not already employ. While certainly some ancient techniques are no longer popular, I do not think it is accurate to say any have truly died out. This multi-millennia consistency provides an excellent opportunity to build understanding of ancient carpet-weaving on a scaffold of modern ethnographic reference.

By incorporating an ethnographic perspective, I introduce more detail and clarity to the three issues faced by historic studies of carpet technology discussed above. Based on discussions with and observation of eighteen traditional hand-weavers living in Kazakhstan, Turkmenistan, and Uzbekistan (Fig. 1.1), I developed a classification and descriptive scheme that goes into far greater detail than any currently used in carpet studies. This scheme includes individual description of very small-scale structural, technological, social, and idiosyncratic factors, such as the specific tools used, the sequences of non-linear steps, the handedness of the weaver, the amount of oversight or quality control the weaver was subjected to, etc.

Figure 1.1: Map of Experimental Locations



1 Ashgabat, Turkmenistan
2 Herat, Afghanistan
3 Isfahan, Iran
4 Khiva, Uzbekistan
(including villages of Angarik, Ingilis, and Gondimiyon)
5 Loulan, China
6 Mary, Turkmenistan
7 Maymana, Afghanistan
8 Qaen, Iran
9 Samangan Province, Afghanistan
10 Samarkand, Uzbekistan
11 Shauldir, Kazakhstan
12 Shymkent, Kazakhstan
13 Tabriz, Iran
14 Torbat-e Heydarieh, Iran
15 Ushak, Turkey

Color Key:
Ethnographic Carpets
Historic Carpets

This addresses the widespread and inherently biased issue of modern carpet categorization schemes based on a very limited subset of traits. By more clearly defining traits and documenting them as individuals rather than as generalized complexes, new and interesting information can be drawn from the existing sample of historic carpet fragments. Describing structures acutely is the first step to identifying similarities and differences, and explaining them

in a meaningful way. A complete database of each modern weaver's traits, organized through their application to individual carpets, is given in Appendix C.

The ethnographic collaborations employed here provide insights that are not usually possible in archaeological assemblages, particularly prehistoric ones: description of lived experience. While many of the traits I documented are physical/structural and can therefore be "read" directly from the carpet with no reference to the weaver, many others require direct knowledge of the weaver, her tools and techniques, her workshop, and her wider cultural context. In the case of the ethnographic classifications, this "invisible" information was provided directly by the weavers. Without direct access to the ancient and historic weavers, these characteristics are generally unknowable in archaeological and historic contexts.

The diversified, multi-dimensional classification scheme built with the modern weavers addresses the first half of my first research question: whether production characteristics create a measurable and consistent change in knots sizes and shapes. Clearly delineating and defining the different traits is a necessary step in linking them meaningfully to any measured variation in knots.

To address the rest of that first research question, I took small-scale measurements of individual knots in thirty modern carpets made by the participant Central Asian weavers. Building from an earlier pilot study (V. Sluka 2017), I refined a method for mapping individual knots in each carpet by marking their corners in the geospatial program QGIS. Using the program's native coordinate reference system, I generated a spatial map of knot corners which were used to calculate the individual shape and size of each knot. Using a normalization scheme representing proportional variation within the carpet, I generalized the knot data across all the modern carpets

made with the same trait(s). Treating the knot size and shape data separately, I identified distributions and patterns of knot variation that correlate to individual production traits. Several patterns were identified, representing both lateral change in knot-size across the length and width of carpets, and differential occurrence of squarer vs. more rectangular knots in carpets made with different techniques.

This completes the first research question: yes, it is apparent that some production characteristics do have a distinct correlation to knot size and/or shape. While not all the measured traits seem to produce correlative results, several do. These are represented by both spatial patterns in variation across a carpet's surface, and by more generalized non-spatial variation levels. These correlative patterns were confirmed using statistical tests for differences in mean and variance, and for non-random sequencing.

Using the correlations derived from the modern ethnographic carpets, I followed the same procedure to map knot data from a set of ancient and historic carpet fragments over the ethnographically-derived data. Where the ancient/historic data followed the same patterns and distributions as the modern data, I produced a predicted characteristic for the ancient/historic piece. For instance, if Historic Carpet A has knots whose size and shape are very similar to modern carpets woven by a right-handed person, I conclude that Historic Carpet A may also have been woven by a right-handed person. This reverse-engineering scheme was used to predict the most likely trait used in production in each of 52 ancient/historic carpets.

Because my production characteristic typology scheme includes both "visible" and "invisible" traits, or ones that can be read directly from a carpet (visible) and ones that require

access to or observation of the weaving process (invisible), some of my predictions could be directly checked against the observed, visible structure of the historic carpets. I determined that many of the trait-knot correlations generate predictive estimates for the historic carpets that are no better than random chance. However, a subset of traits was predicted at better-than-random accuracy. These include estimates based on the physical orientation of warp and weft threads to knots, the fiber material used for the different components of the woven structure, and the number of weft threads between consecutive rows of knots. Although it is intriguing that these specific traits were predicted at better-than-random accuracy, their individual predictive value is, in my opinion, less important than understanding why these specific traits were successful while others were not.

By comparing the data in these successful traits to the less successful traits, I determined that there are some useful observations that can help to winnow down which traits are likely to be predictive going forward, and which are not. First, in general, the knot size seems to have more predictive power than the knot shape. Although some shape-based predictions were better-than-random, they were fewer and have less similarity between them to explain why they were successful. Second, the overall rate of knot-size variation within a carpet was not linked to predictive success. Instead, the *distribution* of variation was the useful feature. And specifically, patterned distribution of variation in the carpets' x-axis, and not the y-axis, is what best suggested a trait's ability to predict the historic/ancient data accurately. While it is not possible to directly check the success of my predictions for the "invisible" ancient/historic data, it seems reasonable to assume they follow similar success patterns as the "visible" data.

These results answer my second research question: whether patterns derived from modern carpets can be used to reverse-engineer historic traits. It seems that in some cases, yes, this is possible. While the overall success rate here was low, it is promising to see that some traits had better-than-random predictive value. I believe this evidences the analytical value of my method, and suggests that even better information could be accessible with refinement of the technique and expansion of the comparative sample.

In addition to answering my doctoral thesis questions, these predictions of invisible ancient/historic production characteristics address all three of the big problems faced by carpet technology research. First, if the invisible traits can be predicted with some reasonable accuracy, or even if they can be used to winnow possibilities to a more manageable subset, then ancient/historic carpets can be described by a larger set of characteristics. These would expand outward from just the basic macro-level physical-structural information readily available now to include technological, social, and idiosyncratic classifications. In other words, this method seems capable of taking some previously “invisible” traits and making them “visible” through close analysis. Just as a more nuanced description of modern carpets would improve our ability to classify and explain similarities and differences between carpets, weavers, or groups today, the same is true of ancient/historic carpets.

This in turn assists with the other two issues in carpet research: the very small sample, which is mostly attributed only vaguely. Although there is nothing we can do to directly expand the small sample, methods like the one developed here may increase the amount of information that can be drawn from the limited sample, increasing its relative historic and scientific value.

Similarly, if ancient/historic carpets can be described by a larger and more detailed web of traits rather than the generalized structural schemes common today, it should become more apparent which carpets should be classified together, and which represent distinct traditions, pressures, or contexts. These webs of similarity and difference could therefore be used to confirm, refute, or refine the surface-level attributions currently available, and in turn create a more robust network of data for tracking technological change across time and space.

Although evaluating carpet evolution as a network process across the Eurasian Bronze and Iron Ages was my original interest, attempting to identify or outline individual invention or transmission events is well outside the scope of this dissertation. Still, it is worth considering when evaluating the method tested here. The general base of the communities-of-practice framework posits that materials made by a single community are more similar than those made by different communities (see Lave 1991; Lave & Wenger 2001; Roux & Krasik 2018, Roux 2020; Wenger 2000). Recent research into small-scale variations has been used to identify where macro-scale typologies and classification schemes overlook finer differences in learned gestures and techniques in other archaeological media (Gandon et al. 2018; Harush 2020; 2025; Roux & Krasik 2018). A similar concept applies here, where carpets have historically been categorized through macro-scale comparisons which overlook or even obscure considerable variation and nuance representing different social structures and technological lineages. Like many fields in both the social and hard sciences, carpets have fallen victim to our inability to differentiate homologous and analogous evolution. The method tested in this dissertation, built on a “micro-typology” (Harush 2025) of many granular traits and measurements, seems to have promising

potential for differentiating not only the traits used in production, but also the more nuanced personal idiosyncrasies and gestural signatures of the communities and individuals involved. This type of fine detail, even to the level of the individual, provides a very strong base for constructing evolutionary models and lineage trees, ultimately leading to a more rigorous and detailed explanation of carpet origins.

Text Outline

The dissertation text is divided into three main parts. These are the theoretical background, an outline of carpet history, techniques, and structures, and the novel experimentation and analysis. Some figures are given in-line with the text: the remaining figures can be found at the end of each chapter. Tables with direct input on the text are similarly printed in-line or at the end of the chapter.

The first section covers the conceptual grounding for the project, given in Chapters 2-4. This begins with a more detailed exploration of the research questions and hypotheses in Chapter 2. This chapter outlines archaeological and technological concepts imminently relevant to the development of those questions, as well as summarizes the limited work that has been carried out on knotted carpets in similar thematic spaces. This section also outlines four longer-term goals. These are outside the achievable scope of this dissertation, but are questions which I believe could be answered through a concerted and refined application of the methodology tested here. These longer-term goals, ultimately including my original interest in network

dynamics of carpet evolution, are the overarching context of the more proximal questions, and the proximal questions were formulated with these larger goals in mind.

Following introduction to the research questions and hypotheses, Chapters 3 and 4 dive more deeply into the theoretical and methodological grounding (respectively) of this project. This background provides context for the development of the research questions and goals, both imminent and long-term, and gives logical support for the basic methodological assumptions employed.

The second section of the dissertation provides formal historical and technical information on carpets and the knotted pile technique. It starts with a historical survey of the knotted carpet technique (Chapter 5), as it stands today. While direct historical questions are not addressed in this dissertation, the historical survey is included as an exploration of the medium. This type of information, presented in a linear narrative and examining all the major archaeological evidence, does not appear to currently exist in the popular or scientific literature. None of the resources I found, including ones presented as holistic outlines of carpet history, detailed more than half of the evidence given here. Much of the literature is presented as if the missing information is not just excluded from that specific work, but as if it doesn't exist at all. Biases and assumptions rampant in the literature are magnified by much of the most recent (and empirical) research being published in Russian or Chinese. This makes it incredibly difficult for English-speakers to develop or report a coherent understanding of the field or our understanding of carpet origins and evolution as it stands today. Without that type of historic grounding however, I believe it is difficult to contextualize the technological and social information gaps that this dissertation's new

methods start to fill. This section aims to create an accurate foundation from which new research can build. Those not deeply familiar with carpets, other textile structures, and general weaving processes may find it helpful to refer to the glossary (Appendix F) while reading this section. This section also includes a discussion of the term 'carpet', and how it is used inconsistently throughout the field, even to the point of misunderstanding and confusion. Reference to the maps in Appendix A may also be useful throughout this chapter and the following one.

A more detailed descriptive structural analysis of the knotted pile technique is given in Chapter 6. This includes formal definitions of 'knotted pile' as well as of all the structural weaving terms used in the data measurements and analyses later in the text. A clear understanding and definition of these terms and variations is critical to a well-rounded report, and to reproducibility in my work or extension into new tests and projects based on my results. Those not deeply familiar with knotted pile weaving may find it helpful to refer to this chapter throughout their reading of the other sections, as many tools and techniques are referenced throughout, but which cannot be redefined at every use. A much simpler and less nuanced glossary can also be used as a quick reference (Appendix F). Additional structural and technical information about the specific sample carpets used in the methodological experiments are provided in the appendices: structural diagrams of all sampled carpets are in Appendix B, and a database of production characteristics for all sampled carpets is in Appendix C.

In the last part of the dissertation, the practical research project is described. In Chapter 7, the methodology for the experimental work is given. This covers the sampling scheme for both the modern and historic carpets included in the measurements, description of the weavers

involved in making the modern sample, explanation for the selection of the historic pieces, and the documentation process. It continues on to describe the preparatory steps in orienting, labelling, and photographing the carpets. Finally, a description of how measurements were collected, transformed, and standardized is given. At the end of this chapter, the research data have been cleaned and are ready for comparative analysis.

Chapter 8 covers this analysis, including description of the statistical tests used, presentation of plots, and explanation for various analytical choices. The data are divided into two categories which are analyzed separately. First is the knot size data, which was studied through spatial distributions within the carpets. The knot shape data is described next. This chapter provides the analytical results that were ultimately used to answer the first research question (whether production characteristics create consistent patterns of variation in knot size/shape). It relies heavily on reference to the analytical plots and statistical results given in Appendix D, as well as understanding of the technical-social characteristics defined in Chapter 6.

To answer the second research question (whether the correlative trait-knot patterns can be used to reverse-engineer information from historic carpets), the knot distortion patterns identified in Chapter 8 were used to estimate the production characteristics represented in the historic carpet sample. These historic estimates or predictions are described in Chapter 9. This includes how the estimates were made and provides a number of representative examples. It also details a few issues in the process. All the trait estimates for all the historic carpets are given in Appendix E, organized by carpet.

Finally, the dissertation concludes with a discussion of the analytical results and how they should be interpreted in the context of the proximal research questions (Chapter 10). Potential issues in the sampling scheme and methodological application are discussed as well. Possible next steps and potential improvements are given, as are considerations for how these results fit in the longer-term goals of describing, attributing, and mapping carpet evolution.

Chronology

This project is not a classic archaeological assemblage analysis; the relative chronology of the ancient/historic carpets included is not of inherent interest here. While certainly their temporal (and spatial) relationships are foundationally relevant to the onward goal of improving understanding of carpet history, the pieces are studied only as individuals here, with no direct consideration of their temporal position or contexts. These pieces are included as a test for the methods, not to learn anything new about the carpets themselves. The chronological framework of this project is instead defined A) by a simple division between the modern/ethnographic carpets and the historic/ancient ones used in the methodological experiment, and B) through a simplified timeline of carpet history.

First, the modern ethnographic carpet samples directly analyzed here are divided from the ancient and historic ones also analyzed. Throughout the text, the modern sample are described as “modern” or “ethnographic”. These carpets were all produced in 2021, and their relative age within that year span is not available – orienting them in temporal order is therefore not possible (or necessary). These carpets were produced in Kazakhstan, Turkmenistan, or

Uzbekistan: their individual attributions and additional metadata details are available in Appendix C, and in Chapter 7.

The archaeological sample carpets are always described as “ancient” or “historic” in the text. These carpets were produced over approximately two thousand years, with the earliest dating to the turn of the common era, 150 BCE – 60 CE (carpets MU-VA-3:4), and the most recent to the late 19th century CE (carpets MU-IN-1:7). See a full table of sample carpet dates in Table 1.1, printed at the end of the chapter. These carpets’ geographic attributions are reproduced as given by their owning institutions, locating to sites across Eurasia. Individual attributions as well as the owning collection, catalogue number, and structural details are available in Appendices A and B, and in Chapter 7.

The methodological or experimental chronology of this dissertation can therefore be summed up simply by the division between the modern/ethnographic and ancient/historic carpet groups. Individual chronological precision is not relevant, except to situate them in the wider carpet history.

The carpet history referenced throughout the text, and narrated in detail in Chapter 5, covers nearly five thousand years and a significant portion of Eurasia and North Africa. Therefore, using the names and dates of each site/artifact’s regional-cultural chronologies is not realistic for a cohesive narrative. It is particularly difficult to make cross-cultural comparisons and links when events and cultural output move asynchronously between local periods. Instead, a generalized chronology is established for the historical discussions which attempts to capture major regional periodization, while prioritizing division between cultural and technological shifts relevant

specifically to carpets. This means that some period terms are used outside of their local definitions. Where appropriate, local chronological ages are given in the text alongside the generalized periods. When no contrary indications are given, periods should be assumed to reference the chronology given below.

The earliest period used here is the *Neolithic*. I here define the Neolithic as before 3500 BCE. This period is touched on only briefly, as no direct evidence of knotted pile carpets or related techniques is known from this time. Limited evidence of other textiles instead provides glimpses into what might be possible for carpet technology in this period, even if it is not confirmed.

The *Bronze Age* follows the Neolithic, defined in this study as 3500-1000 BCE. In carpets, this period sees the earliest (surviving) evidence of knotted pile weaving, both through primary artifact remains and through secondary tools, depictions, and linguistic clues. Primary carpet artifacts are generally one-offs in this period, with no clear bootstrapping or development evidence. Knotted pile is definitively known in Egypt and western China during the Bronze Age, and there is strong evidence that it may also have existed in southern Central Asia/the northern Iranian Plateau and Mesopotamia. Structurally similar but non-pile techniques also appear in Europe, suggesting a continent-wide diversification in weaving technology.

Carpet history becomes much clearer in the subsequent *Iron Age* (1000 BCE-500 CE). It is during this period that widespread primary evidence for knotted pile weaving appears, with evidence from Mesopotamia, the Near East, the Iranian Plateau, Central Asia, south Siberia, and western China. The vast majority of what we might consider “archaeological carpets” date to this time, and many literature resources (both popular and academic) erroneously site this period as

the origin of the technique. Particularly around the turn of the common era, the number of surviving pieces grows exponentially from earlier periods. Similarly, the diversity of woven structures seems to reach an all-time high towards the end of this period.

Following the Iron Age, I use the *Middle Ages* to describe a period wherein there is a relative decline in carpet evidence from the previously-strong carpet centers. I set this period between 500-1200 CE. Until only the last few decades, only a few scraps were known to date to this period, despite the relative explosion in evidence in the late Iron Age. While more recent findings have improved visibility of Medieval carpets, their distribution still seems to have taken a dip compared to the trajectory that might have been expected by their success around the turn of the common era. A few tantalizing references by travelers across the continent suggest the carpet industry itself remained strong, and rather it is the survival rate that drops off for whatever reason.

Like the rebirth experienced in European science and culture in the mid-2nd millennium CE, knotted pile carpet industry also seems to be "reborn" around the 13th century CE. From the 13th-18th centuries, documentation suggests a huge number of carpets are produced, thousands of which still survive in world collections. I therefore use the same evocative term as is used for the European rebirth period. Most (if not all) of the surviving *Renaissance* carpets were produced in court or elite workshops associated with major Asian empires and kingdoms, including the Seljuks, Mamluks, Ottomans, Safavids, and Mughals. These carpets are produced at scales completely unprecedented, and this period also sees the first irrefutable evidence of Asian knotted-pile carpets reaching western Europe. By the time this period of carpet history begins,

the technique has also condensed onto only a few variations, significantly reduced from what is extant from the late Iron Age. The pieces from this period would be recognized as Asian knotted carpets even by a modern lay person, and the techniques used remain generally unchanged into modern day.

I give the end date of the carpet Renaissance as 1750 CE, when the fall of several carpet empires coincide with the early industrial age. Increased globalization, social and political restructuring across Eurasia, and competition from machine-made products leads to a general reduction in carpet production (and most other handicrafts) in this *Modern Period*. Although carpets enjoy a few short-lived regional fads over the subsequent three centuries, they have never re-attained their Renaissance popularity, nor have major changes in technique or material occurred.

Of course, this chronological system has rather fuzzy boundaries. Pieces produced at transitional periods may conceptually or structurally fit better into the earlier/later period than the one their date assigns them. However, I believe this is a useful framework for contextualizing different carpets in both the landscape of carpet production at the time, and in the relative differences that exemplify each period and the trajectory of carpet history.

A summary of my periodization timeline can be found in Table 1.1. This table also includes the historic carpets included in the analytical sample, as well as a few key touchstone artifacts from carpet history.

Table 1.1: Project Chronology (continues to next page)

Project Chron.	Historic Carpets in Project Sample	Key Artifacts in Carpet History
Neolithic (<3500 BCE)		Evidence for weaving in Eurasia (from 7th mill. BCE)
Bronze Age (3500-1000 BCE)		Woolley's Pile Fragment from Ur (?) (2600 – 2300 BCE)
		Beauty of Loulan Woven Pile (c. 1800 BCE)
		Soumak in Central Europe (1700 – 1440 BCE)
		Tomb of Madja Knotted Pile (mid 15th cent. BCE)
		Tomb of Kha & Merit Knotted Pile (early 14th cent. BCE)
Iron Age (1000 BCE – 500 CE)		Pazyryk Carpet (3-5th cent. BCE)
	MU-VA-3; MU-VA-4 (150 BCE – 60 CE)	
	MU-AS-7 (130 – 270 CE)	Dura Europos Knotted Pile Fragments (3rd cent. CE)
	MU-AS-18 (114 – 348 CE)	
	MU-AS-14 (280 – 340 CE)	Al-Tar Knotted Pile Fragments (2-4th cent. CE)
	MU-AS-9; MU-AS-17 (220 – 410 CE)	
	MU-AS-12 (332 – 430 CE)	Yingpan Cemetery Carpets (4-5th cent. CE)
	MU-AS-1 (380 – 540 CE)	
	MU-AS-3 (378 – 598 CE)	
Middle Ages (500 – 1200 CE)	MU-DY-2 (418 – 602 CE)	
	MU-AS-10 (415 – 640 CE)	
	MU-AS-5 (540 – 585 CE)	
	MU-AS-4 (543 – 638 CE)	

Table 1.1: Project Chronology (continued)

Project Chron.	Historic Carpets in Project Sample	Key Artifacts in Carpet History
Middle Ages (500 – 1200 CE)	MU-AS-16 (500 – 699 CE)	
	MU-AS-11 (535 – 680 CE)	
	MU-AS-8 (565 – 655 CE)	
	MU-AS-2 (1010 – 1160 CE)	Konya Carpets (12-13th cent. CE)
Renaissance (1200 – 1750 CE)	MU-AS-6 (1150 – 1260 CE)	
		Marco Polo notes carpets across Asia (1271 – 1296 CE)
	MU-VA-2 (early 15th cent. CE)	
	MU-DY-1 (15th cent. CE)	
		Cairene Carpets with evidence of mass-manufacture (16th cent. CE)
	MU-CH-5 (early 17th cent. CE)	Imperial Carpet Boom (16-18th cent. CE)
	MU-AS-13; MU-SO-1; MU-SO-3; MU-SO-4; MU-VA-1 (17th cent. CE)	
	MU-CH-4 (late 17th cent. CE)	
	MU-CH-6 (1662 – 1722 CE)	
Modern Period (>1750 CE)	MU-CH-7 (18th cent. CE)	
	MU-CH-2; MU-CH-3 (late 18th cent. CE)	
	MU-CH-1 (c. 1800 CE)	
	MU-SO-2 (19th cent. CE)	
	MU-IN-6 (mid 19th cent. CE)	
	MU-IN-3 (c. 1870 CE)	1873 World's Fair sparks Victorian Carpet Boom (1873 – 1914 CE)
	MU-IN-2; MU-IN-4; MU-IN-7 (late 19th cent. CE)	
	MU-IN-1; MU-IN-5 (c. 1875 CE)	
		Tribal Carpet Boom (1960 – 1990 CE)
	All project ethnographic carpets woven (2021 CE)	

2. Questions, Hypotheses, and Goals

Research Questions

This dissertation had two immediate goals, which were answered by developing and testing a new methodology for measuring small-scale variation in knotted pile carpets. These questions were oriented in the wider carpet studies landscape, and aimed to provide a first step towards expanding available information on ancient and historic knotted pile textiles. The two immediate goals were narrowly-defined to be evaluated realistically within the bounds of a single doctoral project. However, they were formulated in the context of several longer-term goals, which I expect to require additional resources and testing to address. Although they cannot be directly answered from this work, understanding the long-term goals is an important part of situating this dissertation in modern carpet studies. The two immediate goals of this dissertation were:

1. To determine if technological, idiosyncratic, or social characteristics present during production leave a consistent, measurable trace in a finished carpet, as measured by variation in knot size and shape.

2. If any such traces exist, to learn to what extent these same characteristics can be backwards-engineered from variation in knot size/shape in historic carpets.

The first goal was to establish links between technologies and production pressures and recognizable, measurable traits in the object. Like the concentric finger marks in wheel-thrown pottery, the fish-eye in crown glass panes, or the distinctive rippling of the Damascus steel, I hypothesized that some aspects of production may leave identifiable marks in a finished carpet. This was based on my wider experience with textile techniques and hand-made media, and on my previous studies using small-scale analysis to draw conclusions about textile production and design. The limited pilot for this project (V. Sluka 2017) showed that a lack of enforced warp spacing in modern Turkmen carpets creates a measurable trapezoid distortion in the knots: even when not visible to the naked eye, the distortion still appeared on closer analysis (ibid., pgs. 45-49). Because the distortion was neither lessened nor reversed as the weaver worked up towards the end of the carpet, we can reasonably say that the warp bars in the loom used did not have an enforced spacing system, which would have corrected the distortion, at least partially, as the weaving approached the top warp bar.

That same project also showed that professional status was not a good indicator for the rate of knotting mistakes, as weavers in a government workshop produced several examples of large-scale mistakes in addition to smaller, more random ones (ibid., fig. 19). Quality, it would seem, is not always a robust indicator of skill or experience.

Another study (V. Sluka 2018) used reflected-light interferometry to measure the diameter of individual threads in experimental knotted textile impressions. In a hand-spun, hand-dyed carpet, the micron-scale measurements were able to distinguish yarns of different stock, which looked identical to the naked eye. This was used to estimate design motifs in the impression,

giving insight that would not normally have been possible for a knotted textile whose aesthetics are completely non-structural. Other conclusions could be possible with more intensive research, including estimating the length of skeins or the number of people involved in spinning the yarn for a single item.

Results from these limited-scope studies prove that fine measurement of textile features can reveal useful information that is normally inaccessible. This type of detailed comparison is already widespread in other media classes (particularly ceramics; Harush 2020, 2025; Herzlinger et al. 2017; Roux & Krasik 2018; Valletta & Grosman 2021, and many others), and I believe there is great potential for its creative application to textile archaeology. This project builds on that potential, and aimed to identify production markers in a controlled ethnographic knotted carpet sample.

Knots are tied individually and can vary both individually and collaboratively. They are also discrete units with definable boundaries for measurement, and a standard carpet has thousands or even millions of knots. These factors together make knots a consistent and robust unit for mathematic and statistical measurement and comparison in knotted textiles. I hypothesized that variation in the knot size and shape, both on average and as a spatial distribution across the plane of the carpet, can carry technological markers that indicate tools, techniques, and weaver idiosyncrasies. The 2017 study discussed above is a limited example of the type of links that may be possible: it was differences in knot size between the center and vertical sides of the carpets that indicated a trapezoidal distortion, and in turn non-spacing warp bars (i.e., the loom structure does not maintain even spacing between warp threads). With more detailed and robust analysis

and added study of knot shape in addition to size, I believed more patterns like that would emerge.

The analysis used here was necessarily based on relative knot size, not absolute knot size. Different yarns, different quality targets, and different materials will naturally introduce absolute variation in size: no matter what techniques are used, a carpet with a knot density of 10 k/cm^2 will always have knots of a different size than a carpet with a knot density of 50 k/cm^2, even when woven by the same person with the same techniques. Instead, I was looking for relative changes. This might have included include random or spatially-patterned changes in relative knot size. A similar analysis pertained to knot shapes, measured separately.

This first research question was answered by analysis of a modern ethnographic carpet sample. Because I could access details about production, weavers, and communities in a modern ethnography that would be completely unknowable in a historic carpet, the modern sample allowed me to link any measured outcomes directly to the production characteristics without having to postulate on possible causes. A varied modern sample including carpets made in different ways contributed to robust results, ensuring that it is the particular production variable in question that is causing changes, rather than individual human or material variation. Detailed measurements of the modern carpet knots were taken and compared to the production characteristics, looking for common patterns and predictive models. Details on the sampling scheme for the ethnographic carpets and the data collection methods are given in Chapter 7.

The second proximal goal of this study was to use the identified links between knot forms and production characteristics, where they exist, to estimate the production characteristics of

historic textiles for which this information is not known. This was based on similar patterns of knot form that are measured directly from the historic pieces: if a similar pattern appears in a historic piece as is linked to a particular production characteristic in the modern sample, it is reasonable to deduce that the historic piece was made with the same or similar techniques. This follows the same inference by analogy used throughout modern archaeology.

These two questions and the dissertation as a whole should be viewed as a methodological test or proof-of-concept, rather than as an absolute attempt to draw firm conclusions about the individual historic carpets studied, their weavers, communities of practice, or technological evolution. The goal was to evaluate the possibility of matching knot-form measurements to production characteristics and the applicability of matching ethnographically-derived patterns to historic samples, and to posit some ideas on how this or similar methodologies could be refined to better explain historic variation. Definitive conclusions about individual historic pieces would have to be a goal for the future, when a more diverse and robust comparative ethnographic model has been built. Every attempt was made to diversify the ethnographic sample for this project, but limitations arise in any project and should not be ignored.

Several topics were explicitly outside the scope of this dissertation and the methodology it tests. Although the knots are solely responsible for creation of designs and the visible surface of a knotted textile, the aesthetics built by the knots were not studied here. This is an analysis of structure and manufacture alone. While structure and design are tightly linked in many textiles, that is not the case in knotted textiles. Changes in color and texture are an aesthetic quality of

the yarn and finishing processes only, and not of the primary structure or assembly of the piece. A huge number of other projects investigate color, motif history, symbolism, and fashion in carpet designs, and that type of analysis should not be expected in this paper.

This dissertation and the methodology it tested focus solely on the carpet-weaving process. That is here defined as the time, effort, and skill exerted by the weaver to physically construct a carpet on a warp, wherein all materials and tools are pre-provided and not altered during weaving except to position and subdivide. This research did not consider fiber preparation processes such as animal care, shearing, washing, carding, spinning, or dying. It did not consider preparatory steps peripheral to the active weaving process, such as construction or set-up of looms or tools, drawing designs, calculating resource usage, preparing a workspace, sourcing materials, or the warping-on process. Finishing processes are similarly excluded, including cutting the carpet off the loom, washing, fringe treatments, or post-weaving trim cycles. Lifespan properties of the carpets, such as degradation, repair, reuse, re-styling, discard, or deconstruction were only considered when they directly contradict the comparative value of the knots in the context of this project's hypotheses (i.e., when knots were too degraded to be measured or have evidence of modern repair). In these cases, the damaged or re-worked knots were excluded as they were no longer representative of the original maker.

From a social standpoint, long-term social processes like the methods, timescales, and systems of weaving education or education in any of the peripheral processes were not analyzed in depth, nor were explicit concerns of class, gender, ethnicity, religion, or other demographic qualities. Nationality was considered only to the extent that it groups the weavers geographically

in a modern socio-political context. The individual activities of managers, administrators, teachers, and quality-control workers was not studied, except in the degree to which these people's presence might have altered the weaver's working process. Post-production economic and consumer processes such as advertisement, value estimation, authentication, sale/export, transportation/shipping, government-issued taxes, tariffs, or certifications, and personal use, styling, gifting, collecting, or archiving were not considered, beyond the degree to which the weaver was aware of these processes and may or may not have altered her work to fit them.

Finally, there were no chemical or biological tests performed here. There are no chromatography or chemical testing of dye, no genetic testing for strains of sheep, silkworms, cotton, or dyestuffs, no isotopic or geological research into loom wood origins, steel recipes, or weaver nutrition. No cognitive research was conducted on perception, memory, or hand-eye coordination.

All of these and other related themes could and indeed should be explored in lateral projects, but are outside the scope of this work. Any information given on any of the above topics is purely for interest.

Long-Term Goals

In the last century, curatorial staff at five major European museums realized that they each had a carpet that was an exact duplicate of the others (Erdmann 1970:187; see Fig. 5.27). These carpets are now believed to have been produced in a single 16th century Cairene workshop, and worked from the same drawn design (a *cartoon*). This is a wonderful discovery: it gives insight

into the technological paradigms of the 16th century master weavers, it is one of if not the earliest confirmed example of duplicate manufacture in the carpet economy, and it is a rare example of carpets having the comparative opportunities enjoyed by other classes of material culture. These carpets today are held in different collections, four of which attribute their copy to Cairo. But the Victoria & Albert Museum, a world-class authority on decorative arts, has misattributed their copy of the carpet to Turkey.[1] Cairo was under Ottoman rule at the time, so an attribution of "Ottoman" would be reasonable. But "Ottoman" and "Turkish" are not synonymous, particularly at the height of that empire. Because we have the other four copies to compare it to, this mistake is relatively easy to identify and correct. But it does not bode well for the field if such a mistake not only went unnoticed by V&A staff for many decades, but apparently by the wider carpet studies community too. How would a young researcher, or a non-specialist, have any way to know that the V&A's carpet wasn't made in Turkey, and does not necessarily represent Turkish traditions or technologies? This inaccuracy and imprecision in terminology is not new: the household staff of English king Henry VIII made the exact same mistake half a millennia ago, cataloguing Ottoman carpets as Turkish when producing a household inventory in 1548 (King 2012:138)! Even the word "carpet" itself is not used with precision. It is not uncommon in surveying the literature to come across a textile implied to be relevant, only to realize that it is a completely different structure and not a carpet at all.

[1] I enquired about this attribution, wondering if there was an unpublished piece of evidence that suggests the Turkish attribution is correct. The curator agreed it was an error and corrected it in April 2026.

Perhaps because the world of carpets is so overwhelmingly controlled by merchants and auction houses and not by scientists, historians, or artists, the incentive to correct, confirm, or refute historical misunderstandings, misattributions, and downright lies is low. I can see why someone laying out thousands and thousands of dollars on an antique carpet would prefer one confidently attributed to the Mughals or Ottoman Azerbaijan, and not one whose attribution is given as a question mark. This problem is confounded by the relatively low overall sample size and the rarity with which historic carpets are recovered in a primary location – carpets of the last millennium are "rediscovered" in attics and estate sales, they aren't excavated from burials or city ruins. This means that by the time an authentication takes place, many carpets are entirely divorced from the place they were made, the people who made them, and the place(s) through which they travelled between then and now. It is often not even clear how long the carpet has been sitting in the attic! Attributions of historic and antique carpets must therefore be made based mostly if not entirely on similarity to already-attributed carpets. This would be fine if we could trace those existing attributions back to a verifiable first source, but that often isn't possible. Somewhere in the chain is a misunderstanding, a guess, or an outright lie. The longer these attributions are allowed to perpetuate untested and without any type of external validation, the longer the chains get and the worse the problem becomes.

A poorly-provenanced sample, no matter how large, how well-described, or how carefully typologized is not a sample that is useful for writing coherent, explanatory narratives about the past. While ancient carpets (< c. 500 CE) are reasonably attributed to their place of discovery with only a few strong counterexamples, historic carpets (> c. 500 CE) are woefully under-described.

The vast majority of them float in a technological-stylistic soup of questionable attribution and association, based on estimates, assumptions, misunderstandings, and biases.

I do not think that these misattributions are (usually) malicious, nor do I think they are all due to lack of care. I am confident that a great many historic carpets have been carefully studied by skilled experts, who are working with the best data available. Indeed, I suspect that many of their conclusions are likely accurate to some extent, providing a basic network of similarity and difference on which more detailed schemes can build. But with no way to externally confirm or refute most attributive links, the best we can do is usually basic pattern-matching. This often only goes so far as giving a typological class and not an actual attribution. This is exemplified best be the modern carpet industry's default tendency to describe carpet mostly or exclusively by their designs and motifs. For example, a reasonably well-known style-group are classified as "Lotto" carpets due to similar scrollwork design. These carpets are generally associated with Ottoman Turkey of the 16-17th centuries, but not absolutely so: wider production across Renaissance Europe and western Asia is known (King & Sylvester 1983:67), and I saw new versions for sale in my fieldwork for this dissertation. If we cannot universally say where a Lotto carpet came from, we cannot give any concrete information or draw any new conclusions about how it fits into carpet history. And perhaps more concerningly, this attribution may be used to scaffold other attributions based on top-level similarity, creating an ever-deeper stack of untested assumptions.

Donald King, the renowned keeper of textiles at the Victoria and Albert Museum for much of the late 20th century, sums up the overall problem quite well: "We are singularly ill-informed about the organization of the production workshops and about the carpet trade" (King & Sylvester

1983:25). While he is referring specifically to issues of Renaissance carpets in Europe, the sentiment applies to the entire field, from the Bronze Age to today. Nearly all attributions are inferences and not based directly on primary evidence. Many of these attributions are suspect or based on erroneous assumptions. Even when they are well-supported and accepted as reasonable, they tell us little if anything else about the lived experience of carpet manufacture in that place or time. We do not know how production was organized inside or outside of luxury court workshops, we do not know to what extent everyday Asian populations used carpets in their homes through most of history, we do not know how their craft communities, lineages, or mythologies were developed, maintained, exchanged, or overwritten. We do not know exactly how our provenanced carpet was made, what tools or aids were used, what idiosyncrasies of the weaver are present, whether she worked with specialized instruments or household objects designed for other purposes. Our inability to say anything with educated certainty has and will continue to limit the study of carpet history, and nearly eliminate possibility of serious evolutionary and technological research. Strengthening our attribution system and establishing guidelines for estimating the many invisible traits of carpet manufacture are the first steps to removing this limitation.

Even when an attribution is present and we accept it as accurate, they are often quite vague. Renaissance carpets are reasonably sourced to empires in many cases, but narrower guesses about regions or cities are usually estimates based on motif pattern or macro-level structure. This overlooks the known phenomenon of artisans changing their styles to fit the market, and confuses the source of designs further. After all, “designs themselves usually are a

poor guide to provenance" (Böhmer & Thompson 1991:30). Structural differences, like the distinctly square knots of the Cairene masters or the unusual 'Spanish'-style knots used by Moors in Iberia, can sometimes be useful in making informed guesses. But again, valuable markets spark copies and forgeries. And quite aside from intentional imitation, the widely-used structural attribution scheme is not specific enough to cover all the cultural variations that likely existed: it is overwhelmingly focused on the court workshops of the major empires. There is little information about what was normal for the Khanate of Bukhara or Yarkent Khanate courts of the same period, much less for normal domestic or professional weavers working outside of imperial luxury production centers across Asia. But the few pieces that exist from outside the major centers suggest that many of the techniques used within the imperial workshops are duplicated, in degree or in whole, outside them too. How, then, can we say that a particular trait is an effective way to link a historic carpet to any one specific place?

Occasionally a signed carpet or one with unusually detailed provenance information appears, but these are rare and cannot scaffold the entire system. The major carpet-producing empires (Ottomans, Seljuks, Safavids, Mamluks, and Mughals) were so large and consumed so many of the historic carpet zones that it feels reductive and probably inaccurate to leave attributions only at "Safavid" or "Mughal". The individual communities and technological lineages encompassed in those empires likely had their own colorful carpet history, their own techniques and styles and idiosyncrasies. These are lost when an empire-level attribution is considered sufficient, or when the only surviving media are luxury court goods. This lack of deeper or more detailed attribution for such a huge portion of the carpet record is a major issue for studies of

technological evolution, innovation, and transmission. Particularly, it is very difficult to understand how much technological variation existed before these empires arose, and to what extent imperial pressures overwrote or expanded upon local carpet-weaving traditions.

Unfortunately, carpets are not just limited by their small sample size, but also by the general inability to read technique in the finished product. Unlike a pot with wheel-thrown finger marks or a pane of crown glass with the distinctive bauble, carpets (and textiles generally) don't usually have distinguishing characteristics that make it obvious what type of loom was used, whether the sheds were open by heddles or rods or by hand, whether the weaver tied knots in order from one side to the other or jumped around sporadically, etc. The final structure is visible, but there are many ways that could have been achieved (with various levels of efficiency and tediousness). Most looms could be easily retrofitted for carpet-weaving. Carpet sheds are among the simplest around, but it is still a useful insight into labor investment and technological complexity to know whether they used a mechanized shed or picked them out by hand. Any sharp implement can cut the knots from the skein, but a weaver using a kitchen knife implies a different cultural-technical approach to and history in carpets than a weaver using a specialty curved knife cast just for this purpose. Because both the final product and most of the loom components and tools are perishable, it is easy to suggest possible solutions for mechanizing and speeding carpet production, but it is much more difficult to actually link those possibilities to ancient remains.

Other studies have looked at ways to confirm certain technologies in other textile classes, some of which might be translatable into carpets. Analysis of a western Chinese twill, recovered from Qizilchoqa in the Tarim Basin and dated to c. 1200 BCE, shows a repeating, regular shedding

mistake (i.e., one pick in the weaving sequence consistently misses the same warp thread) (Barber 1991:146). If the weaver was counting and picking out each shed by hand as it came up in the sequence, she would not have made the same mistake every time around: she either would have only made the mistake once or twice, or if she made repeated mistakes, they would be distributed randomly and not always in the same place. But because the mistake occurs consistently on the same warp in every repetition of that pick, she was clearly using a mechanized shed. The mistake was integrated into the system, like putting a keycap in the wrong place on a keyboard. Every time you hit that key, you will type the same mistaken letter.

Although this shedding mistake itself can't absolutely say what type of mechanism was used, I would guess at a heddle, not a shed rod. Shed rods are not connected to the weaving and can be removed and replaced relatively easily and quickly. Even a large-width loom could be re-shedded in a few minutes, particularly if there was only one shed in error (which seems to be the case here). If the weaver noticed a mistake using a shed rod, presumably she would have fixed it. A heddle is integrated into the weaving in a more substantial way, and re-doing a heddle to fix a threading mistake can be difficult, time consuming, and sometimes impossible. Even if she spotted the error in the first few lines of weaving, it makes more sense that she might leave it to avoid the torture of re-threading the heddle. Of course it is also possible that the weaver didn't notice the mistake at all, or that she simply didn't care to fix it, but weaving is a slow process. She would have had lots of time for bored eyes to notice a threading error, particularly in a repeating pattern like a twill. The distinct type of mistake, therefore, gives some insight into the tools likely employed in its creation, which would have been unknowable from a mistake-free piece.

Similar studies are performed on warp-weighted looms, where the size and shape of the weights themselves are shown to have a direct effect on the finished textile, beyond their simplest function in creating tension. Ideal tension is a careful balance between the diameter and therefore strength of the yarns, the density of the loom weight, the size and shape of the loom weight, and the desired woven pattern and textile use (Mårtensson et al. 2009:378). Modern experiments by Mårtensson and colleagues have shown that there is a direct correlation between the form-factor of the loom weight and different weave patterns. Although the woven cloth has no obvious record of the weights and the weights have no obvious record of the cloth, having either piece allows for inferences about the presence and form of the other.

Some basic assertions of this kind can be made about carpet technology already. The regular use of double-sided techniques in the Iron Age and early Medieval period make it very unlikely that carpets were being woven exclusively (or maybe even predominantly) on horizontal ground looms. Double-sided knotting requires continuous access to the back of the weaving plane, which horizontal looms do not provide. This right away creates problems for the long-held and wide-spread romantic notion that knotted textiles are an ancient nomadic craft, as a transhumant lifestyle would be inordinately burdened by immobile vertical looms.

A carpet recovered from a c. 300 BCE[2] burial in Pazyryk, Siberia has lovely decorative horsemen worked around the border, which are very similar but not identical to each other (carpet recovery in Rudenko 1968; design analysis in Böhmer & Thompson 1991). The forms seem

[2] The date of the burial is variably given as the 3-5th centuries BCE, based on socio-cultural comparisons, radiocarbon dating, and dendrochronology. See Rudenko 1970, Rageth 1999, and Hajdas et al. 2005.

too complex and detailed to likely have been worked from memory, but are too variable to have been copied from a gridded design (cartoon) either, as is commonly used today. The hypothesis then is that they were copied from a drawn image, so the weaver didn't have to remember or invent each horseman, but that the image wasn't gridded, so some border knots had to be re-decided with each iteration (Böhmer & Thompson 1991:31). This suggests a level of forethought, but possibly a novel design that the weaver couldn't be relied on to draw from memory alone. Perhaps this indicates a creative individual weaver trying a new motif, or an emerging local fashion, or a design worked for a specific foreign market with which the weaver is only passingly familiar.

All of these conclusions are useful insights into carpet technology, but they are still woefully vague in describing a sophisticated and specialized system, and one that had such enormous variety in the past.

When technological conclusions can be read from an object, matching manufacturing or material evidence in settlements is often used to associate the objects to places where they could or could not have been made. Egyptian faience production can be linked to workshops with silicate residue in crucibles, and Indus beads can be linked to sites with stone-carving debris. When production characteristics can be read in both the object and the sites, provenance can be greatly strengthened by matching the two up. But as only a few general technical conclusions can be readily drawn from carpets, there is no clear way to link them to communities or time periods, even when those settings have good technological remains.

For instance, the common occurrence of heavy, short-toothed beating combs around the turn of the common era tells us that weaving, likely including carpet weaving, took place with some regularity in the southern Tarim Basin (Wang & Xiao 2001:65). This is good evidence of a substantial community of weavers who favored the comb-style beater over swords or heddles. It also implies a level of woven sophistication and efficiency that does not rely on finger-beating. The number of finds suggests an intensity of production that goes beyond personal home-use (particularly for wooden combs, most of which presumably disintegrated in the last two millennia; for so many to survive, they must have been ubiquitous). This well-established link between the southern Tarim Basin and chunky, short-toothed combs should be a useful data point for identifying their associated carpets and other textiles. However, we have no way to identify carpets beaten with fat, short-toothed combs vs. other devices. Surely some of the extant carpets from the early 1st millennium CE were made that way, but without a method for determining which is which, we are no closer to linking orphaned textiles to this area.

In a similar vein, we believe that the Bactro-Margianic and Iranic communities living along the Kopet Dag Mountains in the Bronze Age had specialized curved carpet knives (Khlopin 1982; Arne 1945: fig. 660; Schmidt 1937: pl. LIV; see also Figs. 5.6, 5.7), but we can't say which, if any, carpets from before or after that period were made with curved knives. If we had a way to identify which carpets were made with curved knives, we could not only link appropriate Bronze Age remnants to the Kopet Dag, but could also track the spread of curved knives across time and space. As certainly the oldest and arguably the only specialized tool of carpet weaving, tracing this object's distribution across the continent would be an almost "smoking gun" for carpet

history. Unfortunately, there is no currently known way to identify which carpets were woven with specialized knives, and which were not. Similarly, hooked instruments for picking warps quickly were not introduced to Uzbekistan until c.1930 CE (Moshkova 1996: footnote 106), which should be a useful way to differentiate Uzbek carpets of that period from other Central Asian carpets that didn't adopt hooks for several more decades, or at all. But as we can't tell a hooked carpet apart from a hand-picked carpet, this known technological difference does not help much with attribution.

Measuring and defining this type of technical links between the tools used in manufacture and the finished carpet was the target of this dissertation's two immediate goals. With those kinds of connections, new information about ancient and historic pieces could be reverse-engineered, and more conclusive and systematic links could be made to the wider techno-social context.

Although concrete conclusions on individual historic carpets is not a goal of this dissertation, it is certainly one that I believe is possible in future, building on the experiment in this dissertation. This experiment's results show that some production characteristics do seem to create measurable and consistent changes in knot size and shape. Although not all production traits were shown to have these measurable outcomes, around a third (of the traits tested) did show some promising patterned results. From these correlations, I was able to compare knot-measurements in the historic sample to those patterns, and predict some production characteristics for historic carpets at better-than-random levels. This reasonable success in the two immediate goals of this dissertation makes me therefore optimistic that this methodology can be used as a foundation for answering the following long-term questions:

1. To what extent do the estimated production characteristics of ancient/historic carpets align with attributions and provenance for that carpet, and our knowledge of those technological and social systems? Where attributions appear incorrect, can patterns derived from this methodology suggest more appropriate alternatives?

2. In conjunction with accepted attributions, what can the estimated production characteristics add to our understanding of technology, weavers, social organization, and idiosyncrasies within a particular time or place? With an expanded technological understanding of a time/place, what parallel conclusions can be drawn about the economy, division of labor, population levels, migration, resource management, symbolism/aesthetics, etc.?

3. With more robust information on production characteristics, can ancient/historic carpets be grouped into cohesive units, even without an accepted attribution? Can the spatial or temporal distribution of linked pieces be used to triangulate their origin point?

4. With a refined map of technological and social characteristics in the history of knotted textiles, how can the evolution, invention, and/or transmission of the technology be better understood?

If successful in these longer-term goals, the current limitations in systematically evaluating craft technologies using evolutionary models may be reduced in carpet research. Evolutionary phylogenetic studies are only as strong as the depth of information included: the more traits/variations that can be identified and included, the more robust the comparative analysis and resulting networks will be. The methods presented here show potential to vastly increase the number of technological traits associated with any individual carpet. These methods could provide new data on “invisible” techniques, gestures, and materials so that analysis does not rely entirely on macroscale observations, as is the case now, and to make new information “visible”. While it currently isn’t possible to authoritatively declare a geographic origin for knotted carpets, a detailed phylogeny based on a larger number of traits may be able to rule out or preference

certain conclusions and interpretations of carpet evolution. Similarly, being able to describe more traits and define more techno-social groups in space and time should make for a more rigorous analysis of carpet communities of practice, their boundaries, their priorities, and their dissolution.

Differentiation of visible and invisible traits is an important aspect of this research's long-term potential. I define "visible" traits as those that can (already) be established from analysis of only a physical carpet or carpet fragment. These are exclusively traits of structure, material, and aesthetic. They include the physical ordering of threads, the presence or absence of physical components, the classification of fibers and dyes, and description and classification of designs and motifs. Many of the characteristics evaluated in this study fall under structural variables, including the knot shapes, number of weft picks, and type of side binding (see a full discussion of all defined traits and their classification schemes in Chapter 6). Of the 73 traits defined in this study, 41 are visible.

"Invisible" traits are those that (currently) cannot be deduced from the carpet alone, and which require direct knowledge or observation of the weaver and weaving process. These are mainly technological, idiosyncratic, and social traits. Technological traits are those related to the sequence and tools of manufacture. These include the use of different shedding mechanisms, the order in which knots are tied, and the use of sword vs. comb beaters. Idiosyncratic traits are ones specific to the individual and are down to her individual capabilities, preferences, or background. These include handedness, years of experience, or nationality. The line between technological and idiosyncratic traits can be a bit blurred, as some technological sequences are not fixed. Structurally and from an efficiency perspective, it makes no difference if the weaver knots left-to-

right or right-to-left, so this could be considered an idiosyncrasy specific to her preference. However, for the purposes of this study, I have grouped all traits relating to technical sequence as technological, even if they have an element of idiosyncratic choice. Gestural preferences that are more about the biomechanics of the weaver's body and physical comfort than about the requirements or limitations of the weaving (such as the direction of movement used to cut yarns) are given as idiosyncratic.

Social traits are those that are imposed upon the weaver by larger social, economic, or class systems. These include the amount of oversight her work receives, whether she uses a cartoon or is free to invent from memory, and the type of economic organization her labor falls under. Again, there is some inexactness in differentiating idiosyncratic and social traits: is the number of hours per day that the weaver spends working a personal decision that she is free to change, or the results of systemic economic and social pressure in her society? The line is not clear, particularly when discussing both unemployed hobbyists, self-employed collective workers, and professional workshop weavers. Of the 73 traits defined in this project, 32 are invisible. If this project considered pre- and post-weaving processes, that number would grow considerably.

Although these classifications (structural/material, technological, idiosyncratic, social) are not directly used to drive analysis here, they are worth considering for their different implications. Structural, technological, and social traits generally apply to entire communities of practice (CoPs), and generally co-vary within that group as natural changes and adaptations are made (Aoki et al. 2011; Dorland 2018; Jolie 2004; Lave 1991; McElreath & Strimling 2008; Minar 2001; Roux 2003, 2013; Roux & Krasik 2018; Roux et al. 2017; Wenger 2000). Similarly, technological

gestures are a strong and very conservative measure of CoP boundaries (see Chapter 3 for a discussion on CoPs). Being able to identify more of these invisible gestures could be a critical data point for carpet research. Structural, technological, and social factors may also overlap or stand at odds for carpets/weavers in separate communities of practice. Two groups using similar knotting techniques might overlap in trends associated with knotting, but not in ones associated with shedding or quality oversight. The more detailed the network of comparative points is, the more obvious these mismatches will become, and the more meaningfully they can be explored.

By expanding the known technological characteristics for individual historic carpets, this methodology can contribute meaningfully to the study of carpet technological evolution. As in studies of biological evolution, multi-scalar and multi-dimensional phylogenies are more robust than those based on only a few measurements. If a larger network of traits can be described, these can in turn estimate timelines of development and transmission and link groups or techno-systems by likelihood of shared ancestry or lateral contribution. Comparison to the random drift model, prestige models, and conformist/novelty bias models could also help to clarify the pressures experienced by weavers in the past, and to confirm or refute conclusions drawn from other sources. In a wider sense, comparison of phylogenetic estimates of carpet manufacture to historical, linguistic, or genetic evidence, or to the phylogenies of other crafts, may indicate where weaving communities are departing from the group standard, or how carpet weavers are differentially described and recorded in different systems. This in turn can provide insight into the social structures of class, gender, age, and other characteristics, and a more colorful understanding of how these textiles become an iconic symbol of middle Eurasia.

3. Theoretical Frameworks

The questions and methods in this dissertation are built on two underlying frameworks in modern archaeology: communities-of-practice and evolutionary archaeology. In the case of knotted carpets, I see these two systems as well-suited to elucidate technological change and transmission across time and space.

The communities of practice (CoP) framework considers how the social and technological relationships between practitioners can cause similarity and conservatism in their material outputs (Dorland 2018:906). This is usually used to explain and expand upon studies of standardization and/or specialization, but here it is a useful concept for conceptualizing historic weaving communities who might have shared or carried their skills across Asia. As it stands, there is not sufficient evidence in carpet studies to say with any certainty where the knotted pile technique developed, or when, where, or by whom it was transmitted. I would expect that weaving groups who developed their technology independently would have far fewer similarities in the structure and outcomes of their communities-of-practice than groups who have a shared ancestry, or ones who were grown from lateral input from an existing source. To be able to outline weaver communities and their technological traditions, even at a basic level, would be a huge step in improving understanding of carpets' ancient development and evaluating basic questions such as single vs. multiple origins.

Evolutionary archaeology has similar goals in mapping technological change and development over time (Rogers & Ehrlich 2008:3416; Shennan 2008:3175, 2011:1072; Shennan & Wilkinson 2001:577). However, where CoP's are particularly adept at finding the edges of communities and understanding composition and pressures of both social and idiosyncratic variations within them, evolutionary archaeology provides a rigorous, empirical method for mapping that community-level data into a larger web of interactions, influences, and time scales. With many traits mapped across many communities and many centuries, an evolutionary phylogeny could refine historic narratives further, particularly where relatively few carpets exist.

Communities of Practice

From the early days of the field, archaeologists have used object typologies to delineate ancient populations. Differences in materials, form, decoration, or technique were seen as an indication of a social and/or environmental boundary, a system that organized, mapped, and often invented ancient populations and identities (Eerkens & Lipo 2007:240; Jolie 2004:309). New theoretical frameworks developed through the 20th century introduced valid concerns about the advisability of linking visual typologies directly to populations (Clarke 1968; Dunnell 1971; Hodder 1977; Shennan 1977; Binford & Sabloff 1982). As has become a constant refrain in archaeology, "pots are not people" (Kramer 1977; Hodder 1982). However, strong similarities in material culture must mean something – surely matching pots, swords, and carpets are not co-locating by chance?

While clearly there is some sort of human-driven social effect taking place that causes the co-location of similar pots, swords, and carpets, explanation of that system, its causes and ripple effects, its variations, its change over time, and how exactly it links to populations at every scale has come under closer scrutiny. Developing this new framework for the relationship between material culture, individuals, and groups necessarily required a shift away from the grander archaeological narratives of mass-migration, trans-continental trade routes, and the political machinations of kings, and towards smaller communities of production where granular difference in objects could be mapped, measured, and eventually explained (Dorland 2018:893). This refocusing in turn requires research to account for a dynamic system of interactions between the physical environment, social organization, knowledge distribution, symbolic and mythological worldviews, and the material-technical production of the objects themselves (Jolie 2004:307).

From this refocusing evolved the communities of practice framework, under this and other names. A community of practice is the relationship between people, their social structure, and a technological system that creates a cohesive techno-social unit (Minar & Crown 2001:115). Members of a community share social hierarchies and structures, methods of signaling identity, the ability to read and reproduce those signals, and the physical-structural techniques, tools, and material outcomes of object production. Importantly, and in expansion of early-archaeological typology systems, the community of practice approach also emphasizes the lived experience and structure of learning, differential knowledge, access, innovation, and conservatism (Dorland 2018:906; Harush 2025:2). This strong emphasis on teaching and transmission has resulted in

communities of practice sometimes being referred to as 'learning spheres', where the organization and method of instruction is understood to have long-term ramifications on the entire process of material culture production (Jolie 2004:310).

But the pedagogical system is only one of various social and technological aspects used to define a community of practice. These aspects can occur and overlap at many scales, from the individual or family to workshops, towns, or nations. The communities themselves may overlap at different scales as well, with individuals and groups sitting comfortably within more than one boundary at once or transitioning between them throughout their lives. These different attributes and scales coincide to produce a socio-culturally, but not necessarily geographically or temporarily, bounded group who share a socio-technological tradition (Eckert et al. 2015:2).

This framework, solidified in the middle-late 20th century and gaining strength and refinement into the 21st, ultimately circles back around to the original goal of early archaeologists and antiquarians: organizing material culture to represent population groups. However, this modern framework is based not only on the obvious, large-scale physical traits and material makeup of artifacts, but on more rigorous and fine analysis of production techniques, chemical properties, individual idiosyncrasies, measurements of conservatism and exploration, networking models of interactions across and along boundaries, study of pedagogical methods and effectiveness, and the social paradigms carried by people who perform these attributes (see Dorland 2018; Eckert et al. 2015; Minar 2001; Minar & Crown 2001; and many more, including many who do not claim to sit within this area of theory). By matching multi-point and multi-scale similarities across assemblages, modern community-of-practice studies can refine or refute old-

fashioned typological demic groupings, lineages, interactions, extinctions, and genesis models (Jolie 2004:310). These multi-faceted community mappings are sometimes known evocatively as 'constellations' of practice (see Dorland 2018 and others), itself an excellent metaphor for the multiple items viewed at different scales from different perspectives in this framework. Even more recently, increasing attention to very fine, often computer-measured data have given rise to the idea of a "micro-typology" (Harush 2025:5; Gandon et al. 2018; Harush 2020; Roux & Krasik 2018). These "micro-typologies represent almost a community within a community, identifying even smaller-scale learned gestures that might apply to only a single person, or which might be able to distinguish multiple production units in a single community-of-practice who are starting to drift apart slight. This type of ultra-fine demic and technological refinement is one of the main goals of my research, and the communities of practice framework provides a foundation of methods and interpretations on which to build. The community of practice framework's foundational idea that production groups tend to make cohesive objects, where differences at every scale represent belonging and cohesion pressures, is the single most critical foundation of this dissertation's experiments and arguments.

Dividing and categorizing different individuals and groups into cohesive technological units is the basic task of communities-of-practice (CoP) approaches. Although using the groupings to estimate contact, social divisions, intermarriage, materials access, or other social-cultural and environmental pressures is usually the point of interest rather than the groupings themselves, establishing thorough and grounded units of study is still a critical component (Wenger 2000:232), and a particular strength of this line of theory. Antiquarians and early archaeologists

drew their boundaries using macro-scale physical attributes of artifacts; CoP studies today acknowledge the basic logic of that system, but add considerable complexity to its creation. The underlying framework, however, is still that groups with similar material culture either are now or were once more closely related than groups who do not have similar material culture (Harush 2020, 2025; Parkinson 2005; Roux 2013, 2020; Roux & Krasik 2018). These groupings may be measured across time and/or space, where increased dissimilarity is associated with decreased socio-cultural relation (Roux 2010:222).

Modern CoP studies are careful to acknowledge that the units they are outlining are communities of practice, and not necessarily cultures, ethnicities, gene pools, or political identities (Minar 2001:397). The communities of (technological) practice necessarily only refer to those involved, whether centrally or peripherally, with production. It is even possible that the members of a CoP as outlined by archaeological research would not have considered themselves to be a cohesive or related unit, depending on how social organizations and identities were structured in their worldview. This is a particular point of relevance to this carpet research: many of the techniques described represent weavers spread over large geographic areas and many generations, and include weavers who would not likely identify with each other directly. How each weaver conceptualizes her weaving community is not necessarily the same as how she conceptualizes her ethnic, national, religious, or other identities, nor do her other identities necessarily exclude her from a lineage or network of practitioner relationships. Although this specific project does not go so far as to define individual CoP groups, a concerted effort will be needed when the time comes to ensure that other socio-cultural connections and biases are not

introduced to the technological-social boundaries and groupings. Similarly, the modern weavers who participated in this research should not be considered to be necessarily bounded by any characteristics except their community-of-practice.

Although CoPs are multi-faceted with both physical technological and social-conceptual attributes, changes in technological tradition are understood to be a good starting point for identifying boundaries (Roux 2013:314). These visual changes might be technical, as in the case of late Chalcolithic bowls differentiated as wheel-coiled or hand-formed (Roux 2010), morphological, as in the case of Great Basin projectile points with different sizes and shapes (Bettinger & Eerkens 1999), stylistic, as in the case of Late-Archaic ceramic decorations in the American Southeast (Sassaman & Rudolphi 2001), or material, as in the widespread transition towards plastics in the post-Industrial Age. Any or all these factors can work in concert to produce a visible boundary between CoPs.

The presence of boundaries implies an active mechanism for the maintenance of these boundaries, as well as possibly mechanisms to 'export' one group's traits and to 'import' another's. Detailed study of these boundary mechanisms helps to explain how they occur, how they are strengthened and weakened, and what causes them to collapse. A few primary mechanisms of boundary maintenance present themselves.

First is a propensity for people to keep doing whatever their group does, even when presented with alternatives. Sometimes termed "homophily" (Roux et al. 2017:321) in CoP spheres or "conformist bias" in studies of cultural change more widely (Aoki et al. 2011; Fitzhugh 2001; Kandler & Steele 2010; Mesoudi 2010; Powell et al. 2010; Shennan 2008, 2011; Tehrani &

Collard 2009), this is a widespread phenomenon both in production settings and in culture generally.

Many technological variations, and most stylistic ones, are shown to have no notable affect on the object's final function. For example, various projectile point forms in the Great Basin do not have any apparent advantage in hunting/kill efficiency, hide damage, ease or speed of knapping, or transportability, and yet different groups perpetuate different designs (see Bettinger & Eerkens 1999). These groups would certainly have overlapped at times, as points occur in overlapping distributions and contexts. In the ethnographic data presented later in this dissertation, different groups consistently use different forms of scissors, knives, and hooks in their weaving work. None appears to have a significant effect on the final product or weaving efficiency, and the types co-occur within the same modern cities, and even the same workshops (see Appendix C). This suggests that preferential choice cannot be explained simply by functional advantage, or by lack of knowledge of alternatives: it seems that many people will choose to conform to what they know even when presented with another option (see Roux et al. 2017; Wenger 2000). Friendly relationships, co-residence, and even intermarriage do not tend to create notable trends for makers to change their patterns either (see Foster 1956; Tehrani & Collard 2009; Tehrani et al. 2010; Roux et al. 2017; Roux 2020; Wenger 2000). This conformity bias can be measured even in situations with a clear functional advantage, and it seems many will not drop their system even when it is shown to be functionally worse than available alternatives. A particularly extreme example sees Hindu potters allow their livelihoods and traditional hand-crafted ceramics to die out completely rather than to conform to the more successful styles &

techniques of Muslim neighbors, despite an otherwise friendly and respectful relationship between the groups (see Roux 2013).

This conformist tendency is important in this onward study of carpet evolution, as it provides the logic along which carpet technology can be traced. When a migration, warfare, intermarriage, or other social event occurs that cause a new group to merge with an existing population, the newcomers would be expected to continue to use their existing traits, particularly if they are not functional. This should allow researchers to trace movement of carpet techniques across space, and to reasonably differentiate newcomers and new traditions from old. Without a conformity bias to perpetuate their styles, we might instead expect the newcomers to be assimilated, or to not show up in the archaeological record at all.

While this preference to conform in non-functional situations could be explained simply as laziness or disinterest at its first manifestation, its repeated occurrence across people and time tends to have a magnifying effect. Eventually, something you used to do because that was how you did it is now something you do because it reflects and reinforces your identity, and increases distance between you and those who identify differently (Roux et al. 2017:334). The cognitive dissonance of a strengthened identity marker paired with a functionally neutral technological trait can in turn lead to formation of mythologies and worldviews that glorify the in-group attribute while vilifying the out-group attribute. Community members can then see their choice to conform not as conformity, laziness, or disinterest, but instead as a righteous and logical choice, as shaped by their paradigm (Roux et al. 2017:333). This cycle self-perpetuates: as more

choose to conform to fit a particular worldview, that worldview gains strength in a community, and more people choose to conform to it.

Many of the weavers interviewed for this project had opinions on the “right” way to do things. Some weavers found specific knot forms to be more/less robust, or stated that different types of people had physiological advantages/disadvantages in carpet weaving. When alternative outlooks were suggested, they were shrugged off as “wrong” or even “impossible”. Clearly, the in-group conformist technological paradigms are still strong among modern hand-weavers. It is reasonable to expect similar responses would have been given in the past, where weavers would have had even less direct contact with techniques or practitioners different than themselves.

This ‘right way’ to do things then may be a mental barrier rather than a physical one (Jolie 2004:312). In this sense, the technical action itself becomes the important aspect, rather than the objects or the physical outcome (Minar 2001:393). The symbolism of an object is transferred to the actions used to produce or use it, where knowing how to assemble or use it ‘correctly’ is more important than having the right object, especially when the resulting objects are functionally the same. Within textile studies, a number of these mythologies are documented: a Diné superstition says that intentionally spinning wool in the “wrong” direction will draw out bad luck (Thomas 1996, quoted in Minar 2001:393), the Aymara see it as a way to cleanse the spirit and beget good health (Buechler & Buechler 1971; Tschopik 1951; both quoted in Minar 2001:393), the Inca used it as a component of witchcraft and spell-casting (Rowe 1946, quoted in Minar 2001:393), and traditional Koreans use back-spun cloth for mourning garments and grave goods (Knez 1960:136). Even modern Westerners, far divorced from the practicalities of

textile production, have cultural associations with spinning & weaving as a mystical act (as in Rumpelstiltskin, Sleeping Beauty, and stories of the Greek fates).

In addition to the mystical and mythological, more mundane explanations and justifications are also developed over time to explain ultimately arbitrary and functionally neutral technical choices. These derive from the period of learning that makers undergo and are structured by the methods used there. When asked why they perform a specific technique or use a particular material, pre-industrial artisans often can't verbalize the answer with the clarity that the researcher hopes for: "this is how we do it" or "this is how it has always been done" (Killick 2004:573; Lemonnier 1986:165; Roux et al. 2017:333). Within the ethnographic work presented here, one weaver even said, "this is the *only* way to do it", even though I had already spoken to many weavers doing things differently, with equal success!

This explanatory framework for technological systems seems to self-reinforce and magnify just as mythological frameworks do, particularly when repeated by teachers, masters, or other people high in the technological hierarchy. The general trust in the teacher's knowledge and experience allows the (relatively unhelpful and sometimes inaccurate) ancestral explanation to perpetuate and gain strength, making it the de facto answer for why things are done this way. Leaners can only assume this to be a good and thorough explanation for a system they do not fully understand yet. The system becomes its own social fact, information that stands as truth in its own right without the need for justification that would be considered causal or logical to outsiders (Roux et al. 2017:321). As carpets, and most other textiles, require a relatively complicated and detailed technological sequence and often many years of training or

apprenticeship, the opportunity for appeal-to-authority explanations to solidify is immense. Similarly, carpets (and, again, many other textiles) are very adept at disguising their manufacturing processes. This means that even when they encounter a piece made in a new or different way, it is very possible and even likely that even a professional weaver would not notice it. Unless directly exposed to another group's active weaving process, many modern weavers may not even be aware of alternative technological options. This means that the opportunities for appeal-to-authority explanations to be challenged or defended in carpet weaving are probably rare, allowing them to slide "under the radar". I would therefore expect these types of explanations to play a big role in community maintenance, and for traits which cannot be readily read from a finished carpet to be particularly conservative. Applications of the methodology described here may one day be able to confirm that hypothesis.

Technological choices could be functional (e.g., we do A because it is stronger/faster/cheaper than B), paradigmatic (e.g., we do A because that is the right way [in our worldview], and B is the wrong way), or classified (we do A because we are A people; there is nothing wrong with B, but we are not B people) (Lemonnier 1986:171). The functional and paradigmatic biases have been discussed already, but the classified ones are perhaps the most notable in defining communities of practice. This classified organization of technological traits and outcomes has the potential to signal any number of overlapping and multi-scalar identities: or, communities of identity (Eckert et al. 2015:1-2). First-order identities such as age, gender, kinship, socio-economic status, and marital status as well as second-order individualisms such as personality, skill/talent, reputation, and vices/virtues can be signaled by materials that

individuals use, wear, eat, etc. (Dobres 1999:134). Association of particular styles, forms, colors, symbols, morphologies, materials, or skill-qualities to particular individual and group identities allows the users to effectively signal belonging to and distance from relevant identities (Eckert et al. 2005:2). Tracing these signaling objects and their associations through the archaeological record is a well-travelled avenue of study. Sudden proliferations or sharp reductions in the numbers or types of object variants in an assemblage could indicate a notable shift in social organization and/or the CoPs that produce the objects, perhaps due to environmental disaster, invasion or migration, disease, expanded trade networks, access to new resources, etc. As a more complicated social system evolves, a larger variety of objects and styles are required to signal new statuses (Wright & Garrard 2003:277; Eckert et al. 2015:3). And similarly, a reduction in complexity of the social organization could be identified by a downturn in the variety of signaling objects. While this type of general tracking of variants and types is already possible in carpet studies, it is hindered by the high number of "invisible" traits present in the technology. Carpets that should really be treated as different types based on micro-scale differences and sub-types are treated as a single unit, and sudden changes probably go mostly unnoticed (Harush 2025: 3; Sinopoli 1991:52)

Interestingly, a direct reference to identity was not a common explanation given by the modern weavers interviewed for this dissertation. None claimed to do any technical step because of their location, age, ethnicity, gender, religion, or nationality. In fact, a few weavers even directly acknowledged that the techniques they employ don't match what their other identities might suggest: weavers in Uzbekistan especially were aware that their techniques were derived

from Afghan-Turkmen tradition, not Uzbek ones, in the last half-century or so. While their appeal-to-authority explanations and functional explanations could be interpreted as identity-reinforcing perspectives too, they did not seem to be explicitly aware of the relationship to identity. Or at least, they did not seem to think it was important enough to mention, nor did a mismatch between their weaving identity and other identities seem to cause any of them disquiet. Understanding how modern weavers contextualize their identities and technological explanations is a useful first step in understanding how those patterns might one day be read from the past.

It is worth noting here that a community of practice is not necessarily co-occurrent with related communities of identity. A community of identity may contain many distinct communities of practice, and vice versa. A community of practice may produce objects for many identities, while a single identity may source its material culture from many communities of practice. The study produced by Eckert et al. (2015) is an example, where similarly decorative Santa Fe black-on-white pottery distributed across the Española Basin of New Mexico (a single community of identity) was chemically determined to come from several distinct communities of practice, using slightly different materials and firing techniques while working towards the same final, visual standard. There are also different hierarchies and goals to consider, such as what the artisans want/are able to produce, vs. what merchants think is most lucrative in trade, vs. what the consumers think is fashionable and appropriate to purchase or use (Anderson & Tushman 1990:617; Roux 2013:315; Roux et al. 2017:321; Schiffer 2010:239). This type of multi-level identity is certainly prevalent in modern carpet weaving. Many of the weavers used different

techniques to produce similar designs popular in the West, where the majority of their customers are based. Although they are part of many communities of practice, they produce materials to reinforce the worldviews of a single community of identity (the Western elite). Particularly in the carpet boom periods of the last half century, when we know that designs were being copied from other groups to build market share (Baker 1995:370; Böhmer & Thompson 1991:34), it is likely that this type of mismatch is prevalent and may create specific patterns of technological change and conservatism. Things have the potential to become even more complicated when we consider the possibility that historic carpet-weavers were drawing techniques, styles, organizational systems and social conceptualization from other media and textile structures (Erdmann 1970:187; Khlopin 1982:117; Schaefer 1943:267).

But it is not the objects themselves or their ability to signal to the wider population that are of greatest interest to CoP studies: instead, research into communities of practice is particularly focused on the maker's experience, rather than the end user's. In a CoP framework, building and maintaining the makers' and peripherals' identities within the CoP and wider population is as important as the production of physical things (Lave 1991:73-74). A shared training background, a tendency for complex manual tasks to be taught through observation and replication rather than individual experimentation, and a strong emphasis on hand-eye coordination and muscle-memory mean that many traditional techniques are extremely conservative. Techniques take years to master and once they are mastered, it takes concerted and continuous effort to change them (for instance, learning to write with the right hand in youth, and then trying to use the left hand in adulthood) (Minar 2001:395). Knot-tying is an excellent

example of this: it is an ultra-repetitive task that must be performed thousands, even millions of times to construct a single carpet.

The extreme difficulty, focus, and time requirement to change or re-train these "techno-gestures" (Dobres 1999), coupled with the general conformity bias already described that disincentivizes changes in practice generally, mean that these muscle-bound techniques are excellent indicators of communities of practice and are derived almost if not exclusively from the community in which the artisan trained. These techno-gestures often do not leave a notable macro-level mark on the finished object, or if they do the marks would be meaningless to the untrained eye (i.e., a non-producing consumer) (Harush 2025:3-4). In fact, studies suggest that even the artisans don't necessarily realize that their small-scale, muscle-bound techno-gestures are measurable in their final outputs (Minar 2001:393).

These techno-gestures therefore are a strong indicator of community membership. Particularly for artisans who might be working in close proximity, a shared set of techno-gestures would serve to reinforce belonging and membership within the community. The use of the particular techniques reflects not only the conformity biases and shared worldviews of the wider population but also signals identity in this particular community (Dobres 1999:137). This signaling of identity may be conscious or unconscious, and can indicate membership at different scales (e.g., as a student or a master, a native member or an explant). These gestures and techniques are not necessarily goals in themselves, but rather are often by-products of the social system in which the artisan is embedded (Minar 2001:392). As in the application of mythological explanatory paradigms to the justification of technological choices, the gestures themselves can

become the socially relevant aspect, not the outcome. The extreme stability of this techno-gesture makes it an excellent candidate for research into both technological change and community formation, and indeed this was partially the reason knots were chosen as the unit of measurement for this dissertation. Knot-tying is the core techno-gesture of carpet weaving.

Ethnographic, experimental, and materials science studies within the CoP framework are increasingly able to identify remnants of techno-gestures in the material record. Groups with more similar methods can then be reasonably associated with each other as sharing a common technological source, as shown in Minar's comparison of the spin direction used in Alachua textiles of the American Southeast (2001). This study notes importantly that other aspects of technology and material, such as pot forms and decorations, did change across time and space, while the spin directions remained constant in the same assemblage: this further indicates the conservatism of base-level technological gestures, pushing through unnoticed and unchanged even as other social and material systems reformed. Again, technologies and communities of practice tend to be self-replicating and magnifying. Students learn from the masters closest to them and are taught to mimic their specific techno-gestures and integrate their explanatory frameworks as truth; the students grow into full artisans as well as consumers and members of wider communities of identity, who tend to conform to what they know and what is used by their neighbors; when it comes time to teach a new student, the artisans replicate the same frameworks used to teach them, which have now strengthened and are even more engrained in social organization and interpretation than they were in the master's youth (Roux et al. 2017:33). Again and again, technological boundaries conform to social boundaries due to this progression.

All of the biases and mechanisms discussed so far are built around a shared education in the techniques, social structures, mythologies, and signaling values of technology and objects within the community of practice (the makers). In this sense, the ways in which learners are welcomed (or not) into a technical setting, how they are instructed, what measurements of progress they are expected to hit, and what social relationships are considered appropriate for them to engage in both within and outside the setting are all relevant to describing a community of practice. A shared material culture is itself a result of a shared system of learning, both intentional and unintentional (Jolie 2004:309). Entering more specialized material-technical spaces requires more specialized learning systems, although they may still be divided between both the intentional and unintentional, the conscious and the unconscious. Anthropologist Jean Lave defines learning in a craft setting as follows:

> "..a social phenomenon constituted in the experienced, lived-in world, through legitimate peripheral participation in ongoing social practice; the process of changing knowledgeable skill is subsumed in processes of changing identity in and through membership in a community of practitioners; and mastery is an organizational, relational characteristic of communities of practice"
>
> Lave 1991:64

In this view, learning is not simply about assembling the ability to reproduce a technological process, but is the process by which a learner gains a new identity as a member of the community of practice.

Lave's definition refers specifically to the model often referred to as apprenticeship, where young people are provided long-term training in a specific craft by being embedded in the physical environments of the practice. This sets apprenticeship in opposition to more didactic

and hands-off approaches where education is removed from the spheres of practice (e.g., modern mass education) (Lave & Wenger 2001:119-120). But even this is not to say that didactic explanation is entirely excluded from apprenticeships: certainly, there are cases of more explicit and conceptual verbal instruction (Tehrani & Riede 2008:320). The specific form that an apprenticeship takes can vary widely by practical concerns such the type of craft, the age of the student, and the physical distribution of production sites, or by more social-symbolic concerns such as lineage or clan ties, prestige of goods, or the expense of maintaining the student (and who is responsible for those expenses).

This definition of apprenticeship also does not exclude domestic and familial learning. Although domestic craft education may be a much smaller community of practice (perhaps even a single household), it is still a community, and it still has instruction taking place embedded in the environment of the craft. If a mother consistently weaves from a small courtyard in her home, then daughters taught in that same courtyard are being taught in the "experienced, lived-in world" of this particular community. Similarly, the archaeological definition of apprenticeship does not preclude the master from being the apprentice's parent or other close relative, or from co-apprentices from being siblings or cousins.

The "experienced, lived-in world" and "participating in ongoing social practice" of an apprenticeship puts the student in direct, or at least semi-direct, contact with the environments, materials, tools, problems, schedules, languages, hierarchies, and social interactions of the practice. It is through this immersion in the lived experience of the community that learners are introduced to some of the explanatory frameworks discussed already: it is at their master's elbow

that they first receive the explanation “we do it this way because this is how it’s always been done”, from a master who themselves heard the same explanation from their own master years ago and integrated it into their worldview as a logical and full answer. It is here that symbolic-mythological associations are built, and culturally inappropriate methods, materials, and styles are discouraged. By participating in this setting at increasing depths, the student picks up the techno-gestures that they will likely never replace by imitating and receiving correction from artisans and other apprentices who learned their skills in the same environment.

The student starts on the edge of the practice, picking up odd, unordered tasks based on simplicity, low cost of mistakes, and ease of explanation (Lave & Wenger 2001:114). This might include tasks with an analogue in homelife, such as cleaning, running errands, tending fires, or caring for livestock. As the learner becomes more accustomed to the systems, schedules, and language of the community, their assignments are increased and complexified, and they take on more and more responsibility for production. Particularly at the early stages of their apprenticeship, the student may actually have very little interaction with the master from whom they are learning: instead, they may spend most of their time with other apprentices, and then with other full but non-master members of the community, before finally reaching the point of needing the most specialized supervision and instruction from the master (ibid., pg. 112). This form of peripheral participation has been colorfully termed “benign community neglect” by Lave & Wenger (2011), referencing the general disinterest shown to apprentices, especially those in early stages of learning. In some systems and egalitarian communities, there may not even be a specific master to whom a student is assigned. Rather, learners are managed more fluidly

between the community members depending on tasks, age, skill level, or social ties. In this type of environment, CoP studies look to emphasize the interconnected dynamics of a system where strengths and opportunities are distributed across the community (ibid., pg. 113).

By transitioning the learner slowly through every facet of the system, the community reproduces and reinforces its own structure and values within the learner's cognitive frameworks. Their thorough grounding in most or all aspects of the system allows them to better understand interactions, material relationships, scheduling & timing, labor requirements, seasonal pressures, customer interactions, problem solving, the role of innovation or tinkering, terminology, etc. In that respect, a master is not measured by simply their ability to produce the target object, but by their ability to effectively lead and maintain a network or workshop within the overarching social system (Lave & Wenger 2001:113). Successful learning is not just in doing the work, but being able to appreciate why, when, where, and by whom the work is supposed to be done. It is the ability to connect with the community's history, mythologies, symbolisms, and wider cultural life (ibid., pg. 117). While a student can only listen to the stories and regalings of past achievements and errors and can only do their best to follow along a complex discourse on the economics of a new material source or application of a new technique, a master is expected to provide their own novel insights and contribute to building that shared lore and expertise (ibid., pg. 120). One day, the apprentice will be expected to contribute and participate in the same way.

The apprenticeship model of learning is a particular hurdle for this dissertation. The weavers included in the modern ethnography, while certainly they received formal training, were

not necessarily integrated into the weaving/workshop community in the way usually assumed in apprenticeship models. Most of the weavers learned to weave as adults, not children, and most learned in only a relatively short training or probationary window (ranging from a few days to a few months). None were fully immersed in the community via co-habitation, and all maintained active families, friendships, and social and economic lives entirely separate from the workshop during their learning and employment periods. The method of instruction they received, which I witnessed briefly in the Samarkand Silk Workshop where a new weaver was receiving training, was more didactic than an apprenticeship usually is. This is important to note, as it suggests that modern weavers may not be learning in the same way that their ancient or historic counterparts did. It may be that ethnographic models built on didactic carpet learners are not well-matched to carpet apprentices, and that their techno-gestures or engrained identities are notably different. However, as no children or adult learners were included in this project, direct comment on learning outcomes is not possible here.

The structure of apprenticeship from within is not the only relevant factor to locating or describing a community of practice: how access to that community is structured from the outside is equally as relevant. Controlled access is an important and common aspect of traditional technological systems, whether intentionally or unintentionally. This considers how an apprentice or other learner gets their position in the first place: through a family connection to the master, or the master's spouse? Was it based on proximity? Was it a particular skill or aptitude shown by the child? Was it an economic venture, where the prestigious apprenticeship was given to the child of the highest bidder? Was the child in active competition with other

children for this role, or was it naturally assumed that the role would go to this child without competition or discussion, or was the master instead in competition to woo a limited resource (children) to join their workshop? Understanding how apprentices are selected, as well as what other types of people are and are not permitted to access technical spaces, resources, and knowledge, informs upon the wider society and organizational structures (Lave & Wenger 2001:112).

Successful CoPs have mechanisms for managing legitimate access to their cores and peripheries, as well as for managing interactions where access is not granted and a hard boundary is maintained (Wenger 2000:2387). These boundaries might be between other communities of practice within the same craft, communities of practice in related crafts (e.g., a spinning community vs. a dyeing community), between communities of practice in unrelated crafts (e.g., carpet weavers vs. clockmakers), or between communities of practice and people who do not engage in production or technology at all.

Access management is an interesting point in carpet weaving. As already discussed, most technological factors in carpet weaving are not readily apparent, and those that can be teased out require close scrutiny of a finished piece. In some cases, it is even necessary to dismantle the piece to identify certain structural characteristics. This means that among experts and certainly among amateurs and lay people, the technology is inherently secretive. While an outsider could reproduce a piece that looks just like yours, they would have no way to know the exact techniques and gestures that you used (my “invisible” traits, discussed already). This means it should be quite clear whether an individual is part of a particular group or not, even when the

outcomes are identical. This could mean that drawing reference or conceptual frameworks from processes or media where technological difference is more readily apparent could introduce unintentional biases in interpretation of carpet communities.

This complicated web of social interactions, hard and soft boundaries, technical skills and social identities, learners and masters and lay people, visible and invisible material attributes, technical/gestural flexibility and permanence, environmental pressures, resource access, mythologies and paradigms, and individual cognitive biases all work together to provide insights into the overarching social systems that act on and within a population and its material remains (Kramer 1982:664). Using a communities-of-practice framework centers the makers and their communities in analysis of archaeological assemblages, as the ones with the most hands-on control over the resulting materials. The framework acknowledges both intentional and unintentional techniques, forms, outcomes, and associations, it allows for both logical and illogical, accurate and inaccurate explanations to have a measurable effect on human behavior, and seeks to explain the materials through the eyes and actions of the makers.

Although the community-of-practice framework has gained population and developed many new techniques in the last half century, it still has limitations. A large set of studies on different media from around the world, including on stone tools in Neolithic Hungary (Parkinson 2005), beads in Neolithic West Asia (Wright & Garrard 2003), ceramics in the Neolithic Near East (Zeder 2009) and the late Archaic American Southwest (Eckert et al. 2015), textiles in Woodland-period Florida (Minar 2001), are all, at their core, studies of communities of practice in the archeological record. And yet, the primary output of all these studies is to suggest boundary lines

between groups. As discussed at the beginning of this section, boundaries are certainly an important step in describing and explaining the past, but demarcation of boundaries is not enough to capture the rich, multi-dimensional value of this framework. In comparison, several ethnographic studies on living artisans including ceramics in East Africa (Roux et al. 2017) and India (Roux 2013) and studies of carpet design in modern Iran (Tehrani & Collard 2002, 2009; Tehrani & Reide 2008; Tehrani et al. 2010) seek to draw the more nuanced social explanations of the boundaries identified, how they emerged, interact, and collapse. Particularly relevant to the textile study presented later in this document, Minar (2001) presents a blended comparative approach wherein modern hobbyist spinners were asked to produce samples and provide conceptual insight of their processes to test the techno-gestural connotations and flexibilities that might have affected Woodland-era spinners in Florida. However, these studies rely heavily on informants and observation of interaction to describe historic social processes, more so than on material culture itself.

The overwhelming emphasis in CoP studies is on conformity, and the social and technical mechanisms that reinforce selection for the artisan's and group's known methods. Clearly there is a strong tendency for groups to resist change in many situations, but there is no doubt that interactions, skill transmissions, and adoptions do occur. The framework is much less nuanced to explain the causes, circumstances, penetration, and distribution of change, and why similar pressures result in strengthened conformity in some situations (even to the point of extinction, see Roux 2013), but fusion or wholesale abandonment of techniques in others. Similarly, the theoretical position of innovation, experimentation, and technological accidents are not clearly

established. In a system where an emphasis is placed on the stubbornness of techno-gestures and worldviews that restrict makers to certain "right ways to do things", it is hard to see where invention (intentional or accidental) can take place, be transmitted, or gain cultural acceptance. While this difficulty identifying the causes or distribution of change is a long-term problem for using CoP frameworks on carpet studies, I am fortunate in that there is not yet enough data to worry about those interpretative difficulties. Carpet studies are still very much in the phase of identifying difference and boundaries; we need to worry about the "what" and "who" before we can consider the "why" or "how".

While all the studies listed here provide comments and suggestions on the social and organizational structures that could have brought about their different boundary patterns, it is not entirely clear how communities of practice archaeology can effectively describe complex social changes, pressures, and choices acting on makers in the moment, or whether these pressures would even necessarily be recorded in most material assemblages. This is especially true in cases of more limited archaeological remains, such as textiles, woodworking, and other perishable goods, where boundaries may be difficult to identify or explain due simply to lack of comparative data. Similarly, it is unclear how this framework would be able to differentiate between many pressures and mechanisms that result in similar outcomes (for instance, analogous vs. homologous techniques). Unfortunately, human intent, logical decision making, and symbolic reasoning are impossible to verify in most archaeological settings (Lyman & O'Brien 1998:618).

Evolutionary Archaeology

Evolutionary archaeology is one of the paradigms that might be able to provide some rigor to communities of practice research, and therefore to provide an empirical scaffold to this doctoral project. Particularly with so few historic carpets extant and so few technological and community traits readily readable from those carpets, it is very difficult to even quantify change, much less explain it. An evolutionary framework is therefore employed here to help A) identify change and B) quantify it and its relative occurrence in the historic record, to allow for the empirical testing of hypotheses and assumptions. Indeed, some more recent papers that situate themselves within communities-of-practice work also make implicit and explicit use of evolutionary ideas and methods (Gandon et al. 2018; Harush 2020; 2025, Roux & Krasik 2018).

In line with the processual movement of 1960's onwards, evolutionary archaeology shifts towards scientific objectivity and away from interpretive, humanist approaches (Killick 2004:572). With a base almost two centuries old in Charles Darwin's *The Origin of Species* (Darwin 1859), evolutionary archaeology has grown from the same fundamental concepts as biological evolution. As bio-evolutionary studies were refined, clarified, and expanded in the mid-20th century, an increasing number of archaeologists began to wonder if a similar framework could be applied to cultural change. This idea really took off with the definition of the *meme* in 1976 (Dawkins 1976). The meme was given as a unit of heritable culture that could be passed between generations, selected for or against, and mutated in a manner similar to biological genes. While certainly not identical to biological evolution, evolutionary archaeology frameworks posit the idea that cultural evolution can be considered analogous to it (Dunnell 1978:197).

A discussion of evolutionary archaeology must therefore be grounded on an understanding of biological evolution, its components, and its mechanisms. First, *evolution* itself: a net change in characteristics and/or organisms (Lyman & O'Brien 1998:616). While many lay people today associate evolution with progress, increased efficiency, and movement towards an ideal, that is not a requirement of the process. Evolution requires a change, but not a positive or progressive one. Changes can have an overall detrimental effect or set the organism down an unfortunate path. Certainly some evolutionary changes are a net positive, like lactose tolerance evolving to allow some populations of humans to continue to consume milk after childhood and opening up new source of consistent, reliable nutrition. Many other changes though, and perhaps most changes in the span of life on Earth, are net neutral: they neither hinder nor help the organism in any notable way, and their continued transmission is a matter of chance rather than fitness.

Darwin himself took a tentative stab at linking biological evolution to cultural change when he suggested that languages follow a similar evolutionary pattern (Darwin 1871, quoted in Kempe et al. 2012:1). Carpet history shows both growth and winnowing of traits, with the carpets produced in different times and places certainly displaying technological change, in addition to material and decorative changes. By this definition then, we can say that human culture, and carpet technology specifically, evolves. It changes through time with positive/progressive, negative/detrimental, and neutral changes occurring constantly. On their surface, these analogies are easy to understand. Putting them into practice in archaeological research is a little more complicated.

Biological evolution can be identified easily by morphological changes in organisms, but the evolutionary forces are not acting on the organisms as wholes, but rather on individual characteristics or traits. While many modern people with a cursory understanding of (biological) evolution would say that these characteristics are the underlying genes, this is not strictly the case. Neo-Darwinian biological paradigms refined by biologists in the mid-20th century instead consider evolutionary forces to act on the phenotypes, not the genes themselves (Lyman & O'Brien 1998:619). Phenotypes are the physical expression of genes. Having light eyes is a phenotype for many different genetic variations increasing photosensitivity, but light eyes are not, themselves, segments of DNA. If we return to Darwin's analogue to language, the genes may be the words as written in the dictionary, while the phenotype is the way that word is pronounced and defined in everyday life. Many different combinations of letters may result in the same spoken sound (their, there, they're), and similarly many different genotypes may result in the same outward phenotype. And inversely, depending on environmental pressures and the combining effects of other genes, the same genotype may result in different phenotypes (the many ways that 'garage', 'schedule', or 'caramel' are pronounced by English-speakers). Evolutionary forces act on the phenotype, but it is the genotype that carries the change.

The effects of phenotypic pressure, both in biology and culture, do not necessarily have to result in a change in genotype. Many phenotypes have some amount of plasticity that allows their implementation to change with environmental pressure: your genes may set a window of possibility for your adult height, but the nutrition you took in as a child (your environment) can cause you to grow to the shorter or taller end of that window. In technology and artifacts,

phenotypic pressure about symbolism or color schemes may change the way a carpet is designed but does not necessarily change the physical structure of the threads.

This subtle distinction introduces two new concepts to the evolutionary system: replicators and interactors. The replicator is the unit that is transmitted between generations and which controls (for the most part) the range of possible visible phenotypes. In biology, the replicator is a gene – a unit that is transmitted between generations (inherited genetically) and that dictates the physical/morphological phenotypes of the organism. The interactor is the phenotype, the outward presentation of the gene that interacts with the environment, and upon which evolutionary forces can act (Lyman & O'Brien 1998:619). In biology, this two-part system of traits is relatively straightforward and not a major hurdle. It even seems that the ability to distinguish the two halves and research them separately is not a critical one: many modern bio-evolutionary studies of extinct taxa start with a comparison of morphology (phenotypes), where similar teeth or pelvic structures are used to group and trace relatedness and change across organisms. In many of these cases, confirmation of the underlying replicators (genes) is limited or impossible, and yet the scientific community generally accepts the value and validity of these phenotypic evolutionary studies (ibid., pg. 619).

This distinction gets a little less clear when applied to technology and culture. First, how do we define a technological organism or a trait in the most cursory sense (O'Brien & Shennan 2010:5; Schiffer 2005:488)? Imagine a woolen carpet traveling along the Silk Roads from the carpet masters of Khotan to the Turkic mega-city at Merv: is the single carpet a single organism? Or is the one carpet an appendage on the entire Eurasian carpet industry organism? Is the larger

organism based on the production of carpets, or their use, or their trade? If the organism is the whole system, what are its traits? The people working within it, or the carpets, the timescales, the Silk Roads, or Merv and Khotan? All of the above? Or perhaps the individual carpet is not part of an organism but is itself a complete organism. In that case, what are its traits? The patterns, colors, and materials used in its design? The geospatial origin? The maker? The symbolic or economic valuation? The species of sheep that produced the wool, and the recipes used to dye it? All of the above, or none of the above, or some of the above? How specific or general is the realm of "traits"? If there is no agreement on what constitutes an organism or a trait, how can evolutionary forces be measured or studied?

There is no answer to any of these questions. But understanding the scope of the problem is a fundamental part of solving it, and to showing that a study has thought through the potential issues. The inability of evolutionary studies to universally define the transmissible traits or organisms of cultural evolution may seem like a fundamental problem, but I argue that it is not. Instead, this flexibility in definition should be seen as a strength of the evolutionary archaeology system. It allows for multi-scalar studies into both small-scale change at the level of a single carpet knot, as well as larger studies of aesthetic preferences and technological systems across centuries or continents (O'Brien & Shennan 2010:5). Even if another research project argues that the carpet organism is the entire Silk Roads industry where carpets, weavers, and dealers are the traits, I can still perform a study like this one where the organism is a single carpet and knots, tools, and production factors are the traits. Both projects can be valuable, without the need to strictly define these concepts and eliminate either.

Of course, allowing this multi-scalar work within the theoretical framework also necessitates clear and careful definitions, hypotheses, and experimental structures in research. Clarity in the methods and critical consideration of scale in interpretation of results are required, to ensure that research on one scale is not misattributed to another. In this research, the organisms are the individual carpets, and the traits are aspects of technological, material, social, and idiosyncratic production. The underlying production and life-use traits are subject to evolutionary pressures, in turn changing (or not) the overall composition of the carpet. In another study, this will not necessarily be the case.

If we accept the multi-scalar nature of organisms and traits in evolutionary archaeology, we are still left with differentiating the replicators and interactors (the genotypes and phenotypes of biology). Proponents of evolutionary ecology, a similar but distinct framework that explains evolutionary change through human intent and problem solving (Boone & Smith 1998:144) rather than non-human evolutionary forces, suggest that evolutionary archaeology collapses replicators and interactors into a single indistinguishable unit (Boone & Smith 1998:144), but this seems to be a misunderstanding. Evolutionary archaeology acknowledges that the artifacts studied are only the phenotypes, the interactors: the underlying genotypes are unknown and unstudiable (Lyman & O'Brien 1998:619). This is not to say that there is not underlying cultural symbolism or social 'genes', no social structures or effects of human choice and intent, but rather that the evolutionary archaeology framework is not equipped to differentiate those various pressures (Lyman & O'Brien 1998:620, in opposition to Boone & Smith 1998:144 and Zeder 2009:1). Evolutionary archaeology again mirrors the biological work on

extinct taxa, wherein it claims only to look at the phenotypic variation and not the underlying genes (e.g., a paleontologist points out changes in tooth morphology between species, he does not claim to know what specific genes were altered to bring about that change). This in turn assists with the trait-definition problem already discussed, in that it is less important what the replicators are if we cannot directly study them anyway. To describe the carpet's production characteristics as traits is enough, without needing to subdivide the traits into the replicators and interactors. I would suggest that identifying and explaining the underlying replicators is a task better suited to the community-of-practice framework, studying gestures and conformity at the level of individuals and small production units.

Instead of focusing on individual human intent and social factors, evolutionary archaeology instead posits that the primary mechanisms that drive cultural evolution are the same as those that drive biological evolution: natural selection and drift (Lyman & O'Brien 1998:620). To reiterate, this does not mean that evolutionary archaeologists do not believe that the more individual social-cognitive factors and behaviors are at play, but rather that they are not the primary driver of large-scale change. In natural selection, phenotypes that produce positive outcomes for organism reproductive success are selected for, survive, and proliferate in the population. In the same way that natural selection selects for positive traits (positive selection), it also selects against negative ones (negative selection): the traits that have detrimental effects on the organism's reproductive success will be selected against and will tend to die out of the population (or at least not spread) (Rogers & Ehrlich 2008:3416).

Natural selection relies on a fitness index, or an understanding of what traits/phenotypes improve reproductive ability, and which are detrimental to it. In biology, the fitness is generally straightforward – traits with high fitness result in healthier organisms that live longer, travel further, and are better suited to resource acquisition, attracting a mate, and reproducing. Traits with low fitness cause disease or deformation, inability to locate or consume resources effectively, or a reduced attractiveness to mates or defection in reproduction. Positively-adaptive traits help the organism live long enough to reproduce, and reproduce often. Negatively-adaptive traits prevent the organism from creating many (if any) offspring.

In cultural evolution, this definition must be shifted slightly, as cultural traits do not reproduce themselves in the way that organisms do. A pair of camels can gestate, birth, and raise a new camel, but a pair of carpets cannot spin, dye, and weave a new carpet. Instead, cultural fitness is generally defined in terms of the human relationship to the trait. The most obvious aspect of this relationship is the trait's effectiveness in relation to the human goal (e.g., an arrowhead that effectively kills a prey animal, or a pot that can boil water without cracking, a carpet that keeps cold or damp out of the tent by insulating the floor). These first-order effectiveness measurements can be complexified with higher-order fitness measurements such as environmental pressures (e.g., silk makes sturdier, softer carpets, but silk worms do not thrive in this climate so we make wool carpets instead), material limitations (e.g., the protein structure of wool allows it to absorb dye better than plant fibers), time/energy constraints (e.g., it is quicker to tie 4-warp [*jufti*] knots, as they are half as dense as standard 2-warp knots), economic realities (e.g., we know that natural-fiber carpets last longer and hold up better to wear and washing, but

synthetic carpets are cheaper), social-perceptual biases (e.g., having a silk carpet is a sign of wealth and prestige, even if a silk carpet is not the most effective way to prevent cold or damp), or cognitive expectations (i.e., weavers choose asymmetric knots because they think it is the strongest/most efficient choice, even if that is not the case). These different measurements can all work together to create an overall cost-benefit measurement of different traits, in turn making them more or less fit (Bentley 2010:125; Schiffer 2010:247). Over time, a natural selection process would normally see traits with higher fitness out-compete those with lower fitness (Shennan & Wilkinson 2001:583).

Evolutionary archaeology suggests that many of these fitness pressures are cross-cultural, and therefore eligible for study independent of specific cultural contexts (Roux 2003:9; see also Schiffer & Skibo 1987). This suggests that some aspects of fitness, such as environmental and climactic pressures or the physical limitations of materials, should result in similar traits proliferating across time and space. This provides an interesting comparative mechanism, where similarity or dissimilarity in solutions to problems could be used to indicate or refute a correlated environment. This type of cross-cultural comparisons is a fundamental assumption of this dissertation. I assume that certain production characteristics (technological, material, social, and idiosyncratic) will always result in similar knots due to universal influences of weight, pressure, gravity, fiber characteristics, and human morphology, and therefore that the presence of certain knots can be used to reverse-engineer the carpet's production in any setting.

Design theory, a subset of technological studies, posits that there is no single optimum solution to most (technical) problems, and that the collection of traits selected to perform a

particular task are likely to be guided by social-cultural, behavioral, and environmental contexts (Hayden 1998:4). This does seem to be the case for carpets, or many other classes of material. The structural inputs can and often do result in objects that are equally successful, much less distinguishable – see Chapter 6 and Appendix C for more than 60 traits that do not seem to affect the ultimate success of the carpet! This evidence of traits that don't appear to have any effect on fitness brings up the possibility that there are some choices that have neutral fitness. These neutral traits are generally considered stylistic and are often set in opposition to functional traits in evolutionary archaeology (Nieman 1995:7).

Functional traits are those which have a measurable fitness value (positive or negative) and which are acted upon by natural selection (Shennan & Wilkinson 2001:578). In carpets, these might include wear-resistance of the material or the time and opportunity-cost required to follow a specific technique. Stylistic traits are those which have no measurable effect on the organisms' success, and which therefore are not shaped by natural selection (Shennan & Wilkinson 2001:578, also Nieman 1995). In carpets, a great number of the production traits seems to be neutral/stylistic, including warp positioning, weaving direction, and beater type, to name only a very small selection. Many archaeologists, in both evolutionary and other frameworks of cultural change, suggest that the majority of cultural traits are functionally neutral (Boyer 1998:877; Hansen 2013:137; Lemonnier 1986:174). These functionally-neutral traits would be acted upon by drift rather than selection. As I suspect the majority of the carpet characteristics measured in this project are functionally neutral, I expect them to act mainly under drift, and not selection. There is therefore little direct consideration of trait functionality in this dissertation. Additional

targeted studies would be required to individually test the fitness values of specific traits, and the corresponding beliefs of various weavers about the functional benefits of their community's traits.

Drift is considered a random process. 'Random' here does not mean that all options are equally likely or that successful traits are chosen for no reason, but rather that the rate of occurrence is not related to the relative fitness/adaptivity of the trait (Boone & Smith 1998:148; Powell et al. 2010:141). Drift is instead guided by patterns of transmission and the introduction of novel traits (Shennan & Wilkinson 2001:578). The relative frequency of traits can be predicted with some basic input about population size, rate of interaction, and transmission method (Nieman 1995). The simplest model of drift is known as the neutral model: here, the traits that are inherited are based on an entirely unguided/unpatterned, 1:1 copying method (Bentley et al. 2004:1443). In this system, a person learns a trait (whether that be a language, a bread recipe, or a carpet knot) from a random other person in their community, with no bias for who the teacher is or which traits they take on. In general, systems acting under the neutral model will see a reduction in traits over time (Shennan & Wilkinson 2001:582), while more complicated drift models that include transmission biases and innovation would see more of an oscillation of different traits gaining and losing popularity over time. Although the intuition would be that the sharp decline in carpet structural variations from the Iron Age into the Renaissance (see Chapter 5 for details) was due to some refining pressure selecting for more efficient or stronger structures or massive changes in demographics that wiped out many weavers, it may actually be evidence that these structural traits are neutral, and were instead acted upon simply by drift's natural

winnowing. After all, many of those traits seem to be functionally neutral, so a decline in variation would fit well with a drift model. Even today, the continual shift away from handicrafts and toward machine production is causing an ongoing loss of variation among carpet weavers.

These measurements of fitness and neutrality, both in regards to culture generally and to carpet technology more specifically, may seem straightforward on the surface but are increasingly complex with more attention. In biological evolution, even a complicated interaction of environment, organism, and random chance can often be measured empirically by clear-cut outcomes like lack of mating/reproduction rate, lifespan, and health. Outcomes are usually less clear-cut in cultural studies. Individual humans can have all kinds of reasons and explanations that we could class as functional, even if they are not measurable in the physical record or consistently applied across time or space. Identity signaling, prestige biases, teaching costs, anticipated consequences, misinformation, spiritual beliefs, and the conformity biases already discussed are not exactly adaptive in the traditional bio-evolutionary sense, but they certainly aren't random either (Boone & Smith 1998:149; Shennan & Wilkinson 2001:578).

Complexity in separating functionalist from stylistic traits applies not only to the benefits, but also to the costs. Traits that are functionally neutral in outcome may still have different costs associated with them, which means that selecting to perform one trait over another has larger ramifications on an individual's resources and time. For instance, one weaver in this study reported that asymmetric knots are faster to tie than symmetric knots (Survey 1).[3] Although the

[3] I suspect that this is not actually the case, but the weaver believing it may as well make it true, if it affects her perceptions and resulting choices.

outcome of the two knots is (generally) functionally identical, the increased time costs and opportunities lost to tie one or the other creates a negative fitness value for symmetric knots, in this weaver's technical opinion (Shennan & Wilkinson 2001:578). The line between functional and stylistic, adaptive and neutral is clearly blurred. Any combination of functional and neutral traits may co-occur and interact in any number of ways that can change the visible outcome, even when the inputs were the same (ibid., pg. 578). The same trait may even vacillate between positively-functional, negatively-functional, and neutral across time, space, and social situations. It is therefore reasonable to expect that effective study of technological evolution will require separate and combined analyses of functional and neutral traits, and careful delineation of the methods applied and assumptions used (Dunnell 1978:199). My research should assist with this in carpet studies, by providing an empirical measurement of change that does not currently exist for carpet-weaving, which can then be tested in experimental-ethnographic contexts, or which can be mapped across assemblages to identify differences and rates of change.

Another fundamental property of evolution is the heritability of traits. That is, a mechanism wherein differential success in one generation can have a direct impact on the succeeding generations. For Darwinian biological evolution, the heritable traits are genes carried on chromosomes and passed directly from parents to offspring. In that system, organisms can pass on only the traits they were born with, with environmental pressures guiding natural selection by killing the organism or preventing reproduction when it carries maladaptive traits. The mechanism of natural selection interacts with heritability not by the altering traits themselves, but by controlling which are passed on.

Interestingly, a classic example of a rival (and ultimately disproved) theory to Darwinian biological evolution may be a better model for heritability in culture and technology. Jean-Baptiste Lamarck proposed an evolutionary system at the end of the 18th century that is now known eponymously as Lamarckian evolution, or simply Lamarckism (Lamarck 1809). In this paradigm, traits *acquired* during a parent's lifetime are eligible to be passed to offspring. This contrasts with the Darwinian approach, where the parent can only pass on the traits they were born with, and any acquired traits necessarily die with them. This is sensible in biology, where our genes are not editable by our experiences and new genes are not introduced to our bodies during life.[4]

But humans are not born with genes for weaving carpets or dying silk with walnuts. Human culture is not limited to the traits contained within our parents. Instead, we *acquire* our traits during life from many sources. Certainly, many of these traits are acquired directly from our parents (to speak a particular language, to follow a particular religion, to celebrate particular holidays, to follow a specific apple pie recipe, or to take our shoes off when entering a living space). These traits are said to be transmitted vertically, directly from parent to child. But many other traits are learned elsewhere. Unlike biological traits, cultural traits can be acquired from non-parents in preceding generations: grandparents, aunts/uncles, teachers, community leaders, etc. This is known as oblique transmission. Traits can also be acquired from peers within a generation: siblings, cousins, coworkers, classmates, and friends. This type of transmission is

[4] We will overlook 21st century gene-editing techniques and epigenetics for effectiveness of the analogy.

considered horizontal, as it does not span generational divides at all (Cavalli-Sforza et al. 1982:20). Through all these connections, the traits an individual is eligible to acquire culturally are not limited to only those carried by their parents. This means that if a well-described web of traits were available for carpet studies, it may be possible to identify points where transmission patterns change suddenly – perhaps through a sudden influx of immigrants providing new horizontal transmission opportunities, or by a war which results in the death of a significant portion of adults, disincentivizing vertical and oblique transmission.

This difference in transmission is not just in source, but it also covers the ability to archive multiple trait variations in a single individual. In the biological inheritance of organisms with sexual reproduction, an offspring can carry only two variations of a particular trait, one passed along by each parent. Between those two traits, the organism has no ability to control which is deployed, or to switch between them during its life.

This is not the case for cultural traits. It is possible and quite common for individuals to carry many variations of a single cultural trait. Humans are not limited to only the one or two native languages spoken by our parents, but could learn any other language too: in fact, we are not even required to learn our parents' languages. An individual could theoretically acquire an infinite number of variations for cultural traits, if they were willing to put in the time to locate and learn them. The individual may actively use multiple variations across their lifetimes in different situations, or they may hold some traits as an unused archive. These archived or "dormant" traits are known and understood by the person and have the potential for use, but are not employed all the time, or even at all (Mesoudi 2010:180). This archival ability creates

more flexibility, allowing the organism to deploy different traits to succeed in different situations. This provides a bit more adaptive freedom in cultural traits than biological ones: if your biological traits cannot save you from a detrimental situation, there is nothing you can do. But if your default cultural trait fails you, you may be able to draw a solution from your archive. In turn, this may mean that non-functional cultural traits do not get weeded out by natural selection as efficiently as they do in biological evolution, because they are archived rather than being killed off. It is therefore important to consider the possibility that a particular carpet trait's survival is not due to active fitness or even to neutrality – it may survive in a population and periodically reappear even if it is objectively unfit. In cultural evolution, as opposed to traditional biological evolution, it is actively incorrect to assume that a trait's survival means that it does not cause harm.

Evolutionary archaeology therefore has an advantage over other evolutionary frameworks (such as evolutionary ecology) in how it deals with maladaptive traits. In evolutionary ecology, the underlying conceptual framework is that all cultural/technological traits are driven by human intent, that the implementers knowingly select for increased functionality and efficiency, and that ineffective solutions are intentionally discarded. That makes it difficult for this framework to explain actively maladaptive traits, which certainly occur. Evolutionary archaeology, however, acknowledges the possibility for maladaptive traits to proliferate through both natural selection and drift. Drift is easier to explain, as it is based on essentially random interactions: if you have the misfortune to have parents or teachers with maladaptive traits, you are likely to acquire maladaptive traits. Without direct exposure to alternatives or active

cognitive consideration, you are likely to continue to use those traits, and to ultimately pass them on yourself. You may even believe that it is a useful or "correct" trait, if that is the bias associated with your community's technological paradigm (again returning to community-of-practice concepts to explain evolutionary patterns).

In a natural selection process where fitness and functionality are the drivers of change, we would assume that maladaptive traits should be weeded out. And it is true that ineffective or actively harmful traits are often eliminated from the trait pool eventually. But because evolutionary archaeology does not pre-suppose that the individuals know what they are doing, are well-informed of consequences, understand the cause-and-effect sequence, are aware of alternate methods, or that they have a worldview that allows for trait-changing, it is possible for a maladaptive trait to masquerade as a functionally adaptive or neutral one (Shennan 2008:3175). Shennan gives smoking as an excellent example: we know that it is bad for you and those around you, we know that it could even kill you, and yet smoking is still perceived as cool in many circles. It proliferates on the social fitness of prestige, not the biological or economic fitness of lung cancer. Despite it being well-known that smoking is a medically maladaptive trait and the relative ease of *not* smoking, that trait persists. And of course, the selecting-out of maladaptive traits (like eating off lead plates or using lead makeup) requires the individuals to actually know that this trait is dangerous/maladaptive, which they may not. And if they do not know it is dangerous, then it may as well not be from an evolutionary standpoint: it is likely to transmit and proliferate through the population as if it were adaptive or neutral.

This occurrence of maladaptive traits need not be so severe as lung cancer or lead poisoning, and need not work directly on human health. A mildly maladaptive trait was observed in this ethnographic study, where two weavers emphatically assured me that only right-handed people can tie carpet knots (Surveys 2, 7). I (and other informants interviewed) know this to be untrue and know that the handedness of the weaver makes no difference in functionality or efficiency. And yet, at least two weavers (11% of the participants) carry the "trait" of believing that only righties can weave carpets. This in turn would suggest a prejudice against lefties who might have been excellent weavers if given the chance, therefore reducing the weaver pool and unnecessarily limiting the chances of workshop success. It might even encourage natural lefties to masquerade as righties to get a weaving job, despite their work being slower and/or less accurate when they force use of their non-dominant hand. Although only these two weavers explicitly stated that lefties can't weave carpets, it is worth pointing out that zero of the eighteen weavers included here reported being left-handed (the global average suggests there should be ~2 lefties in the group). Admittedly eighteen is not a huge sample and zero left-handed weavers appearing here could easily be random chance, but I wonder if it indicates a wider prejudice against left-handedness in the weaving community that could be effecting outcomes.

A willingness to perpetuate maladaptive traits may even contribute to the extinction of a technological system if carried far enough, as seen in Roux's study of Indian potters (2013). This consideration is an important one for research into carpet weaving or other technologies: if we were to encounter an ancient weaving community of all right-handed people, we might interpret that as A) random chance, or B) a culture-wide aversion to left-handedness that forces conversion

of natural lefties to right-handedness. In the case of some of the weaving communities interviewed here however, it seems to be a carpet-specific exclusion of left-handed people, based on an (erroneous) assumption that left-handed people are biomechanically incapable of the work. The weaver's personal biases and how they are applied create a trait for right-handedness that we might have attributed to other causes, if I didn't have the chance to speak to the weavers about it.

The possibility of archiving is another way for maladaptive traits to persist. If the trait is not used often, detrimental effects may not be a major concern. If the trait has not been deployed recently, and negative outcomes may even be entirely unknown or forgotten. This means the trait will continue to be passed along even when it has negative fitness. Imagine you inherit a box of recipes from your great-grandmother: there are a few favorite cards you pull out for holidays and birthdays, but most are never touched. When you one day pass the box to your own grandchildren, they have no way to know that a particular card is a disgusting recipe, because no one in their lifetime or yours has ever tried it. The maladaptive trait gets bundled and passed along with the rest of the archive. This seems to be the case for the prejudice against left-handed weavers, as it was presumably taught to these weavers by their own teachers in adulthood. As they are not left-handed themselves and the rate of left-handedness in the general population is low, it is possible that they will never be confronted with the objective inaccuracy of this belief, meaning they could continue to turn away left-handed weavers for no measurable technical reason. Again, it would be nearly impossible to tease this anti-leftie trait from the archaeological

record without reference to the weavers, so it is very important to be cognizant of this issue and careful in how results are interpreted in evolutionary studies.

A final difference between biological and cultural transmission is the ability to self-edit. This returns to the Lamarckian perspective, wherein an individual can make active changes to their traits and then pass the new versions on to offspring and the wider community (Lamarck 1809). Individuals are not therefore limited to transmitting only the traits they were born with, or even the traits that already exist in their community. Instead, you can create a completely new cultural trait. This ability to change the heritable traits adds a new layer of complexity and divergence from biological evolution.

Humans can both identify cultural-technological problems and develop solutions. This ability to innovate is a major component of evolutionary archaeological research (see Ariew 2010; Bentley 2010; Lyman & O'Brien 1998; Roux et al. 2017). Darwin's original work on (biological) evolution had no explanation for the origin of new traits at all (Ariew 2010:31-32). But it is clearly necessary for there to be a mechanism for novelty in both biological and cultural evolution, based simply on the patterns visible in the world. Without a mechanism for introducing new traits, a population would forever be limited to the traits of the founders. Negative traits would eventually be selected out, adaptive traits would eventually become universal, and neutral traits would vacillate in frequency but ultimately reduce in number over time, until they die out completely. A population without the ability to novelize can only see a reduction in variation over time (Shennan & Wilkinson 2001:582), as traits are selected out or lost randomly but never replaced. At the end of an evolutionary cycle, a population would carry exclusively positive traits,

without any negative or neutral ones. Diversity would drop continuously, until all individuals shared exactly the same traits.

This is clearly not the pattern that is seen in the world, which means that both biological and cultural evolution must have mechanisms for the introduction of novel traits. In biology, it took over a century for biologists and geneticists to identify the replicators of evolution (genes/DNA) and determine their method of novelization (random mutation and recombination) (Bentley et al. 2004:1443). Fortunately, it is quite easy to see where new cultural traits come from: they are intentionally developed through cognitive effort, they are the result of combining existing traits into a novel configuration, and they are the results of accidents or errors (Cavalli-Sforza et al. 1982:19; Powell et al. 2010:140-141; Shennan 2011:1070). Even archived traits could perform like a novel trait, if they go unused long enough. Unlike the evolutionary ecology framework which has already been discussed, evolutionary archaeology does not necessitate intentional invention. Instead, it acknowledges that many inventions are accidental and may even be unnoticed (Henrich 2010:107; Shennan 2011:1070). This has led to a staunch opposition to the "necessity is the mother of invention" idiom within the field (Henrich 2010:107). While certainly necessity *can* lead to invention, it is misleading to theorize that it is the only explanation for novelty, or that situations of great need always result in invention (Fitzhugh 2001:156; Henrich 2010:109; Schiffer 2005:497). Any number of historic disasters provide examples of people with great need who were not able to invent their way to safety.

Like the widespread pop-understanding of evolution as moving towards a progressive ideal, many interpret invention as an inherently good thing that moves society towards some

cultural imperative or shared goal (Schiffer 2010:243). In the evolutionary archaeology framework, and in modern bio-evolution too, novel mutations are random and directionless. They are not inherently good, functional, or effective. Unhelpful, inefficient, and actively harmful mutations occur, as do completely neutral ones (Kempe et al. 2012:1). Mutations that used to exist but were lost can even re-emerge; this makes it particularly dangerous to use technological features as the only method of dating artifacts (as so many merchants and scholars use design typologies to date carpets). To deal with this mismatch between generally positive connotations of novelty and the reality that not all novel traits are a net benefit, many cultural evolution frameworks distinguish between "inventions" and "innovations". In this system, an *invention* is analogous to a gene mutation or recombination. It is any new trait, whether functional, neutral, or maladaptive. Many, and possibly most, novel traits live and die as inventions without ever getting any further. The invention becomes an *innovation* only when it takes hold in the wider community and spreads beyond its inventor (Ariew 2010:21; Fitzhugh 2001:128; Schiffer 2005:486). This means that invention may be an individual process, but innovation is inherently social and larger-scale (Roux 2010:217).

This difference between an invention and an innovation means that innovation is more visible in evolutionary studies and in archaeology generally (Schiffer 2010:235). Because an invention does not extend beyond a few people or maybe beyond a single person, the chances of it being preserved in an archaeological context are very low. Even if an invention-artifact is present (a prototype tool, a creative novel style), it may be very difficult to distinguish it as novel when compared to an assemblage of materials in various states of development, production, use,

reuse, repair, deterioration, or discard. This is particularly true of perishable materials like carpets, where the presence of a single object in a deposition would be considered remarkable, and the presence of an assemblage with sufficient size and temporal/geographic breadth to evaluate novelty is essentially unheard of.

This inability of archaeology to reliably identify inventions and the invention process means that evolutionary archaeology cannot meaningfully comment on it. Instead, innovations are the focus. However, innovations follow the same transmission patterns of natural selection and drift as existing traits (Ariew 2010:22) – their novelty does not grant them any special mechanisms or patterns. This unfortunately can make it very difficult to distinguish truly novel innovations from other transmission patterns. A new technology, material, or style may appear suddenly in the archaeological record and without a clear development pipeline: is this a truly new innovation creditable to a creative technician or artist in the local population, or is this a case of an interaction with another group who passed along a new-to-you but otherwise long-standing practice (Lyman & O'Brien 1998:617)? Similarly, how would a novel innovation be distinguished from an archived trait, which may not have been used in many years, but which is widely known and accessible in the community's memory and not recently innovated?

I propose that the best (and possibly only) way to begin to untangle these questions is simply by expanding and improving the data. Take a carpet hook, for instance. There is no direct evidence for its use before the modern period, and despite its expanding range, many modern weavers still do not use it (only about half of the ethnographic weavers interviewed here). We might therefore assume that it was innovated in the last few hundred years, when direct

evidence appears. However, if studies like this one can identify markers that are consistently left behind by hooks, it may be possible to identify an ancient or historic population using them. With enough data, we could show that there is consistent use of hooks from long ago, and therefore we could assume that the hook was not recently innovated, and is in fact an ancient technological trait. Or perhaps a more sporadic pattern might appear, where most carpets do not use hooks, but one appears every few generations. That might suggest an archived trait, rarely used but not lost to the weaving community. However, if we have no way to identify the use of hooks in a finished carpet (as now), there is little choice but to assume it was innovated in the last few hundred years. Expanding the dataset, rather than just finding creative ways to study it, is an important component of improving evolutionary research.

A final scaffold from biological evolution arrives here: phylogeny. From the Greek φῦλον (*phylon,* tribe*)* and γένεσις *(genesis,* origin*)*, phylogeny is the process by which (biological) evolution can be seen to bring forth new populations. In biology, this is generally in reference to the differentiation of new species; in cultural evolution, it refers to complexes of related traits (for instance, carpet-weaving or glass-blowing). Although a phylogenetic tree could be built for a single trait, they are usually used for evaluating the relationships between many traits and many groups. This multi-point comparison allows these methods to create more detailed and nuanced trees and networks of relationships, where groups with many overlapping traits are generally more closely related than groups with few overlapping traits (Boyd et al. 1997:2). More specifically, the cladistic framework would suggest that groups with more shared traits share a common ancestor more recently than groups with fewer shared traits (Tehrani & Collard

2009:12). In turn, the shared ancestor will have set a basic pool of original traits, naturally limiting (or at least, slowing) the diversification of descendant populations (Boyd et al. 1997:2). These mappings allow for expanded conclusions on rates of change, founders/origins, transmission networks, migration, and other large-scale social and environmental pressures (Matthews et al. 2011:1).

In technological studies, the lineages present in a phylogenetic tree are usually differentiated by major technical and physical differences (Lemonnier 1986:168). Trees and networks drawn from technology (and culture generally) are therefore based on qualitative and descriptive traits, and not on geospatial distributions of trait frequencies (Moore 1994:934). However, it is important that these traits cover not only the outward appearance and form of an artifact, but also aspects of the techniques, materials, and gestures that may be invisible or obscured in the final object (Roux 2010:219). A firm grasp on the object's materials, resource processing, gestures, and *chaîne opératoire* is therefore an important step in an effective cladistic study. The *chaîne opératoire* represents a holistic explanation of a technology's steps and processes, particularly useful for crafts with linear or prerequisite sequences (Dobres 1999: 124; Dobres & Hoffman 1994:214; Roux 2003:9). This dissertation is a first step in developing deeper understanding of these aspects in carpet weaving. Outward appearances of carpets are already known, and have already been shown to be unreliable methods of attribution: the methodology introduced here has the potential to expand those descriptions to aspects that are not readily apparent in the final object, but which represent the complex socio-technical production of carpets in ancient communities.

The type and direction of technological relationship in a phylogenetic tree is one of particular interest in carpet studies. The low rate of carpet survival in archaeological contexts, plus their apparently unpatterned appearance across Asia in the Bronze and Iron Ages makes it very difficult to say if the technology was innovated once and transmitted, or if it was innovated independently many times, or if it was lost and rediscovered. A phylogenetic study, if built on enough traits, could help to clarify the situation even without access to an expanded sample (which seems unlikely to ever appear). It may even be able to begin to separate locally-made products from imports, which at the moment are often indistinguishable and limit our ability to describe transmission and use patterns of carpets across Eurasia before the Renaissance.

Statistical methods and computer models developed (mainly) for biological studies are effectively used in cultural studies as well (see Matthews et al. 2011; Tehrani & Collard 2002 2009; Tehrani et al. 2010), particularly to calculate phylogenetic trees. These methods evaluate relatedness by mapping similarity across many points of reference and estimate the likelihood of different descent patterns. This in turn can be used to clarify the source of traits. Differentiating between truly novel, recently transmitted, and archived cultural traits can be exceedingly difficult, particularly when constrained by an assemblage that may not be representative. Fortunately, as in biology, cultural phylogenetic work can estimate the probability that similar traits are homologous or analogous (Lyman & O'Brien 1998:621). A homologous trait would be one that is similar across groups because they all received/derived their trait from a common ancestor. Analogous traits are those which may appear similar but have no evolutionary links: the two traits evolved separately, often to fit the same or similar evolutionary pressures, but

without a biological or lineage relationship to each other. While by no means able to provide absolute guarantees of relationships, these bio-evolutionary concepts and associated models provide another avenue of information against which to compare historic, archaeological, linguistic, or genetic evidence (Lyman & O'Brien 1998:621, Matthews et al. 2011:2). This again has important implications for carpet research, where many techniques were likely drawn from other textile traditions rather than being innovated specifically for carpets, and where it is possible that many groups independently arrived at similar methods. To be able to empirically estimate homogeneity vs. analogousness could be incredibly useful for carpet research and understandings of Eurasian textile tradition development. While outside the direct scope of this dissertation, this type of research is what I hope my methods can contribute to in the long-term.

Although phylogenetic methods in evolutionary archaeology can produce interesting trees of cladistic relationships, these should not be confused with demic groups. Even a complex phylogeny based on many traits could never have enough detail to completely separate populations in every situation. The networks produced are only a network of the traits included, which may overlap with or contradict other lines of evidence (historic, linguistic, genetic). The work of Tehrani & Collard (2009) on Iranian carpets and rugs is particularly of interest here, as it gives a good example of multiple lines of evidence appearing to contradict each other within the realm of carpet/textile studies. Their study generated a cladistic model of several textile motifs to estimate the level of interaction between different groups of Iranian weavers. When compared to models based on genetic and phylogenetic data, the weaving motifs seem to follow a different line of transmission, displaying a different network of relatedness. The authors of that paper

were able to effectively explain the discrepancy by reminding the reader that their work only traces textile motifs and not other aspects of culture or the movement of peoples. They point out that as an exogamous and patrilocal society, genetic relationships, migrations, and linguistic patterns would tend to match the male line better than the female line. However, the weaving technology is carried mostly if not exclusively by women in that culture, which would explain why those phylogenies follow a different pattern than others. While the historic and linguistic evidence traces the male history of the population, the technological carpet evidence traces the female history. This is an interesting example of how an evolutionary archaeology method can be used to create a fuller picture of human interactions, and a better understanding of how culture transmits and reproduces through communities specifically in carpet studies. This work is based only on the design motifs: I would be very interested to see how those lineage trees change or diversify with the addition of structural-technical details like those studied in this dissertation.

These phylogenetic methods can only comment on the traits and degree of relatedness included in them. Traits that are not included, or which may be entirely unknown, may influence the results but cannot be directly commented on by the results (Moore 1994:936). A poorly-defined evolutionary study, or one based on a limited or non-representative sample, can easily fall into a “you don’t know what you don’t know” fallacy.

A related problem is that evolutionary trees tend to simplify as they move further back in time. This can sometimes give the false impression that life (whether biological or cultural) was less complex and less varied in the past than now (Moore 1994:933). While it is certainly possible

that a particular region, group, or time period may be less complex than the modern network you are comparing them to, it is also possible that the results have been "pruned". This is not intentional or malicious, but simply an emergent property of a method that can only incorporate traits that it already knows exist. A particular trait may have existed and even proliferated in the past, but if its evolutionary lineage died out (i.e., was pruned), then it will not appear in the results because it has no daughter populations that still carry its traits. Not only does this mean that evolutionary research may be missing significant chunks of life/culture, but also that it may not be possible to understand how, where, when, or why a visible trait was competing against a trait that has been pruned, and why one was able to survive and one died out. Hyper-focusing on the one ancestor that can be reconstructed while ignoring or downplaying the contributions of others results is a skewed understanding of the complex relationship and interactions that occurred in the past, and in the factors that contributed to the present. The methods presented in this dissertation are naturally limited by this issue: the conclusions I draw are inherently based on the ethnographic data I used in developing the comparative sample. Of course, my comparative sample is limited. It did not and could not include every variation in carpet weaving used today, and so it certainly could not include everything that occurred in the past. Instead of trying to map every possibility, I hope that my methods will be identify places where something is missing. Perhaps an ancient carpet whose knots do not well match any of the tested beater types – we could interpret that to mean an unknown beater type was used in the past, or that the specific ancient carpet wasn't beaten at all. It is not realistic to hope that this method or any other could

entirely describe ancient weaving, but I believe it has potential for identifying some holes in our knowledge that we aren't currently aware of.

In discussion of related-but-possibly-unknown-traits, there is a risk that a group of traits may transmit and evolve as a unit, but that only one has a direct impact on fitness or selective choice (Matthews et al. 2011:9). This in turn may obfuscate results, giving the impression that one of the "hitchhiker" traits has more adaptive value or meaning than it does. For example, a workshop may see that their best-selling carpets are all red, and therefore interpret that their customers would react well to a wider offering of red designs. However, they may ultimately find that it was not the redness that the customers were drawn to, but rather the Turkmen gul designs, which are traditionally worked in red. The gul designs may sell equally-well in any color (and indeed, may even sell better in other colors), while the expanded offering of red designs may not do very well if they use non-Turkmen guls. To focus only on the color and ignore co-occurring traits like the design is to misunderstand which traits the patrons find important and appealing. In a trait complex where the interrelationships and relative selective value is not well defined, this could lead to wildly inaccurate conclusions about what ancient groups valued, noticed, or knew.

Overall, evolutionary archaeology's biggest strength is in the use of rigorous scientific methods and frameworks, based on almost two centuries of theorizing in biology and life sciences, and half a century of computer-driven evolutionary models. It has clear hypotheses against which to test ideas and provides a way to double-check conclusions drawn from other sources. It does not rely on understanding individual or collective human intent (so difficult to

read in the archaeological record) and rather proposes only to identify and map the outcomes of those intentions. It's true strength may therefore be not in its own internal research output, but in comparison and cross-checking with conclusions drawn elsewhere.

Discussion

The communities of practice and evolutionary archaeology frameworks are two that may be more effectively deployed in conjunction than individually when trying to advance and clarify carpet studies. Each can bolster the other's weaknesses and create a fuller, more nuanced picture of technological change. Although the research presented in this dissertation is only the very first step in such work, the overarching goal of it is to provide additional data on which communities-of-practice (CoP) and evolutionary archaeological work can be performed.

The problem of defining scale in evolutionary studies is one of the more fundamental issues. Inconsistency on the definitions of traits, their variations, and the level of inclusivity/generality vs. exclusivity/specificity in models and lineage trees is a major stumbling block in effective and clearly-defined evolutionary projects, and therefore in useful and clearly-synthesized results (Matthews et al. 2011:2; Moore 1994:933). The introduction of a CoP framework may be able to clarify the target scale by helping to establish structural-cultural boundaries and units of comparable breadth, complexity, makeup, and goals. From a long-term view, the methods presented in this dissertation should be able to expand and differentiate the practices of historic communities, and to be able to more accurately delineate traits that are individual, community-wide, or even universal. This should allow for better refinement in

evolutionary research, by bounding the carpet data and any contributing perspectives (genetic, historic, environmental, etc.) to the same or similar scale.

Similarly, clear delineation of CoPs would help to clarify which traits do and do not co-occur, co-vary, or co-transmit in different contexts. For instance, the evolutionary study and interpretation of a group where weavers, dyers, and spinners are the same people may expect to have different results than in a group where those tasks are performed by different people within a single techno-social enclave, versus a group where those specialist crafters are distinct and do not have any techno-social overlap except to transfer goods. A recent project on the famous Terracotta Army uses similar community-separation concepts to understand how labor was organized in construction of the tomb complex in early unified China (Martinón-Torres et al. 2014). That team was able to use different patterns in the structure of components across the army to determine that each soldier was not a single-artisan project, nor was each medium/class a single-workshop output. Instead, they showed that the production was batched and serialized, allowing for efficient production with built-in resistance to shortages and hold-ups. A similar work (Harush 2020) identified small-scale inconsistencies in the morphology of Levantine ceramics, where pots that otherwise seemed comparable and part of the same community-of-practice had some distinct reductions in specific traits in specific towns, but not others. In that paper, the author argued that the increased standardization in particular towns indicated a production unit facing a local market pressure to prioritize ultra-standardized vessels for measuring supplies for a building site. The otherwise analogous traits of the different towns suggested a wider shared CoP, where one production unit was subject to slightly different pressures, rather than several

unrelated CoPs producing separate wares. I believe similar projects should be possible in carpets, and textiles more generally, where a clearer understanding of techno-social grouping can inform on community interactions, knowledge transmission, and standardization outcomes between related fields of weavers, dyers, spinners, etc., in the context of different local and regional events.

As evolutionary studies are strengthened by multi-point comparisons, a CoP framework may be useful in identifying traits that could appropriately be grouped together and used in a single comparison (like Martinón-Torres et al.'s grouping of armament manufacture and exclusion of soldier, wagon, and decoration processes). These traits of scale and co-occurrence would likely differ from situation to situation, and therefore specific and localized CoP analyses would be of enormous benefit to a rigorous evolutionary study. This would be particularly useful in estimating relationships, unique pressures, and drift among groups who share evolutionary roots.

The difficulties described already in distinguishing between ancestral vs. lending populations and innovation vs. transmission vs. archiving in evolutionary studies may also be lessened when studied in conjunction with CoP frameworks. While the evolutionary archeology system is well-equipped to identify when apparently-new traits appear in the record, it is less able to explain where those traits came from. Reference to CoP studies may be able to provide helpful insight into the pressures of conformity and novelty biases, the relative importance and structure of social signaling, economic, mythological, or environmental factors of social organization or resource acquisition, etc., felt by the relevant groups. This in turn could allow for reasonable estimations of where an apparently new trait was more likely to have come from.

While a better description of historic techniques and practices should help to clarify invention vs. transmission vs. archiving to some extent from other lines of evidence, and a more community-history based framework would still be invaluable in a medium with such a small global assemblage.

The inverse may be true too, where evolutionary studies can be used to refine CoP understandings. First, evolutionary models can empirically test for random drift vs. directed change and can generalize the types of patterns often seen in cases of various types of bias, pressure, and transmission. These include aggrandizer and prestige models (Appadurai 1986; Hayden 1998), conformist transmission (Aoki et al. 2011; Powell et al. 2010; Sassaman & Rudolphi 2001), novelty bias (Bentley 2010), accumulated copying error (Eerkens & Lipo 2005; Hamilton & Buchanan 2009; Kempe et al. 2012; Rorabaugh 2014), economic pressures (Kandler & Steele 2010), learning modes (McElreath & Strimling 2008; Mesoudi 2010), and others (Nieman 1995; Rogers & Ehrlich 2008; Shennan 2008; Tehrani & Collard 2002, 2009; Tehrani & Reide 2008). When information on a CoP is incomplete, evolutionary studies and estimates of bias and transmission patterns may help to fill in the gaps. This in turn can guide CoPs studies to look at factors or pressures they might not otherwise have considered. Particularly with the small-scale technical changes, gestures, and idiosyncrasies included in this pilot research, very detailed evolutionary models may be possible, in turn commenting on biases and pressures affecting the community at different scales.

The testable and generalizable patterns of evolutionary archaeology also provide a way to confirm CoP conclusions by comparing results to established generalized patterns. Particularly,

evolutionary models can empirically test transmission, biased, and directed change against a random drift (or neutral) model, ensuring that patterns expected by CoP study are actually being represented in the archaeological record. Empirical confirmation of random drift is particularly relevant here, as the notable reduction in knotted technologies from the Iron Age to today is a very distinct change: knowing whether it was driven by increased efficiency and improved tools or by the natural die-off of neutral traits could provide interesting insight into the process (or lack) of active development in the technology.

Cross-comparison of phylogenies produced for specific carpet technologies/groups and those produced using genetic, linguistic, or historic data could also work together to identify where a technological community is not tracking one-to-one with spatial, familial, ethnic, religious, or socio-national groups. This dissimilarity can be used to refine the boundaries of CoPs, which might otherwise be limited by biased notions of how big or small, inclusive or exclusive, or gendered the group should be. A mismatch between technological and other phylogenies might show that a community of practice is more insular than their wider society, or that a single technological unit cuts across many demographics that are not otherwise linked. As carpets have been made in both domestic and court settings, by both men and women, by sedentary and mobile communities, and by adults and children, a more nuanced description of how communities situate themselves in larger identity narratives is an interesting avenue of study.

These kinds of integrated, multi-disciplinary studies have the potential to greatly expand understanding of ancient technologies and the people who (re)produced them. The project presented in later chapters is only the first step in just such an integrated study, focusing on more

clearly outlining technological variations and the communities of practice they define. I believe, however, that a better description of these variations and communities has much wider potential ramifications for study of carpet evolution.

4. Methodological Grounding

Although some typological systems exist in modern carpet studies, they are mostly based on design, not structure. Carpets of similar design are grouped together often without significant consideration of structure, materials, age, geographic, or cultural origins, with little acknowledgement of copying or counterfeits, coincidental convergence or duplication of design between populations, or the effects of a regional or global fashion zeitgeist on style distribution. While the designs, color schemes, and symmetry styles are valid dimensions along which to classify artifacts (when done critically), it is a problem when easily-changed and market-driven aesthetic dimensions are the only ones used. It is particularly important to note that the vast majority of extant historic carpets were produced either A) in an elite court setting for the world's most powerful people, or B) intentionally for a global market. There are exceptionally few historic pieces that we could definitively call household, local, or regional products which were not unduly influenced by continental, foreign, or global market pressures. This bias of the sample is almost entirely ignored in carpet studies, where designs sourced from particular cities or workshops are assumed to be a representative of the local, domestic, and traditional style.

Because carpet typologies place so much emphasis on design, a completely non-structural dimension, the typologies can be used for little except understanding the history of style or design. I do not mean to say that this is not an important or interesting avenue of study, but rather

that focus entirely on that aspect misses out on other interesting and important technological narratives, and greatly oversimplifies the movement and distribution of carpets in the past.

What little structural-material classification exists is limited almost entirely to the knot forms, as the knots are the most obvious differentiating structural factor. This narrow focus is particularly true of merchants and auction houses with no particular specialism in textile structure or technology, and an incentive to uphold romantic notions about exotic histories and rugged nomads. Even when we focus on the knot-based typology that exists, little can be said. The knots are an important aspect of the textiles to be sure, but they are ultimately only one factor in tens or hundreds. Especially as only two knot forms are widely distributed in the last millennium (when nearly all extant carpets were made): a categorization scheme with only two options is going to be vague at best. Basing our entire classification system on them, or even on a handful of other obvious structural characteristics, cannot hope to produce nuanced types or a well-rounded view of carpet variation.

The methods I used in my experiment (discussed in detail in Chapter 7) were built on several widespread and generalized methodological frameworks in archaeology. First, I work to diversify the typological system for knotted pile carpets. This includes considering new structural, technological, social, and idiosyncratic factors. The design-focus of most modern carpet typologies is the one aspect I do *not* consider here, as it is so thoroughly covered elsewhere by better-informed specialists.

From my expanded typological scheme, I use ethnographic and experimental methods to construct a comparative sample of modern carpets. Due to the poor preservation rate of most

textiles in archaeological contexts, it is not realistic to make robust comparisons between large assembles, as can sometimes be done in ceramics, metals, or stone. An ethnographic sample therefore acts as an artificial extension of the historic data.

Finally, I refine a method I derived in my earlier works (V. Sluka 2017) to measure small-scale difference in carpet knots. Unusual among textiles for being both discrete and relatively stable components, the knots are well-suited to empirical measurement. This creates a large sample of nearly 1,000,000 knots, which are interpreted against concepts of standardization and specialization to better understand how carpet structure is influenced by production characteristics, pressures, and settings. This ultimately leads to my conclusions that some production characteristics can be reverse-engineered from historic carpets, in turn providing new insight into ancient and historic carpet production, and providing a new dimension along which comparisons, differentiations, and ultimately attributions can be made.

Typology

While increased attention to assumptions and antiquarian oversimplifications has trended modern archaeology away from the Linnean typologies of the 19th century, typologies are the fundamental core of both community-of-practice (CoP) and technological evolutionary studies (Harush 2025:2; Zeder 2009:2). The models and descriptions that underly both theoretical fields rely on accurate description and differentiation of features at every scale (Mesoudi 2010:176). Both fields require some differentiation in people and objects, some line where the

in-group and the out-group are separated. It is not meaningful to say that textile process A evolved from textile process B if we cannot clearly articulate how A and B are different.

Most typologies, both antiquarian and modern, are fundamentally functional, morphological, and/or stylistic (Dunnell 1978:196), based on the physical appearance of the object. While this system can be useful as a surface-level pass to distinguish large regions or eras, it is often lacking the nuance to narrow things down further (Harush 2025:3-4). The goal in traditional typologies is usually to assign each thing to a single class: it is an arrowhead or a spearhead, but it can't be both. Duplicity of function, blending of materials, style, or technique, and simple material differences can all make objects unclassifiable in a single-answer system (Shott 1986:17, Sørenson 2015:91). Even the term "carpet" falls victim to this typological oversimplification. Many historical records try to cram multiple use-functions into that word: wall carpet, table carpet, and throne carpet are all used, presumably to emphasize the structure and aesthetic language of the object. To classify these things as just carpets isn't quite right as they aren't used on the floor, but to classify them as hangings, tablecloths, or chair covers seems wrong too, as it doesn't encapsulate their structural or material qualities.

A common problem of traditional typologies is their inconsistency. When asked to divide the same assemblage into a typological system, different people will create different numbers of classes with different priorities (Eerkens & Bettinger 2001:500; Fish 1978:86). There is no widespread standard on how different things need to be to justify a new class, nor along what ruler we measure those differences (Sinopoli 1991:44; Sørenson 2015:91). Researchers will variously emphasize material, technology, function, morphology, size, decoration, or other

physical attributes, based on their personal research interests or their cultural biases about value and relevance (Sinopoli 1991:43). This is very apparent in carpet studies: some modern researchers use the term “tribal carpet” to reference an item made by nomadic (or at least rural non-professional) weavers, while others use it to mean a carpet with a coarse, geometric design. The typological systems don’t exactly contradict each other, as you could certainly have a geometric design woven by a nomadic weaver, but they don’t align well either, and confusion is predictable when the two systems talk past each other.

Most typologies pick one or two axes of priority and divide objects based on that. When other axes are added, they are positioned as lower on the hierarchy and therefore less deserving of attention and having less useful explanatory power. This tendency to place classes in a hierarchy poses its own problems, namely that it overemphasizes some characteristics while down-playing others. This biases research and conclusions. One of the more popular and well-known carpet classification systems falls victim to this. It is reasonably common, even today, for dealers, auction houses, and specialists to describe carpets as “Lotto” or “Holbein”, among others. These names were drawn from European Renaissance painters (Lorenzo Lotto, Italian, b. 1480; Hans Holbein the Younger, German, b. 1497). Each painter became associated with a specific style of carpet design because he tended to include them in his work. “Lotto” carpets have a complex, almost lace-like geometric design, and are characterized by red grounds and yellow designs (King & Sylvester 1983:20). “Holbein” carpets use medallions or guls, often octagonal, in geometric but usually non-gridded positions on a central field (ibid., pg. 26-27). From these classifications, modern carpets are attributed to the area around the city of Ushak in

west-central Turkey. The classification and attribution often stops there: it is a knotted carpet with a design popular in/near Renaissance Ushak. Consideration of material, structure, or technique are not made. This means that the system has no method for accounting for copies made elsewhere to capture a corner of the market, it has no method for distinguishing workshops or artisan communities within western Turkey, it does not even entirely limit to carpets woven in Renaissance Turkey. A modern carpet made in India or Canada would be called a "Lotto" or a "Holbein" by many, if the design was similar! Because the design is given priority over all other characteristics in this system, the design becomes the defining and interesting aspect of the carpet, and biases conclusions and understandings about its production and past (O'Brien et al. 1994:264). Robert Bettinger and Jeltner Eerkens make a similar note of inconsistent Great Basin projectile points (1989). Despite the considerably better preservation of stone points compared to knotted carpets, different typologies are still hierarchically arranged in different ways, resulting in different numbers of classes and different objects in each class. While this particular example of different hierarchies attracted the authors' attention and resulted in an interesting explanation of how different technological and social processes could result in two hierarchies variously prioritizing size or weight (ibid., pg. 239), this is not the normal outcome. Bettinger and Eerkens used the inconsistency to re-frame their thinking, but more often the inconsistency is ignored completely and the underlying biases are not addressed.

In this mess of competing dimensions, a curious tendency to avoid classification by time is notable. Of course many objects are *described* by a local or regional temporal period (e.g., an Iron Age carpet), but this is not quite the same as *classifying* by time period. Our pattern-

matching brains don't like grouping objects together when they clearly differ in quality, use, or origin, even if they date to the same period. I posit that this is all the more reason to use this and other jarring classification metrics: distinct pieces make an interesting and useful typological unit because they are bound by a feature that emphasizes their difference, not their similarity. Expectation of physical similarity is itself an assumption that should be avoided. To assume physical similarity is to ignore non-physical similarities and to overlook the cultural and artistic processes that *create* similarity, and the comparable processes that don't (Sørensen 2015:89-90).

This view of time as an inappropriate typological class is probably due to the common practice of using the typological class to identify time period. A newly discovered artifact can be dated by its similarity to items already in the typology, rather than using the artifact's age to place it within that typology (Sørensen 2015:86). This is often the case for the "Lotto" and "Holbein" carpets discussed above. Specialists with some rigor usually limit use of these words to only carpet made in the Renaissance, c. 1400-1700 CE. If an object is classified as a "Lotto" carpet, then, it is dated to that window, often without any external validation (few auction houses are carbon-dating their wares). Age or date is a characteristic that typologies spit out, not one that is always put in. Again, this completely overlooks the known phenomenon of copies produced outside this window to appear antique, and likely overlooks early iterations woven before the style crystalized fully.

Rather than considering the possibility that a particular object is dissimilar to its contemporaries, it is often easier to assume it is from another time, and to never check that assumption directly. Although I cannot provide a definitive example, I worry that many carpets

are misdated because they do not seem to match the prevailing trends of their time, particularly in the Renaissance when the vast majority of surviving carpets are court productions, and the appearance and structure of more domestic or novice works is essentially unknown.

The impulse to order, prioritize, or place classes in an unsupported hierarchy is a problem for typologies in evolutionary and CoP research. For nuanced work to progress, a more multi-modal classification scheme is required. Rather than trying to fit every carpet into the single best class based on a single arbitrary characteristic, instead we should describe them as the sum of their many parts: this multi-dimensional typologizing is sometimes known as a "quantitative typology" (Sinopoli 1991:53). If that creates typological classes of one, then so be it. Rather than emphasizing neat boundaries and discrete bins, modern carpet typologies should emphasize the network of overlapping or individual traits. This dissertation seeks to aid in that endeavor, by providing new information on the techniques and social pressures present in different carpets, allowing descriptive and classification networks to expand and complexify outward from the macro-scale decorative and structural features that guide classification and resultant attributions today.

A quantitative or network typology would inherently deprioritize the hierarchical or dendritic shape of traditional typologies. Importance of one trait should not be placed above another, especially by a living researcher who does not have direct knowledge of which parts were/were not of salient importance in the past. The function of a textile as a carpet or a saddle cloth cannot be assumed to be more relevant to its core character than its structure of pile- or flatweave (see Chapter 6 for definitions of woven structure). To classify it as by design first and

age second may prime any research conclusions on the “Lotto” and “Holbein” carpets to assume that cultural value was based on the design, and not on the material, labor, ethnic-cultural associations, or functional use of carpets. By emphasizing a network without biasing some classes over others, new patterns and connections can come forward. It may even be beneficial to think of typologies as descriptors rather than classifications: the goal is ultimately to differentiate forms and robustly describe their variation, not to group them or collapse their variation.

Similarly, it is important to work against assumptions of progress. A seriation based on externally-confirmed evidence like carbon dating or dendrochronology is one thing, but a seriation based entirely on an assumed elaboration or refinement in technique or style over time is another. This means that effective seriations and chrono-typologies must be built from some external reference, and not purely an advancement of technique. They must include technological breaks and regressions, where technology simplified or became less functional, and should not artificially condense long periods of plateau. Objects that seem too advanced or not advanced enough for their date can’t be removed from analysis as outliers: the network of traits that underlies the typology must be neutral and unprioritized. Particularly in the early history of carpets where the evolutionary/transmission track is unclear, it is important to consider the possibility that the technique was invented, lost, and reinvented several times, and that improved quality may not always match to a later date.

Despite the many problems with typologies and seriations, they are still a necessary component of technological evolution studies (Bettinger & Eerkens 1999:231; Shennan 2011:1072). Again, it is meaningless to track change over time or between groups if you cannot

define what changes have occurred. By building network-style typologies that emphasize small-scale differences without a hierarchical valuation or underlying assumption of progression, the models of technological evolution should become more robust. The value of these models is less in confirming what we already know or suspect, and more in showing where our assumptions and *a priori* conclusions do not fit the data. By removing biases from the underlying data, the conclusions can only be strengthened.

Sample Size, Provenance, & Perishable Goods

The perishable nature of the carpets themselves, and their tendency to appear in a fragmentary state, has resulted in a general trend of under-study (Costin 2013:180; Cybulska & Maik 2007:185). It is therefore often necessary for study of textiles to rely on secondary evidence rather than primary artifacts, including depiction and descriptions, tools, refuse/discard rates, dye residues, pseudomorphs, changes in economic systems, the distribution and genetics of woolly animals, etc. (Bender Jørgensen & Grömer 2012:47; Good 2001:209; McCorriston 1997:517521). When secondary evidence is available, it is not usually detailed enough to effectively differentiate between different textile structures, functions, or uses, and therefore is not especially helpful in reconstructing technological change and innovation within a specific textile class.

The structure and properties of individual textiles also greatly impact their chances of survival: loosely-woven fabrics are more susceptible to dirt, insects, and microorganisms than are tightly-woven fabrics; animal fibers (e.g., wool, silk) are more resistant to decay than are plant

fibers (linen, cotton); it is easier to reconstruct structural design and texture than to reconstruct color-based design whose dye is susceptible to light and water (Cybulska & Maik 2007:186-187). Fortunately, these factors mostly work in carpets' favor. Carpets are extremely dense, to the point of being almost waterproof, and are almost always made of wool. However, their designs rely entirely on color and not structure. A carpet that is entirely one color is structurally identical to one with an intricate design.

Despite a relatively good preservation prognosis, carpets are still exceedingly rare, even rarer than some other textiles with a less ideal preservation prognosis. This is likely due at least in part to the relative rarity of carpets even in living communities. Requiring an immense amount of time to weave, they have likely been an expensive and therefore scarcer product throughout their history. I suspect that their robusticity also means they are likely to be replaced less often: even today, the majority of hand-knotted carpets used in homes are antiques (although ours mostly date to the late Victorian era, not the Iron Age!) (Bier 1996:70). This means that carpet studies, particularly before the Renaissance, are based almost entirely on samples of one (Tsareva 2012:3), many of which were looted or badly provenanced. This is a worse-case scenario for robust technological study, particularly when attempting to evaluate higher-order processes of community formation or boundary maintenance, social stratification, ritual or mythological importance, reciprocity or exchange, scheduling and management infrastructure, environmental maintenance, or the role of tinkering, experimentation, and accidents in innovation (Lechtman 1993:245-246, 251; Martinón-Torres & Uribe-Villegas 2015:377; McCorriston 1997:517; Schiffer 1972:158).

The limited physical remains of knotted carpets can define only a correspondingly limited number of the various traits that likely existed in the past. Even a large sample is not especially helpful if it is not reasonably representative of the variation that existed in the past. The problem is complicated further because there is no way to know the extent of an ancient technology. Not only can we not know the missing values, but we can't even say how many missing values there might be. Mathematical models used in evolutionary studies are generally limited to inferences within the available data, and cannot estimate missing data either (Jolie 2004:308). New data, rather than fitting within or expanding an existing model, will often crash a model as it had no mechanism for acknowledging unknown alternate possibilities in the way that a human brain can.

A large, representative sample is, frustratingly, still not enough for effective modeling of technological evolution, or for meaningful use of a CoP framework. The data must not only be extensive and well-rounded, but also well-provenanced (Jolie 2004:318; Killick 2004:574; Shennan 2008:3176). This is a particular hurdle for carpet studies, as most extant historic carpets are entirely orphaned from their place of manufacture. Any provenance data that exist are usually a guess based on a dubious, hierarchical and narrowly-defined typology (such as the "Lotto" and "Holbein" carpets discussed earlier in this chapter). Even when extensive information exists on carpet variations and traits, they often cannot be linked to a time or place. Or at least, they cannot be linked to a time or place with any specificity. This lack of nuance in the data makes it very difficult to establish changes over time/space, possible transmission or migration events, or invention or loss periods. The combination of both a very small sample and very poorly

provenanced one, while certainly not unique to carpets, is also not universal in archaeology, and the difficulty of that combination should not be overlooked.

An ideal sample for technological evolution studies is one that is A) very large, for robust statistical analysis, B) very diverse, capturing a large proportion of the traits and variations that have ever existed, and C) has high temporal and spatial resolution, where individuals within the data are chronologically and spatially well-located. Although the creation of typologies and large descriptive datasets are not especially popular or glamorous in modern archaeology, it is a critical component of robust scientific research. Unfortunately, this level of sampling control is difficult even among modern studies of health or education, much less for perishable archaeological fields like carpet studies. Creative solutions are therefore in order.

Where it isn't possible to extend the extend carpet sample through additional historic carpets, it is possible to expand it by describing the existing carpets with considerably more detailed measurements and traits categorizations. That is what this dissertation shows, at least in preliminary findings: that thousands of fine measurements can be effectively and accurately measured from a carpet, and that those measurements can be used to reverse-engineer production characteristics in some cases. This accounts for the mathematical dream-scenario of both a very large sample, eligible for essentially any statistical test, and a well-described and detailed sample, which has data on all aspects and dimensions of its being. These ultra-fine measurements and micro-view look at structural differences is an increasingly popular avenue of study in CoP work, particularly among ceramicists, but it seems to have potential in textiles too.

Achieving high spatial and temporal resolution of the data is a little trickier. As a biological material (until the introduction of synthetic fibers in the last century or so), carpets are carbon-datable. This should make serializing them relatively straightforward, if expensive. And certainly, many historic carpets and fragments have been carbon-dated, mostly by major world museums. Developing temporal resolution strategies is in less need of creative solutions, as an accurate and feasible option already exists that provides external validation of age.

The spatial resolution could use some refinement though. The ability of this dissertation's results to reverse-engineer production characteristics from historic carpets, and to better document similarity and difference in existing pieces, should help with this issue. Although a deeper understanding of production traits and similarity between carpets can't directly give provenance, it can identify where strong similarity might indicate a shared provenance, or strong dissimilarity a mistaken one. Similarly, references to tools, techniques, or social factors that might be available in secondary archaeological evidence, depictions, written histories, or experiments and theorizing in other textile types can be used to guide conclusions about where specific carpets could and could not have been made, by situating them and their production characteristics in the wider technological context. Through an increasingly detailed network of similarities and differences, carbon tests, genetic and biochemical tests on strains of fibers and dyestuffs, and situational context in history, genetics, and non-carpet archaeology, carpet attribution should be improved over time. The sample of historic carpets eligible for complex mathematical and evolutionary modeling therefore is expanded not by recovering new, well-

provenanced carpets, but rather by moving existing carpets from the poorly-provenanced category to the well-provenanced one.

Ethnography & Experimentation

Ethnographic and experimental methods and concepts were an integral part of this research. The goal of both ethnography and experiment in the archaeology of technology is to provide a more well-rounded understanding of techniques, materials, and social constraints acting on technological (and other) processes, in order to draw analogies and explain patterns present in the archaeological record (Costin 2000:377; Kenoyer et al. 1991:45; O'Brien et al. 1994:266). These comparisons can be used to challenge assumptions about difficulty or time requirements, to highlight when there are steps, materials, or techniques missing from the archaeological record, or to illustrate how a process can function in a specific social setting. Ethnographic and experimental research tends to be comparative, where differences noted between different groups or conditions are used as a focal point for further research (Killick 2004:572). These comparisons, whether they result in similarities or differences, can give insight into the relationships between technologies, language, ethnicity, class, gender, etc. Tim Ingold sums up the deeper understanding provided by hands-on work (whether by an ethnographic analogue or performed by the researchers themselves) in his well-known essay on materiality:

> "Might we not learn more about the material composition of the inhabited world by engaging quite directly with the stuff we want to understand: by sawing logs, building a wall, knapping a stone or rowing a boat? Could not such engagement – working practically with materials – offer a more powerful procedure of discovery than an approach bent on the abstract analysis of things already made?"
>
> Ingold 2007:3

Despite their long history of popular focus in archaeology and anthropology, there is a tendency to *make* ethnographic records, but to then not use them to test hypotheses or refine conceptual frameworks (Lemonnier 1986:153). This is unfortunate, as ethnographic and experimental projects are particularly valuable in their ability to reinforce, refine, or refute existing conclusions (Costin 2000:379). Rather than acting as sole lines of evidence, they are most useful as scaffolding for ideas based more directly on the archaeological record in collaboration with mathematical models, history, materials science, and other methods (Schiffer 2010:236). Where models and experiments can test specific hypotheses under controlled conditions, ethnographic and archaeological data can provide natural observational data (Mesoudi 2010:188). Ethnographic and experimental descriptions of textile processes have been used in archaeological, historical, and art research for many years, and textile experiments can be dated all the way to Swiss researchers Jakob Messikommer & Ferdinand Keller in the 1850's (Bender Jørgensen & Grömer 2012:50). My research follows this tradition, in that it relies entirely on ethnographic-experimental analogy to trace relationships between production characteristics and finished carpet knots.

Despite their long history and clear potential, these methods need to be clearly defined in order to provide helpful insights into the past. At the most basic level, ethnographic and

experimental projects need to be able to show similarity to and continuity between the modern practice and the ancient or historic one (Kenoyer et al. 1991:44; Killick 2004:574). This is necessarily deeper than a mere similarity in visible output, and should be based on reasonable similarity of material, technology, resources, and a shared history in the studied craft (Martineau 2001:210). Major periods of loss/reinvention or technological replacement between the modern practitioners and their historic counterparts should be avoided. Archaeologists relying on these techniques should also be careful to evaluate their underlying assumptions and the limitations of the tests, which are not insubstantial (Kramer 1982:672).

Although there does seem to be considerably more variation in carpet weaving in the past (hitting what might be the all-time high in the late Iron Age) than is popularly used today, I believe it is still reasonable to use modern hand-weavers as an ethnographic analogue to their ancient counterparts. Firstly, although the number of popular weaving variations appears to have reduced in the last two thousand years, the ones used today did exist in the past. It is really the combinations of traits that have changed, and not the traits themselves. As my research looks at each trait individually and does not measure them as complexes, this should not be a huge concern. The modern carpets are predominantly built on similar materials, with most made of wool (as in the past). Some addition of silk and cotton were not unheard of in the past either. The only modern material included here that does not appear in the past is a synthetic yarn. I do not expect this to have a big impact on weaver's movements or sequences, but acknowledge it could have different properties of friction or tensile strength that might affect results.

Maintaining a shared history in the craft is also my reasoning for selecting weavers in Central Asia; although the exact origin of carpet weaving is currently unknown, Iranic and Turkic populations in Middle Asia (from Mesopotamia to western China) are one of the leading contenders. Even if they did not truly invent the technique, they certainly picked it up relatively quickly, and their work in this field has run for at least 3,000 years.

The major issue faced by ethnographic and experimental studies is that it is not possible for a modern test, no matter how thoughtfully formulated, to perfectly recreate the social-cultural factors that drove the ancient world (Hurcombe 2008:84; Shimada & Wagner 2007:164). This is important to acknowledge in this study. Ethnographic/experimental studies may focus on processes, tools, techniques, materials, or social concerns that did not exist in the past at all, or inversely, there may be things we would like to study in the past that there is no extant analogue for (ibid). The use of synthetic yarns here is a good example, as are other factors that would not have occurred in the deep past (synthetic dyes, machine-spun yarns, plastic loom components, electric lighting, worker's rights and labor laws, medical corrections for poor eyesight, etc.).

The time frames of ethnography and experiment can also be a sticking point, as the complex social, economic, cultural, and environmental processes that drove technologies and craft production in the past played out over years or even generations: modern ethnographies and experiments rarely cover more than a few months, and more often only a few hours or days (Binford 1981:197). This dissertation only covers one to three carpets per weaver: a larger selection of her work across years, or even her entire weaving life, would be a better representation of her personal variation, development, and artistic signature.

These studies also often only focus on one craft, or even a small facet of one craft. While this builds robusticity in conclusions about that particular thing and minimizes obvious confounding factors, it may simultaneously reduce our ability to situate that craft in the larger socio-technological landscape (Shimada & Wagner 2007:165). This overlooks issues of technical sequences, material supply, pre-processing, seasonality, multi-component products, knowledge or tool sharing, and scheduled or shared labor. Again, this type of limitation is present in this project. The weavers included here did not shear, clean, spin, or dye their yarns. Some of them did not design their carpets, or cut them from the looms, or perform finishing processes. Few of them were directly involved in the sale of their works, and most are employed in carpet-making year-round without time off for seasonal agricultural tasks. My ethnography does not cover the sourcing or production of tools or materials, nor the training weavers receive in childhood or adulthood.

Although these dissimilarities between ancient weavers and the ethnographic ones who collaborated on this project are alarming when listed like this, I do not think they are insurmountable problems. Firstly, there are essentially no people left in the world who still have all the same constraints, opportunities, pressures, resources, and outlooks as their ancient counterparts. If small discrepancies invalidate ethnographic analogy to archaeological remains, then ethnographic analogy to archaeology could not exist. I also suggest that the small-scale differences I am measuring here are universal. One of my fundamental hypotheses is that if X tool or idiosyncrasy causes knot distortion, it always does so in the same way, based on universal constants like gravity, tensile strength, and geometric distortion. Other factors may exaggerate or

eliminate the visible results, but I do not think they could cause them to invert. And in fact, if confounding factors *can* cause a specific pattern to invert, then that pattern probably was not useful for historical research anyway! It would not have been distinct or reliable enough to use for comparisons to damaged, orphaned archaeological textiles. Overall, I do not worry too much about the perfection of the ethnographic analogy here. It could never have been perfect, and this is only an initial attempt at this specific comparative method. I would, however, hope to expand the work later with a wider ethnographic sample, covering more people (and the same people more often), more locations, more weaving traditions, more resource types, etc. The larger the ethnographic comparison is, the more robust my conclusions about universality can be, and in turn the more reasonable any resultant historic interpretations become.

The underlying assumption in many ethnographic and experimental projects is that A) there is a practical reason behind different choices, B) all the practitioners know what those reasons are, and C) the reasons line up with a modern explanatory rubric (Schiffer & Skibo 1987:596; Shimada & Wagner 2007:165). This is rarely the case. There are many examples throughout ethnography of craft practitioners not realizing that there was an alternative option at all, or if they did know about alternatives, their only explanation for why they do things their way instead of another is because “this is how we’ve always done it” or “this is the right way to do it” (Killick 2004:573; Lemonnier 1986:165; Roux et al. 2017:333). These vague explanations are often not satisfactory for researchers and do little to answer the technical questions at the heart of the research. However, these responses are valuable insights into the interplay of community, trust, authority, culture, and technology, where explanations given by teachers or

leaders are accepted as valid even without explanatory power. A community-of-practice study might be able to tease out the causes of these explanations in some cases, as a conformity bias, an appeal to authority, or a mythological worldview that sets this technique above others. In the case of the weavers in this study who stated that left-handed weaving was impossible, I would suggest that this is a widespread remnant opinion of the still-prevalent bias against left-handedness in wider Central Asian culture, rather than a belief specific to carpet-weaving (although, it is a little suspicious that none of the weavers interviewed were left-handed!). A dedicated study into this bias might be worthwhile though, as well as an empirical study into speed or accuracy in knot-tying between right- and left-handed weavers. Unfortunately, as no lefties volunteered to participate in this project, I have no empirical evidence to confirm/refute this idea myself, and can only rely on the other members of the carpet community who disagreed with these opinions to know that left-handedness is not a disadvantage.

This type of vague explanatory justification is particularly tricky when using modern practitioners who operate at a different level than their ancient counterparts: just because the hobbyist doesn't know why X technique is used doesn't mean the ancient master didn't (Schiffer & Skibo 1987:596). I would not be surprised if this was particularly the case for the ethnographic weavers, none of whom were involved with the entire fiber-processing system, and many of whom were not even involved with more immediately-relevant tasks such as warping the loom or deciding on the pattern. It may be that factors from those processes radiate into their weaving work and were the original functional explanations for some of their practices, even if they don't know it and can't explain it now. Particularly for weavers who were trained in professional settings

as adults, like most in this study, their opportunities to tinker, experiment, play, or explore alternatives may have been limited or nonexistent. Their ability to test other options and understand explanations and preferences for themselves may therefore also be reduced, compared to historic weavers who might have been more integrated into the weaving process from a younger age with less continuous oversight and in a less didactic setting.

Similarly, observations derived from modern artisans, who likely have a different social-economic imperative for the craft than ancient artisans did, can artificially skew results based on different levels of practice, time commitment, and attention (Eerkens 2000:667; Tiedemann & Jakes 2006:303). This is particularly troublesome when a significant portion of the archaeological samples are court or elite products for which there is little industry (Shimada & Wagner 2007:166), as is the case in carpets. Only a handful (6) of the weavers I interviewed might be considered elite or court producers today, although that terminology is already tricky as average carpet quality has steadily increased over time. It is hard to quantify how historic and ethnographic practitioners should be balanced in cases like this. Does knot density (the common modern measure of carpet quality) dictate ethnographic compatibility, in which case a great many modern casual/domestic weavers are “court quality”? Or does the weaver/consumer’s perception of the work and social status dictate compatibility, in which case very few “court quality” weavers still exist? I do not have an answer, but it is a concern I have grappled with throughout the course of this work. Perhaps a dedicated project could formulate some experiments to test this relationship. As my research studies the knots as individuals, however,

and not in their density relationship to each other, I hope that confounding factors relating to this issue of density and quality are minimal.

Ethnographic and experimental analogies where tools and materials have changed drastically is another set that merits extra consideration, and another that is relevant here (Eerkens 2000:667). Although in concept the weaving technology used by this project's ethnographic participants is very similar to those known historically, they are not identical. Particularly for research into small-scale differences, it would be preferable to use perfectly matching tools. As this is not realistic, I instead aim to build only generalizations: I cannot say to what numeric degree any tool affects the knots, only that it does seem to affect the knots in a specific direction. Documenting the specific tools of the ethnographic weavers was therefore an important step to me: it can't confirm anything about ancient weavers, but if someone wants to expand my research in 2200, they will at least know exactly what types of knives and scissors *these* weavers had! I am essentially building the comparative tool library that I wish I had when producing this dissertation.

Although ethnoarchaeology has problems of poorly-formulated goals, methods, and bias, particularly in drawing conclusions from groups with more dissimilarities than similarities (Roux 2007:154), that does not make it or its experimental cousins wholly useless. When executed thoughtfully and lodged solidly in a grounding of archaeological and material-cultural evidence, these methods can produce conclusions that are scientifically robust (Killick 2004:573). They provide a good base for more abstract social studies on community formation, economics, value and prestige, symbolism, and other concepts (Shimada & Wagner 2007:164), and in testing that

a specific feature is possible at all before searching for it in the archaeological record. The danger in ethnographic and experimental research isn't so much in the projects themselves, but in the overextension of conclusions to things that cannot be known. But just because an experiment produces more questions than it answers doesn't mean it is wrong, or that it wasn't worth doing (O'Brien et al. 1994:299).

Experimental and ethnographic research has been conducted successfully in many object media, on a number of different technological questions. Examples specifically in textiles include evaluating the speed at which fiber can be spun and the correlated labor costs (Tiedemann & Jakes 2006), quantifying the structural differences between comb- and sword-beaten flat-weave textiles (Grömer & Rösel-Mautendorfer 2013), understanding how the morphology of the weights affect textile structures in warp-weighted looms (Mårtensson et al. 2009), and the effects of community and biomechanical standards on fiber spin direction (Minar 2001). These and hundreds more projects incorporate both ethnographic comparison and controlled testing to better understand textile processes in relation to archaeological data, by matching possible or likely outcomes viewed among modern practitioners to estimate the constraints and skills of ancient ones. To my knowledge, there have been no controlled experimental studies of knotted carpet weaving except my own (this dissertation; and V. Sluka 2017, 2018).

One benefit of experimental and ethnographic analysis in understanding technological evolution is the tendency to highlight visible and invisible variables, and those properties which are inherent and intentional, and those that are emergent. One difficulty of evolutionary frameworks is that the selective pressures can act on any of these traits, simultaneously and to

different extents. A feature may be unintentional, unnoticed, or even in error from the maker's perspective (Costin & Hagstrum 1995:622), but still make the object more/less functional, or more/less valuable to consumers: trading cards with typos and dollar bills with round serial numbers are often higher-value than their more common counterparts. These traits, whether intentional and/or necessary to production or not, are visible. These objects can be intentionally sought out or avoided by users, the irregularity's presence could cause the maker to discard the item as faulty, or could cause an authority to remove it from the market. Any of these pressures would in turn drive evolutionary forces to select for or against the trait and the techniques that produce it. More than one carpet professional told me that carpets are not and should never be perfect: reasons ranged from honoring the Islamic belief that only God is perfect, to the more mundane explanation that mistakes are normal and the hallmark of handmade goods. I wonder how those two could be interpreted differently in an archaeological assemblage though. One is an intentional choice to introduce imperfections as a mark of respect, one is a byproduct of natural human error, but both would appear as a few mis-tied knots, and both would be interpreted as appropriate, expected, and/or necessary in different contexts.

Invisible traits can have similar effects, despite them being not visible. Invisible traits are those that are not readily apparent to the user, purchaser, or maker. This might include traits that are produced by multiple possible techniques (hammering a nail in with a purpose-designed hammer has the same final result as hammering a nail with a brick, so hammer-work and brick-work are invisible traits to the consumer). It also can include traits that are personal idiosyncrasies of the maker (a weaver working from left-to-right or right-to-left), and traits that are associated

with cultural biases about place, person, environment, politics, etc. (20th century enthusiasts preferring carpets made by nomads over carpets made by sedentary communities, regardless of differences in material, quality, or decorative style).

These invisible traits cannot currently be identified simply by looking at the finished object but are where ethnographic and experimental studies, including this one, really shine. A researcher might not even realize that weavers have the option to work in different directions if they did not have the chance to observe them, because weaving direction is not visible in a finished carpet. Even I assumed that, given the option, most weavers would choose to weave in the same direction as their native language is written and read (left-to-right in the case of all weavers interviewed). This turned out to not be the case – those that wove in a consistent direction all work right-to-left. When asked why, one weaver (Survey 11) stated that the right side is considered lucky, so it is best to start there when you can. I had not considered a mythological explanation for this choice at all: not only was my assumption of weaving direction wrong, but my grounding for that assumption was wrong! This sort of bias in invisible techniques is exactly the sort that ethnographic analogy is so adept at highlighting. These distinctions are crucial in evolutionary archaeology, because selective processes work on the phenotypes (the observed traits), and not on the genotypes (underlying causes). While the observed traits can be the physical or cultural manifestations of the object or the technological skills used in its production, it is important for researchers to understand and clarify what aspects are being acted on by evolutionary forces, and which are simply along for the ride (Boone & Smith 1998:156). Explaining why the carpet industry shifted to produce coarser works is a selective effect of the 1960's

romantic obsession with the unseen nomad, not with a direct functional or stylistic preference for coarser wool or geometric designs. It was the cultural identity of the (imagined) maker who drove the market and resultant structural and stylistic changes, not the objects themselves, and not the other way around. Understanding which aspect is the salient driver of evolution, which is the phenotype in that situation, is critical (see Carr 1995). While it will never be possible to say with certainty what drove individual changes in the past, an ethnographic and experimental grounding are useful in highlighting research biases and assumptions, as they did here.

Specialization & Standardization

Although the experiments and analyses presented later in this dissertation were not focused explicitly on measuring or evaluating carpet specialization, attributes and outcomes associated with specialist production are relevant. One of the goals here was to investigate how specialist production might be read from historic carpets, but not to perform in-depth analyses on the social-cultural, political, and economic factors that shaped or radiated out from specialization among the represented groups (historic or ethnographic). More detailed studies of craft specialization might be possible based on the technique tested here though, and should be incorporated into the wider study of ancient and historic carpets.

Specialization is an important and popular theme in archaeological studies of craft and technology. It represents a shift away from a self-supporting system where households are responsible for making or providing the goods and services they require, to an optimization scheme where fewer individuals specialize in a process to increase efficiency and provide for the

larger community. Specialists are generally understood to be those who produce more of a product than their own household needs, while simultaneously producing less of other products than their own households need (Blackman et al. 1993:60; Costin 1991:3-4). The surplus product is then exchanged for the deficient ones, resulting in a balanced household supply. To some extent, specialization depends on a larger specialized economy where multiple (or even all) products and services are specialized to some degree. Particularly in pre-industrial economies, it would be difficult for one family to specialize in the production of ceramics without another corresponding family specializing in crop maintenance and making up the net agricultural loss accrued by the potters. And the family specializing in subsistence would need the support of other families specializing in textile weaving or metalsmithing, as they would not have time to meet their own needs in those areas around the higher-output subsistence work. This becomes an increasingly complex cycle, ultimately resulting in the modern system where adults specialize in one role/profession and the vast majority of household needs are purchased, outsourced, or mechanized.

Often considered a marker of complex societies, specialization can range from common public products like plain ceramics, bricks, and iPhones to elite products like silk carpets, fine furniture, and private jets. By focusing individual labor on a specific product or task, improved outcomes can be achieved: faster speeds, higher standards, increased quality control, pooled labor and knowledge banks, shared tools and workshops, reduced shipping and logistical costs, etc. Rather than each family having to support their own carpet production, with sheep herds, looms, dye vats, and beating combs that are only used occasionally in the long carpet-production

process, a specialist workshop can use those items more consistently, spread start-up and maintenance costs over a larger output, and reduce prices overall while training individual makers with higher skills and quicker work.

Specialization is a relative state, not an absolute one: what would be considered highly-specialized system in one community or craft medium might be less specialist in another (Costin 1991:2). This is part of the reason that direct ethnographic comparison of quality between modern carpets and historic ones is tricky. A mid-range knot density produced by domestic or semi-professional weavers today would be elite in 0 CE. The degree of specialization can be estimated from the amount of time individuals spend producing an artifact, the proportion of their total subsistence that is derived from that product compared to other outputs, the consistent sale of the product, the use of a specialist word or profession for makers of that object, a formal system of training or education in production of the product, materials and tools that are centralized to a few locations or designed for a narrow technical function, and reduced variation in the physical form of the goods (Blackman et al. 1993:60; Costin 1991:2). The eighteen weavers who collaborated on this project range from domestic to professional, with some working ad-hoc for their own personal enjoyment, and others working consistent 8-hour days in professional workshops. Their work would therefore be classified as not specialized at all through to highly specialized.

The reduced variation in physical form that often accompanies specialization is known as standardization; the object becomes increasingly similar to a standard as the labor becomes more specialized and skilled. Standards may be a physical object to copy, or a mental model held in the

minds of makers and consumers. Increased standardization, like specialization itself, is due to many factors, including a smaller number of makers introducing their individual idiosyncrasies to the pool (Costin & Hagstrum 1995:622), more consistent raw materials and techniques (Blackman et al. 1993:61), or economies-of-scale, repetition, and differentiation of technological steps (ibid).

Not all specialized work is standardized (Arnold 1991:364; Blackman et al. 1993:61). Specialized artisans can and do produce entirely original and unique works that are not directly comparable to anything else. The ability to purchase one-of-a-kind art and furnishings from acclaimed specialists and artists can be a mark of prestige, wealth, or power. These artisans are highly skilled specialists and work in dedicated workshops with efficient methods and fine materials, but are not mass-manufacturers. And inversely, a high rate of standardization is not sufficient evidence for a specialized craft in all cases (Arnold 1991:364). Very narrow functional requirements or limited material availability can incentivize movement towards a standard even among individual domestic makers, as could regular comparison to guides, measures, or instructions.

Physiological limitations can artificially impose standardization too, such as smart phones limited in size to comfortably fit in the average hand, or the length of a bed sized to fit the height of an average adult (ibid., pg. 367). This kind of physiological limitation was seen in some of this project's purchased sample carpets: although I did not specifically dictate a size requirement for them, they are all relatively small, and all can be produced by a single person sitting in a single position. The weaver, and therefore the loom itself, prioritize carpets within easy arm's reach. The similarity in the carpets' widths should therefore not be taken as evidence of widespread size

standardization across all the weavers' communities, but rather an emergent property of biomechanical comfort and efficiency, and the arm-span of the modern Central Asian woman.

Improved tools over time can cause a shift in the level of standardization required to be considered specialist, where medium-standardization with poor tools is considered highly specialized but high-standardization with better tools is less specialized. This reflects the increasing standard of woven carpet seen over the last few millennia – higher-quality, more consistent, and more sturdily produced tools and yarns have allowed an average modern weaver to work at what would have been an elite level two thousand years ago, and we should be wary of interpreting modern carpets as more specialized than historic ones for only this reason.

Although these exceptions exist, the general rule is that most standardized goods are also specialist (Blackman et al. 1993:61), as the variable pressures, preferences, and resources of many non-specialist makers will tend to diversify the sample even when these other constraints are present to standardize it. This ambiguity is why it is important for specialism and standardization to be defined relative to individual communities, and not viewed as a universal quality standard. These attributes, and the pressures that create them, occur as a continuum and not a binary (Costin & Hagstrum 1995:622).

Measuring and describing craft specialization has received a lot of attention in archaeology. The most relevant to this project are descriptions of the specialization scale, representing type and intensity of production and level of external control exercised over the artisans. This scale has been variously defined by many authors, but in general it runs from truly domestic production for home use (not specialized at all) to highly skilled artisans working entirely

on a made-to-order model for courts and other elites (extremely specialized) (Costin 1991:8-9; Grömer 2016:247).

The lowest or non-standardized end of the scale is taken up by household production. This involves people making only the products their household requires. This type of production requires technological knowledge to be widespread and the materials to be easily accessible. This would not usually be considered specialization at all. Of the eighteen weavers included in this research, only one would be considered a true non-specialist, weaving for fun in her own home. Her items are for personal use or gifts to family and friends: she does not normally sell her work.

The simplest system that would be considered specialized is the independent cottage industry, where individuals working from home in their free time produce small quantities to sell. These cottage makers are distributed throughout the population and sell to the general public, with no restrictions on purchasing (Costin & Hagstrum 1995:621; Grömer 2016:247). Cottage industries could be considered “side-hustles”, as they are not the primary labor task of the maker, nor are they the primary source of income for the household (Thompson 1993:11). Because there is a relatively low economic incentive or risk and a large customer pool, individual specialists of this style tend to have more room for creativity, experimentation, and personal style in their work, and can more quickly adapt to changing fashions and preferences among the consumers. Four of the weavers interviewed here would be classified as cottage-industrialists. These weavers work out of their own homes, but earn some money from carpet-making. They are not part of a formal organization or scheme, but have a loose camaraderie with other weavers in the area with whom

they can share sales leads, tools, and ideas. They are neither as wholly integrated as a dispersed workshop should be, nor are they as wholly independent as true domestic producers are.

When the artisans move out of the household and into dedicated spaces is when specialization of the kind usually imagined starts. Public workshop production sits in the middle of the specialization scale, but likely represents the majority of items produced in a specialized setting (Costin & Hagstrum 1995:621). Workshops aggregate labor, skill, knowledge, tools, materials, quality control, education, and peripheral resources like water and fuel into a single location. The distribution and scale of workshops can give clues to their role in society. Dispersed public workshops are those distributed throughout a population, offering products for the general public (ibid.). These units are relatively common and are more integrated into the community, with local labor and local sales (like a neighborhood bakery or coffee-shop).

Nucleated public workshops, on the other hand, draw labor and materials from further afield and concentrate them in fewer, wider-spread locations (ibid.). They might produce more complex objects, those requiring niche materials or knowledge, or things that are slightly more expensive to buy. The objects are sold to consumers in a wider region and may be designed for export. Because of the direct consumer pressure, workshops usually produce items in-line with public fashion and preferences, resulting in objects that standardize around the current fashion ideal (Grömer 2016:247). However, they may also be slower to adapt to changing fashions or preferences, as they need to shift a more complex workforce and logistics scheme to the new style.

Five weavers in this study fall somewhere between a cottage industry and a nucleated workshop, but are not a dispersed workshop either. They are specifically employed/commissioned to produce carpets, mainly for foreign export, and are held to some quality control standards. However, they work from their own homes and on their own time, which would usually not fit with the expectations of a workshop worker.

Two weavers of the eighteen do fit into the definition of a nucleated workshop specialist, working in a dedicated space on controlled products, with established quality standards and little personal control over output. Their work is produced mainly for export and sale to the wider region, and is not generally expected to be sold to the local community of neighbors or peers.

With considerably larger-scale production, even to the scale of mass-manufacturing, workshops are able to streamline costs and produce comparable objects for a lower price than domestic or cottage industry can. Because they are driven by consumer preference and quality expectations, artisans working in workshops are generally restricted to specific tools, techniques, and materials, and have little /(if any) control over the style, form, or decoration of their output. Workshops can use either voluntary/economic labor, corvée labor, or slave labor (ibid.). The larger-scale social-economic systems required to organize either corvée or slave labor mean that these types are usually (although not exclusively) limited to workshop production, and tend not to appear in household industry. Of course, none of the weavers or workshops included here use anything except voluntary/economic labor, and none of the included weavers were children (<18) at the time of participation.

Finally, attached, retainer, or patronage systems represent usually the most tightly-controlled and highest-quality production available. These artisans are hired or retained by elite individuals or institutions to produce works solely for the elite individual/institution. The artisans selected for these roles are usually among the best available: some may have gained their skills organically through education or training in public workshops or through individual virtuosity, while others are trained from childhood specifically for the patron. This work takes place in dedicated, highly-specialized facilities which often have restricted access, and retainer workshops do not usually produce items for public sale (Costin & Hagstrum 1995:621; Grömer 2016:247). Production may be at the scale of single, individual artisans, or large-scale workshops producing high volumes. The output may be produced continuously or sporadically, may be duplicates or one-offs, and may be the particular request of the patron or by personal preference of the artisan. This means that attached artisans can regain some control over their own work, and often have the freedom and trust to exercise their personal creativity and sense of style. The patron, in turn, earns prestige from possession of the artist's distinctive and high-quality works.

Although none of the weavers in this project truly reach the level of attached or patronage production, a few could be said to fall somewhere on the spectrum between a nucleated workshop and a retainer one. These weavers (six in total) work in highly-specialized silk workshops, producing very expensive pieces for the world's elite. Their manager indicated that a significant portion of their sales were to the local and national governments, intended as gifts for domestic and foreign dignitaries. However, these workshops are not directly funded by or associated with any elite individual or institution, and are perfectly happy to both sell their work

to the general public (if the public can afford it) and to welcome the public in for tours. They therefore do not totally meet the common expectations of retainer production despite their luxury products and high skill, as their labor and expertise are not controlled, rationed, or restricted by an outside influence.

I would be surprised if there are any weavers left in the world producing household carpets in a truly attached/retainer setting, as the demand for carpets for any single person, family, or organization is just not high enough to justify keeping weavers on payroll. The occasional commissioning of a single silk carpet from a workshop like this one is, I suspect, as close as modern carpet-weaving gets to a patronage system. I would therefore not expect any of the modern carpets studied to reach the level of specialization of the court products of 14-18th century Turkey, Iran, Egypt, or India, where elite retainer workshops generated the majority of the extant Asian carpets of that period.

Because specialization, in of itself, is not a focus of this study, it is worth digging deeper into standardization. As already discussed, standardization is often used as an indication of specialized production, on the assumption that very similar objects are more likely to result from some sort of concentrated, organized, and repeated activity than from random, independently-driven household output. Levels of standardization and their distribution are used to estimate specialization, labor organization, and resource management from limited archaeological remains. Standardization can be measured on many different axes, including form/morphology, material, decoration, size, and more. Like specialization itself, standardization occurs on a continuum: object can be very standardized on some axes but not standardized at all on others.

Standardization studies therefore require a large sample, as evaluating similarity between objects is not meaningful without objects to compare.

Archaeological standardization is studied through measurement of variation. Variation is the differential characteristic that allows evolutionary processes like selection and drift to occur (Schillinger et al. 2014a:129). Variation occurs in features that sit on a spectrum, and which do not have a clear line between correct/incorrect or good/bad. For example, a ceramic cooking pot may vary in size, shape, and design, without greatly affecting its utility as a cooking pot or its value to its owner. Many styles and forms are equally valid pots. Variation is usually quantified by direct measurement of physical aspects such as height, weight, thickness, chemical composition, etc. (Schillinger et al. 2014a:130). This means that studies of variation tend to prioritize measurable and objective traits: it is very difficult to quantify the artistic style, color scheme, or aesthetic balance of a piece, much less to do so in a way robust enough for statistical analysis. In the case of the methodology tested later in this dissertation, the unit of standardization is the pile knots, which can vary individually. They are visually discrete, making them relatively easy to measure in a consistent way, and they occur in the thousands or even millions in a single carpet, which creates an artificially robust statistical sample even when relatively few carpets are available. Standardization in other textile types is very hard to measure, as boundaries and components are less rigid and more amorphous. Trying to measure the length of a warp thread or the gauge of a weft would be quite difficult while ensuring that they are not compressed, folded, looped, stretched, or otherwise artificially distorted by the measurement process. Even defining the ends

of warps/wefts can be ambiguous, as they often loop around edges and continue across long sections of the textile.

Variation can be introduced intentionally or accidentally by the maker (Gandon et al. 2018:300-301). Intentional variation is quite easy to understand and explain, even if it can be difficult to identify in the archaeological record. These are choices that the maker is cognizant of: the choice to make this carpet a little wider than the last, or to use silk instead of wool. This is not the type of variation studied here. The small-scale variation in the knots measured here would be unknown and mostly invisible to the weavers, and is not intentional.

Variation can also be introduced accidentally through misunderstandings of process or instruction, unpracticed gestures, inconsistency of tools or materials, or inattention. They can even be introduced against the maker's best efforts, as human biophysical limitations make it impossible for us to reproduce exact duplicates by hand, and sometimes even to see where two objects differ. These types of unintentional variations are often called copying errors (Eerkens & Lipo 2005:319; Eerkens & Lipo 2007:256; Gandon et al. 2014:99-100; Kempe et al. 2012:2), in reference to the maker's inability to exactly copy the presented standard. However, I dislike this use of "error", as it implies a binary system where some qualities are fully correct and others are fully incorrect. I think copying variation is a better way to conceptualize these inconsistencies, as there is rarely a definitive line where 'correct' ends and 'error' begins. I would consider any trait that occurs on a continuum or spectrum to be a variation. I would only call something an error if there were a definitive, measurable threshold or test that had been failed.

The knots in this dissertation fall under this copying variation category, as the differences between them are introduced accidentally be the weavers, and mostly without their knowledge. There is no hard line between a 'correct' knot size/shape and an 'error' knot size/shape, and so they sit on the variation continuum. I have performed some research on knot errors too, however, in the form of their accuracy in following a pre-drawn pattern (V. Sluka 2017). In this case, the color of the knot rather than its size or shape was the dimension of interest. Because there was a drawn reference to compare to, knots were truly correct or errors: either they were the color dictated by the pattern or they were not.

Studying variation has some limitations. The inability to systematically measure or describe stylistic change in a statistically meaningful way is a big one, although as mentioned above, there is some opportunity for this in the case of knotted textiles. Another limitation is that conclusions drawn from a specific media and class are, for the most part, only relevant to that specific media or class. There is no agreed-upon method for comparing variation rates across media (e.g., comparing the rates of variation in a knotted carpet to the rates of variation in a felt rug used in the same home) (Eerkens & Bettinger 2001:494). This means that individual conclusions must be drawn for different media, and that in turn requires large comparative samples of each object class. Relatedly, there is also no system for multi-variate comparisons: you can look at diameter or angle of curvature in the pot, but it is much harder to quantify and study the overall shape/form as a cohesive, multi-dimensional concept (Schillinger et al. 2014a:129). This has been improved in the last twenty or so years, as computer and mathematical methods become increasingly adept at modeling, measuring, and comparing multi-dimensional shapes

(Gandon et al. 2018; Grosman 2016; Harush 2020, 2025; Roux & Krasik 2018). This dissertation faced that problem to some extent, in finding a way to measure, quantify, and meaningfully compare knot shapes. However, I was able to simplify the problem through use of shape standardization and dimension-reducing methods, including a generalized Procrustes analysis and a principal components analysis (see details and explanations in Chapter 8, starting on pg. 500). However, my shape data were only two-dimensional (x-y), and the shapes were represented by only four vertices and no curved edges: overall, it was a relatively simple "complex" form. Other research into other dimensions and materials are not so lucky. And yet as far as I know, my own work is the only attempt anyone has made at measuring variation (or error) in knotted textiles.

Differentiating intentional variation from unintentional variation in historic samples is difficult, as they can look the same: is this pot slightly thinner because the potter wasn't paying attention, or because he noticed that the thicker pots kept exploding in the kiln and is experimenting to correct that? Similarly, as we do not usually have access to the idealized standard towards which duplicate objects are working, it is hard for us to say if a objects fall into a high-variation assemblage working towards one standard (which might imply multiple makers, low skill, inconsistent materials, etc.), or two separate low-variation assemblages working towards two similar but not identical standards (which might imply higher skill and/or fewer makers).

By linking variation rates and patterns to specific social or technological settings, it is sometimes possible to infer production characteristics from measurements of variation/error in

archaeological assemblages (Eerkens & Bettinger 2001:494) and to clarify these similar lines of evidence. This is usually done by controlled experiment or by comparison to known ethnographic analogues. Patterns that appear in the modern sample, whose production is known, are used to explain the variation that appears in archaeological remains. This is the foundation of the method employed here, where consistent links between known production characteristics in ethnographic carpets are linked to rates and distributions of variation in the knots.

Over the course of many tests on a variety of different media over the last few decades, some overarching and generalizable principles have emerged (Fig. 4.1). These experiments show that some types of variations are directional (i.e., a reductive method will make the target size smaller over time, not bigger), or random (unskilled hands make many errors, but they both overshoot and fall short of the target size). The maker's skill level, the use of external rulers and aids, the size of the product, the frequency at which steps are repeated, the reversibility of steps, the number of makers involved in the object's production, and the amount of time it takes to complete an object can all give general insight into the amount of variation expected (Eerkens 2000:665-666; Schillinger et al. 2014a:130; Eerkens & Lipo 2007:247-248; Eerkens & Bettinger 2001:500). Again, these rates are relative: what would be considered a high variation rate in one craft or along one dimension might be considered a low rate in another.

Variation in crafts is also affected by biological limits in perception. There is a point at which the average human eye is no longer capable of detecting differences, even when they are present. Limits theoretically exist for all senses/perceptions, including size, weight, color, volume,

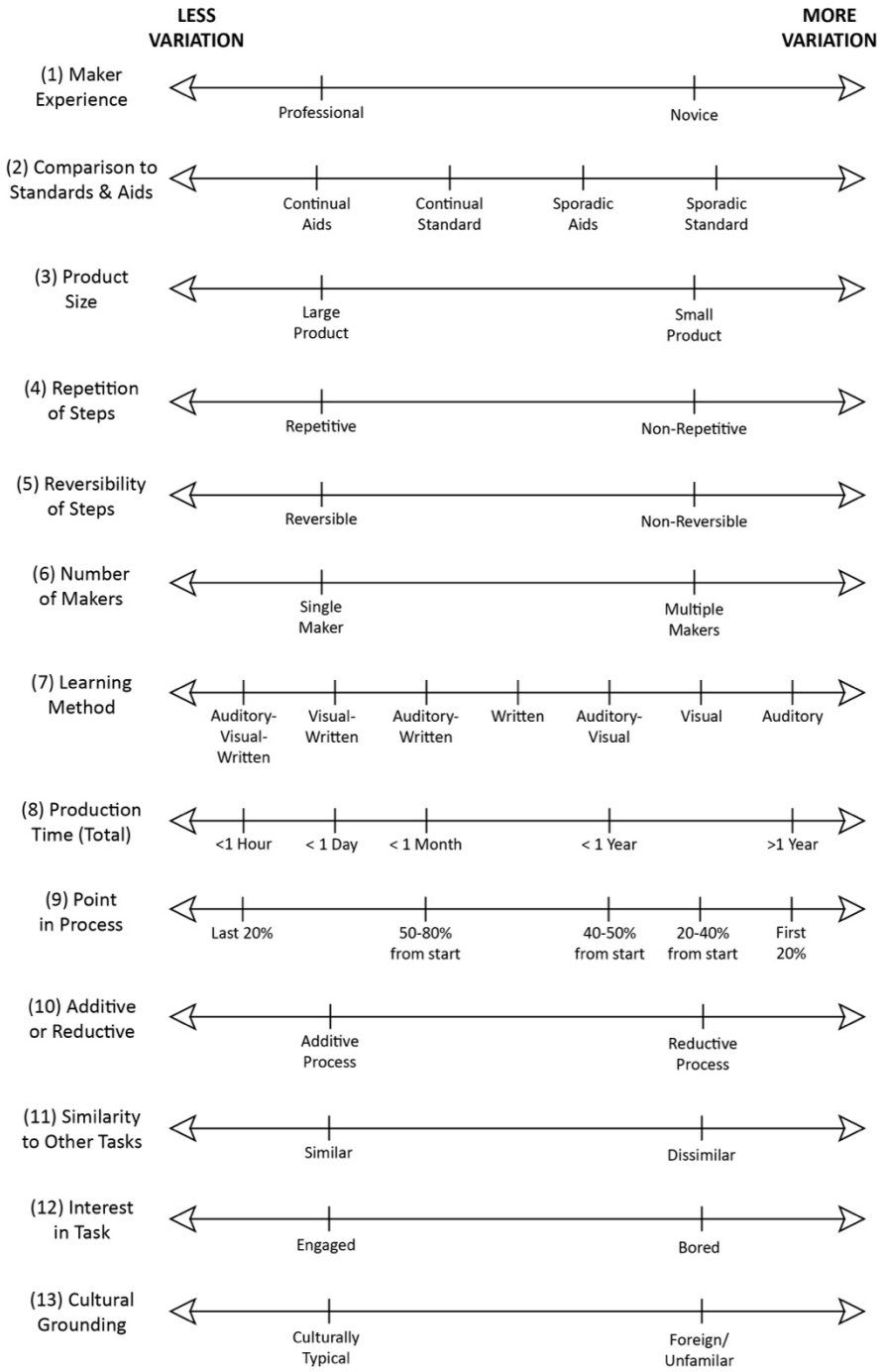


Figure 4.1: Factors Affecting Variation Rates

Summary of factors affecting variation rates. Not to scale. Figure by author.

Eerkens 2000 [1, 2, 3, 11, 12]
Eerkens & Bettinger 2001 [6, 8]
Eerkens & Lipo 2007 [4, 5, 6, 7]
Gandon et al. 2014 [13]
Schillinger et al. 2014a [4, 5, 10]
Schillinger et al. 2014b [9]

brightness, sweetness, heat, pain, etc. (Eerkens 2000:664). These physiological limits are known as Weber fractions, referencing the work of 19th century German doctor Ernst Weber who conducted experiments to determine the average detection limit of humans differentiating weights (Weber 1834). He estimated that the difference between two weights had to be more than 2% for the average person to tell them apart by hand. Based on his original work, fractions for other senses and perceptions have been established over the last two centuries (Eerkens & Bettinger 2001:494). The one used most often in archaeological studies is the Weber Fraction for Length, which estimates that if two items are within 3% of each other's length, the average person will not be able to tell them apart by eye (Teghtsoonian 1971, quoted in Eerkens & Bettinger 2001:495). These fractions are based on the physiological limits of an average, healthy adult with 20/20 vision, and do not allow for the use of supplemental tools such as magnifying glasses or rulers. This fraction also represents only single-dimensional size detection, and not multi-dimensional evaluation of area or volume.

Because of this physiological limit, a craft is usually considered increasingly standardized as it approaches 3% variation. Highly-skilled artisans working with their hands towards a clearly-defined standard are generally in the 4-8% range (Eerkens 2000:667; Eerkens & Bettinger 2001:496). Assemblages that have less than 3% average variation are assumed to have been produced with external aids such as rulers, molds, or machines. It is important to point out that the Weber Fraction only estimates our ability to *see* a difference: it does not account for our ability to eliminate a perceived difference by hand. This 3% limit also references only accidental or copying variation, and cannot comment on variation introduced intentionally by the maker.

This 3% value is used in a limited sense for this dissertation. Although the goal of this research isn't to individually evaluate the standardization abilities of the participant weavers, comparing their outputs to this clear threshold is a useful way to conceptualize their work and situate it in a larger archaeological-technological context, and in reference to each other. The modern weavers averaged around 10% error in their carpets, which fits with the general expectations for a group of mixed hobbyist and professional craftspeople working in a range of specialization settings. This finding and the way it was calculated is described in detail in Chapter 8, pg. 463.

Discussion

Critical evaluation of typologies and series, corrections for limited samples through comparison to ethnographic and experimental data, careful delineation of provenance, and narrowly-defined studies of object standardization and variation are all important underlying components of effective evolutionary studies. By employing these themes and methods thoughtfully and with clear inputs and outcomes, larger explanations of technological change can emerge. This project aimed to make small, incremental improvement in all of the topics described in this chapter, specifically with a view to improve outcomes in onward evolutionary studies of archaeological textiles. Although the evolutionary research itself is beyond the scope of this dissertation, consideration of evolutionary aims, methods, and common limitations are considered in testing this new method, to improve its applicability going forward.

To start, I developed my own system for cataloguing carpet structure. This addresses the vague and poorly-formulated typological schemes widely used in the carpet world today. It covers not only the knots (in more depth than they are generally given), but also the warp and weft structures, bindings, and selvedges (see Chapter 6, from pg. 295 for details on this system, and for carpet structure and term definitions generally). This system has more than 40 structural dimensions which were evaluated for each carpet individually (see the database reproduced in Appendix C). While I would not claim that my typology is exhaustive or without problems, it is certainly a step in the right direction when carpet studies of the last century have noted only the designs and a few basic structural characteristics.

The system I present also has no hierarchy. No dimension is placed above any other, and no class can be organized entirely within another. If a particular class in this sample appears to be situated within another, that it due simply to the limited sample size, and not due to a structural or imperative reason that is must be so. By establishing a more comprehensive and multi-dimensional typological network, I hope to minimize bias in the underlying typological system. The statistical analyses used do not preference any particular characteristic, and any outcomes measured are assumed to be specific to the characteristics that they are correlated with, rather than being a de-facto property of any larger group.

Like most carpet and wider textile studies that have come before, this project is hindered by the naturally low sample size of perishable goods. In some regards, there is nothing I can do about that – I cannot conjure up more ancient carpet remains than there are, nor can I grant myself access to carpets that museums and collectors do not wish to share. I cannot do much to

improve the low resolution available in the archaeological sample, but I can use ethnographic materials to generate a new, comparative analytical unit, which can handle the robust analysis that archaeological materials cannot. By directly observing eighteen modern weavers and collaborating with them to incorporate their deeper understanding of the processes, tools, and explanations, I was able to expand my typology to include another 30 dimensions that represent technological, gestural, idiosyncratic, and social-cultural factors that further categorize and differentiate a set of thirty ethnographic carpets. Not only does this expand the typological network to include factors that are usually "invisible" in archaeology, but it also provides direct links between lived processes and the resultant material culture. This, I believe, strengthens conclusions about lived processes in the past, and provides grounded explanations for observed variation. While of course it would be unreasonable to claim that an ethnography in the 2020's CE entirely and comprehensively mimics the lived or material carpet industry in the past, the depth of knowledge and the confirmed links available for modern products is a useful starting point for understanding the past, and identifying biases and assumptions that still underly my own work. Patterns, transmission events, and technological limitations identified in historic pieces by comparison to the ethnographic sample and placed alongside lateral evidence from history, biology, and materials science can create a more well-rounded picture of ancient carpet weaving.

The patterns and conclusions drawn from the modern ethnographic sample are produced through a study of material variation. To the best of my knowledge, my projects (this paper; and V. Sluka 2017, 2018) are the only ones that have ever attempted to quantify variation in knotted carpets. By refining my earlier methods (V. Sluka 2017) and adding new dimensions of

measurement and evaluation, I aim to more accurately and more robustly describe the variation visible in carpets. While again, I do not claim to document all dimensions of variation, I do believe that a focus on the knots (which make up more than 90% of the carpets' surfaces) and careful measurement of their size, shape, and density can expand study of variation in this field in a way not possible through descriptions of style, design, or basic knot classifications.

Thoughtful, critical description of and explanation for technological change over time and space is only as thoughtful and critical as the underlying samples, methods, and interpretations. Typological refinement, creative methods for expanding sample size in perishable materials, and detailed study of small-scale variations are all building blocks for the generation of larger ideas. Carpet studies, plagued for over a century by flimsy attribution and romantic ideals, are due for a complete overhaul and a rebuilding from the ground up with scientifically-backed and historically-grounded data. Before abstract themes like transmission biases, maladaptive traits, pedagogical structure, or identity signaling can be meaningfully examined, before we can link artifacts or show how they've changed, we need to be able to clearly and accurately describe them, along all dimensions of their being.

5. Carpet History

Defining a carpet is an important first step in a carpet study. English has an unusual disadvantage in that we have two commonly-used but not well-differentiated terms for similar items: carpet and rug. This duplication may not seem like a big deal, but it can cause a lot of confusion when trying to execute serious research into carpets. Many texts use the terms interchangeably, but also use both words for different classes of material. This means that it is easy and common to read up on what seems to be a relevant object, only to learn later that it is a completely different class of textile. Clarifying how I use the terms, in addition to considering how they are used by other English-speakers and in other relevant languages, is an important step. Ignoring this aspect results in misinformation, as references to “carpets” pile up in the literature when in fact, they are referencing a different class of object. Or the opposite, one might overlook a reference to a rug assuming it is not relevant, when it is. Authors often seem to not check the assumption that a particular reference is actually a reference to knotted textiles, and thus flat-weave and other structural information and history is misattributed at times, or grouped in with an analysis where it does not belong.

Based on at least a hundred conversations with friends, relatives, and colleagues about my doctoral research, it is clear that in many people’s modern western English, a carpet is generally understood to be a textile stapled or glued to a floor. This contrasts with a rug, which is

a textile laid on the floor but that is not secured to it: a rug can be easily repositioned or removed. Carpets have connotations of built-in fixtures, while rugs are decorations. Carpets have connotations of permanence, rugs are transient. This common English vernacular understanding of carpets and rugs does not align with the definitions in technical studies, or with the languages where the objects explored in this study were made.

Technical and specialist spaces have not reached an overwhelming consensus on if/how a carpet differs from a rug, or when it is appropriate to use either (or both) terms. At the most basic level, however, it can be said that a specialist does not refer to the permanent vs. transient quality that is at the base of the vernacular definitions. In specialist spaces, both terms will appear in reference to transportable, un-secured floor textiles. The fact that a particular homeowner or interior decorator chooses to nail or glue the item down is not pertinent to specialist work. In fact, even the "floor" textile aspect is not universal (see the definition for 'rug' given by the Textile Museum [2025])!

It is relatively easy to explain the occurrence of two apparently synonymous words in English. Like many other common words, there is one term derived from Germanic roots (rug) and one from Latinate (carpet) (Oxford English Dictionary 2025a, b). Anger/rage, moon/lunar, teach/educate, and king/emperor are all examples of the same phenomenon (all have the Germanic word first). We could consider the proliferation of the two words to be only a quirk of the language, and not an indication of different meanings or connotations. However, it does not seem to be the case that the two terms are wholly synonymous. A quick survey of art libraries, museum catalogues, and auction brochures will show that the two terms are very often used

together. Sotheby's has auctions of rugs **and** carpets, not one or the other, nor of rugs/carpets or rugs (carpets). Many scholarly and collector's books are titled in reference to rugs **and** carpets. The fact that so many scholars and organizations choose to use both terms in titles and categorization, without a clear hierarchical preference, suggests that the two words are somehow different: if they were wholly interchangeable, surely most scholars and organization would pick one or the other, especially for internal consistency in catalogues and references. Like the Germanic/Latinate pairs given above, rug and carpet appear to be subtly different.

Modern scholars do not seem to have an answer, and most don't display any consistency in how they use these two words even within their individual work. The eminent 20th century American scholar of floor textiles, Murray Eiland Jr., chose to title comparable books "Chinese and Exotic **Carpets**" (1979) and "Oriental **Rugs**: A Comprehensive Guide" (1973), despite both texts focusing on floor textiles made with the same techniques, in similar places, and at the same times. Even the analysis and historiography given in both books is similar, and I would class both books as the same type of text, for the same type of audience. Individual works may use both or either 'carpet' and 'rug', even in reference to the same object! Brian Spooner, in a now well-known discussion of authenticity and tradition in the carpet market, outright states that he does not have sufficient reason to distinguish the words and uses them interchangeably (Spooner 1986: footnote 1). Carol Bier, another prominent modern textile scholar who made her name curating the world-class rug/carpet collection (among other things) at the Textile Museum in Washington DC, defines the words as hierarchical, using rug as a more general term for all textile floor-coverings and carpet specifically for pile-woven floor-coverings (Bier 1996:70). Others use similar

logic to establish a lateral definition, where rugs are without-pile, and carpets are with-pile (Helfgott 1994:11, Topalbekiroğlu et al. 2010:51). The Textile Museum itself now uses 'rug' for all items made from knotted pile, including hangings and animal trappings, while carpet is reserved for knotted pile floor coverings (Textile Museum 2025). However, it is far more common for an author to use the words interchangeably, with no explicit mention of if/how they differ, no obvious pattern in application, and no rigor in ensuring a reference's application of the terms matches theirs.

It may therefore be useful to look at other languages to determine if it is appropriate to differentiate the words, and how. Modern Turkic and Iranic languages used in Central Asia also have two words that are commonly used for textile floor-coverings: *kilim* and *haly* (spellings and popularity vary by language, see the Glossary in Appendix F as well as Gyul 2023; Moshkova 1996; Tsareva 1984; Zhang 2015, 2019). Versions of these words appear in reference to textile floor-coverings in New Persian texts from as early as the 8th century CE (Zhang 2015), including gilīm, k̲h̲ālī, and qālī. A reference to either word in a modern Central Asian bazaar will lead you to textile floor coverings. Unlike in American and English shops though, it is clearer in Central Asia how their two words differ. A kilim will usually be a flat-woven textile without pile, while a haly will usually be a textured object with pile. A more detailed description of textile structure and pile is given below, but for now it is sufficient to say that kilims are flat, and haly are fluffy.[5] I suspect

[5] Both *kilim* and *haly* are singular nouns in their native languages. Different individual languages pluralize them in different ways. Because *kilim* has been adopted into English more thoroughly, it is commonly pluralized using the English suffix *-s* (kilims). *Haly* has not been linguistically naturalized to the same extent, so I use *haly* for both the singular and plural (like fish and fish).

(although have not tested) that the prevalence of the word ‘haly’ can be correlated to the incidence and importance of pile-knotted textiles in a society. Kazakhstan, which historically was predominantly a felt zone and has a weaker ancestral pile-weaving industry (Khlopin 1982:117), uses ‘haly’ rarely. If an English-Kazakh speaker is asked to produce the translation for either rug or carpet, they will usually supply ‘kilim’ (кілем) for both – my Kazakh-English dictionary does not give a ‘haly’ option under either carpet or rug. But based on my own experience with weavers and lay people in Kazakhstan, there does seem to be some general recognition of the ‘haly’ term, although they seem to see it as an esoteric, outdated, or specialist word. The artisans I spoke with in Kazakhstan recognized it as a specifically pile-woven item, but would tend, without prompting, to lump those items under ‘kilim’ (кілем). And indeed, ‘kilim’ was the word I used when ordering and discussing the project carpets with Kazakh collaborators.

In Turkmenistan, however, where pile-weaving is a national treasure and significant cottage and state industry, weavers are quick to correct inaccurate or indiscreet application of ‘kilim’ vs. ‘haly’. Even lay people with no textile specialism seem to differentiate the words naturally there.

When these foreign words are used directly/untranslated in English-language texts and studies, they are applied consistently to flat-woven vs. pile-woven objects, as in their origin languages. ‘Kilim’ especially has become popular in English, usually in reference to Turkish tribal weavings – it is not unusual to see catalogues or books referencing carpets and kilims, with no mention of ‘rug’.

It might make sense then to transfer the Turkic-Iranic differentiation directly onto rug/carpet. Although certainly not universal and with thousands of contrary examples, there is a noticeable preference for 'kilim' to be translated as 'rug', while 'haly' is translated as 'carpet'. This difference is rarely outlined explicitly (Helfgott is a rare example, 1994:19), but the pattern does emerge when reading historic and modern literature. Even official government translations will usually follow this pattern: the state-sponsored museum for pile-woven floor-coverings in Ashgabat is translated in official documents from *Türkmen Milli* ***Haly*** *Muzeýi* to the Turkmen National **Carpet** Museum.

It is possible that while few specialists worry explicitly about the difference between carpet and rug, the underlying patterns of English, Turkic, and Persian groups are creating different connotations for the words. The consistency in translating kilim → rug and haly → carpet from Turkic/Persian languages into English based on structural differences in the object is the most obvious link, but we might also look at a wider pattern in how English uses Germanic and Latinate words. Many Germanic/Latinate pairs have connotations of the mundane and popular in the Germanic, and of class, wealth, or refinement in the Latinate. A poet who is angry is less eloquent than one who rages, a study of the moon sounds less advanced than one of the lunar surface, to be taught is populist while to receive an education is elite, and a king wears coarse wool in a drafty stone castle while an emperor is resplendent in gold and silks at his marble palace.

I suggest that a similar pattern applies to rugs/carpets. When handwoven, pile-weaving requires orders-of-magnitude more labor hours than a flat-weave of comparable size. Even modern mechanized looms cannot replicate a traditional hand-knotted pile textile, and simpler

structural imitations are used where machines are employed (there is no such thing as a machine-made knotted carpet). Therefore, both historically and today, the increased time and manual dexterity required for pile-weaving makes those objects considerably more expensive than their flat-woven counterparts. It may be that, like many other English words, there is an underlying bias towards perceiving the Germanic word (rug) as cheaper and more readily available than the luxury Latinate word (carpet).

I therefore propose a clear division between rug and carpet, following the same one well-established in the carpet's homeland: rugs are flat-woven, and carpets are pile-woven. This is the convention that will be used throughout this work. While in other works a reference to "rugs" may well be a discussion of pile-weavings and vice versa, here it should be interpreted as a reference exclusively to flat-weaves/kilims. And similarly, "carpet" will be used exclusively for pile-weaves/haly. The common vernacular differences of transportability and permanence do not factor in at all, and the two terms are set as headings on the same hierarchical level in the tree of household furnishings.

While the definition of a carpet is amorphous even in specialized spaces, one aspect is (mostly) agreed: it is a textile used on the floor. This slightly glosses past the myriad examples of identical objects being used on walls, tables, thrones, or other surfaces. The common use of the term "wall carpet" or "table carpet" instead of "hanging" or "tablecloth" suggests that even historic collectors recognized the structure and/or design language as more important than the day-to-day use in a particular home (see the posthumous inventory of Henry VIII, broken down in King 2012).

Similarly, while we almost always see the pile-weaving technique applied to (floor) carpets today, it can and has historically been used for many other objects: bags, animal trappings, curtains, chair covers, decorations, tenting, clothing, etc. The Victorian carpet bag is a reasonably well-known modern example. These items have the same underlying structure but are formatted a different way. While these objects are relevant to this dissertation due to their structure, they are rarely produced by modern artisans and therefore were not included, as it was not realistic to acquire a significant modern sample. However, the historical and technical outlines provided below, as well as the structural analyses and methods in later chapters, are focused on the technique rather than the utilitarian application and should be seen to apply both to carpets as well as to the many other objects produced the same way. 'Carpet' is therefore used here as shorthand for all knotted-pile textiles, of which the floor-covering is the most common type by far.

Finally, a note on the term "weaver". Modern English does not distinguish between different textile manufacturers working on a loom – any use of a loom denotes a weaver (Oxford English Dictionary 2025c). Whether they make plain-weave linen or wool carpets or elaborate silk brocades, "weaver" is always used. This is not the case in all languages however (see some examples in the Glossary, Appendix F), and English-language specialty spaces sometimes choose to use "knotter" for the makers of pile-carpets. While I do not find this term inaccurate, as certainly these artisans are primarily employed in tying knots, I worry that the use of that term in many cases can be reductive. Firstly, while knotting is the primary activity in making a carpet, there is considerable true weaving involved too. Secondly, most of the modern artisans included

in this study produce other, non-knotted textiles as well. Limiting them to the narrow and specific "knotter" may be less accurate and less representative of their skills than the more wide-reaching "weaver". I therefore use "weaver" throughout this study, to acknowledge the multiple skills held by the modern collaborators and the likelihood that their historic counterparts were similarly multi-talented.

The Current Narrative

The history of knotted carpets is difficult to trace. This is due primarily to their poor rate of preservation: like other textiles and many other classes of material culture, they are organic and therefore do not persevere in the archaeological record (Tsareva 2012:3). Despite being a craft that has existed for 3,500 years at the most conservative estimate, it would be entirely feasible for a single publication to survey every known pre-Renaissance (< c. 1300 CE) fragment, assuming they had the connections to access the bowels of the world's most restrictive museums and reclusive private collections. This dearth of corroborating evidence means that most carpet-research conclusions are based on a very small sample, often samples of one (ibid.). Additional biases act on these small samples, which while certainly not uncommon in archaeology, are a bigger hurdle for perishable goods than non-perishable goods. The oldest carpet fragments are exclusively associated with burials, suggesting that they may not be representative of day-to-day material culture (see the Tomb of Kha & Merit [Riefstahl 1944], the Beauty of Loulan [Barber 1998:648], and the Pazyryk carpet [Rudenko 1968, 1970]). More recent survivors, mainly from the late Medieval period and Renaissance, are mostly associated with royal courts, religious

holdings, and other wealthy collectors, and therefore are again perhaps not representative of the widespread craft.

Finally, carpets have experienced two notable 'booms' in the last century and a half: first in the late Victorian and into the Edwardian era, and then again in the 1960's-80's (Baker 1995: 365; Bier 1996:66; Edwards 1953:4; Eiland III 1993:860). The rapidly growing commodity market, the rise of fast and cheap intercontinental shipping, and the expanding global middle class created a perfect storm for carpet merchants, who jumped at the chance (Thompson 1993:40). A dubious mix of exaggeration, generalization, and pure fiction became the de-facto truth for carpet provenance and history data, which is still given as fact in many publications, catalogues, and exhibitions, and which only a small handful of scholars really seem cognizant of (see Spooner 1986 for a passionate summation of the problem). Many foundational pieces of information are presented as indisputable facts in the literature, including in academic publications. But with a bit of digging, they do not seem to be backed up by evidence; or at least, the conclusions drawn are one of many equally reasonable options. This is truly concerning and desperately frustrating for serious inquiry into the technological and social history of knotted carpets. The popular narrative has four basic parts:

1. The knotted-pile technique was invented by nomadic peoples.
2. The knotted-pile technique was invented in the arid zones of Mesopotamia or Central Asia.
3. Knotted-pile objects were predominantly woven by women in ancient times.
4. The oldest surviving knotted-pile object is the famed Pazyryk carpet.

While an in-depth point-by-point analysis, confirmation, or refutation of these narratives is beyond the scope of this dissertation, they are important biases to keep in mind when evaluating the history of knotted carpets, and the position of this project within the wider scientific context. In turn, understanding the scope of known carpet history is, I believe, and important component of this dissertation's wider aims, and the first step in understanding the attributive and descriptive problems that characterize the field today.

None of the literature I read, neither academic nor popular, presented a holistic look at *confirmed* carpet history like the one presented below. None covered all of the most notable evidence, and many seem wholly unaware of some notable evidence. Overall, the most well-rounded analyses I found were Russian-language publications (particularly the many works of Elena Tsareva, who is not even a carpet specialist!). In discussions with other Silk Road textile specialists, I have also heard that Chinese-language documents might be more useful than English-language ones. Unfortunately while I can hobble through Russian texts, I have no ability to access Chinese ones. I therefore can only assume that my own summary of carpet history is missing important clues that are not readily documented in Western publications. All the more reason, I think, to present a detailed summary of what is available in English, as a base for further work.

Maps of all the locations mentioned in the next sections are available in Appendix A. Already discussed in Chapter 1 (pg. 21), a summary of the chronology used is shown in Table 1.1.

The Neolithic & Bronze Ages

The history of knotted carpets necessarily starts with the history of spinning, weaving, and looms. As this is a complicated and well-studied area in of itself, I will not take up inordinate space describing it here. It is sufficient to know that flax, cotton, wool, and silk woven textiles are all present in Eurasia by the 3rd millennium BCE at the latest (Good 1995:962; Good 1998:658; Moulherat et al. 2002:1400). Although the existence of woven textiles suggests that looms existed earlier, direct evidence for horizontal looms dates to the 4th millennium BCE in Egypt (Collingwood 1968:43), for warp-weighted looms in Europe by the late Neolithic (Grömer 2016:243), and for vertical looms by the mid-2nd century BCE in Egypt (Broudy 1993:46; Collingwood 1968:43). Some date woven textiles as early as the 7th millennium BCE in Mesopotamia, before the rise of domestication or settled villages (Kawami 1992:7).

Particularly relevant to this project, textile evidence in central Eurasia includes impressions in ceramics from the 5th millennium BCE at Seh Gabi, Kurdistan (Kawami 1992:7). Other impressions come from Begash, eastern Kazakhstan c. 2450 BCE, the oldest currently known from the north steppe area (Doumani & Frachetti 2012:370). The technique used to produce these fabrics would have required tension (i.e., a loom), which in turn pushes the date for looms of some variety back into at least the 3rd millennium BCE in the northern steppe (ibid., pg. 377). Slightly younger impressions occur on Oxus or Bactria-Margiana Archaeological Complex (BMAC) sherds from Gonur Depe in eastern Turkmenistan, dated to c. 2000-2200 BCE (Hiebert 1994: fig. 4.34). Physical remains of wool textiles themselves appear first at Sharh-i Sokhta, eastern Iran, in the early-mid 3rd mill. BCE (Barber 1998:658). Together, this evidence suggests a

culture of loom-woven wool textiles in central Eurasia by the mid-3rd mill. BCE, and almost certainly earlier.

The rise of textiles themselves, or of wool fiber, is not the relevant part of this survey of carpet history. While knotted pile is produced on a loom and has components of what we might call "traditional weaving", the knots themselves are a notable departure from other textile forms. Where other textile forms may have supplementary yarns acting in the warp or weft directions in a myriad of complex and technologically sophisticated ways, they are all characterized by the *weaving*. Even the most detailed brocades have all the colors woven in. The knotted pile technique, on the other hand, requires a technological step sideways (see Chapter 6 for a technical description of structure). The pile must be tied in individually, requiring the addition of a new spatial dimension as well as supplementary problem-solving regarding how best to secure the knots themselves, how to stabilize the underlying warp-weft grid, how dense or loose it must be woven to maintain the desired pile effect, and many other new concerns. To understand carpets, therefore, is to understand the history of the pile knot, and pile generally.

Knotted pile is not the only type that exists, and other types are produced by weaving the pile threads in (usually) as wefts (Burnham 1980:100). The use of pile (in any format) is often cited as an effort to produce artificial fleeces, pelts, or hides (Edwards 1953:1; Eiland Jr. 1976:3; Hirsch 1991:105; Kawami 1992:9; Riefstahl 1944:22; Thompson 1993:67), likely for warmth and insulation against the elements. While direct evidence for this does not exist, it seems like a reasonable and logical idea, and one I do not refute. Like a natural pelt, pile textiles have a smooth side which is often at least water-resistant and insulating if not water-proof, and a fluffy, shaggy

side that creates pockets of air and trapped heat. When worn shaggy-side inward, a pile textile would make an effective ancient coat (Barber 1999:74). The wearing of heavy fleeces might seem counterintuitive for the hot, dry landscape of the Fertile Crescent, but such garments are good defenses against sunburn, heat stroke, and dehydration (Tsareva 2012:2), and provide a barrier against nighttime chill and wind.

The distinction between natural fleeces and pile-woven textiles is where the study of pile truly begins. Depictions of ancient Mesopotamians wearing shaggy garments, often as a mantle or wrap, date to at least 2900 BCE (Boucher 1987:34) (Fig. 5.1). These garments are commonly referred to as *καυνάκην* [kaunakes], a Greek word first used in Aristophanes' 5th century BCE play "The Wasps" in reference to a Persian cloak of artificial fleece (Aristophanes 1907: line 1137; Barrelet 1977:83; Eiland Jr. 1976:3; Hirsch 1991:105; Riefstahl 1944:22). Whether Aristophanes was referring to the same type of garment as is worn by 3rd mill. BCE depictions is not known, but his word is still widely applied to 3rd mill. BCE carvings, figurines, and seals from ancient Mesopotamia. Similar figurines, including the stylistically iconic "Princess of Bactria" form, are also found in Bactro-Margian sites at a similar period (Sarianidi 2002:148; see Fig. 5.1b).

It is unclear, particularly in earlier periods, whether the depicted garments are made from natural sheep/goat hides, or if they are artificially produced. Both seem possible, as woolly sheep start to appear in Mesopotamian art by around 3000 BCE (Hirsch 1991:105). This would provide the necessary resources both for fluffy natural garments, and for the long tassels of an artificial





Figure 5.1: "Kaunakes" Garment

Figures wearing variations of the "kaunakes" garment, which may be an early pile textile.

A: Early Dynastic III (2600-2300 BCE), Diqdiqqah, Iraq. Inv. No., British Museum: 116666 © The Trustees of the British Museum. Shared under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) licence.

B: Bronze Age (2500-1800 BCE), Bactria-Margiana. Inv. No., Metropolitan Museum of Art: 1989.281.41a, b. Image courtesy of The Metropolitan Museum of Art, New York; Gift of Norbert Schimmel Trust, 1989

one. A particularly famous example is the 'Standard of Ur' recovered by British archaeologist Sir Leonard Woolley in Ur's Royal Cemetery in 1928 (Woolley 1934:266; Fig. 5.2). One side of the object shows a procession of fluffy sheep and goats, along with other livestock. This same object shows several depictions of the kaunakes garment: a more refined version worn by the seated figure at top-left, and less sophisticated tasseled versions worn by the parading shepherds. Woolley himself is the first to suggest that the garments shown in these depictions might be man-

made imitations rather than natural hides, noted when he recovered a fragment of pile textile at the Royal Cemetery:

> "One stuff was rather coarse with a plain over and-under right-angle weave; the second was a finely woven cloth with a diagonal rib; the third was a loosely woven right-angle weave fabric on one side of which were long threads forming either a very deep pile or else 'tassels' like those on the skirts of the figures represented on the monuments. This was the only case in which we found cloth that could have been a woven imitation of the fleece, but cloth of any kind was so seldom preserved that the single instance may well witness to a common custom."
>
> Woolley 1934:238

Irish artist and historian of ancient and historic costume Mary Houston reinforced Woolley's suggestion of a pile-textile imitation in the 1950's, which had gone largely overlooked by textile scholars in the intervening quarter century. She suggests that the symmetry of many kaunakes depictions is too geometric and uniform to suggest a natural product, and that instead these garments should be interpreted as man-made reproductions (see the garment worn in Figure 5.1 and that of the seated figure in Figure 5.2, in contrast to the garments of the shepherds in Figure 5.2) (Houston 1954:120). Houston, however, suggests an embroidered or looped pile, rather than a knotted one. Unfortunately, as Woolley's Ur fragment disintegrated shortly after excavation, it is not possible to confirm his interpretation or Houston's, or to provide any further technical details (Hirsch 1991:106; Tsareva 2012:2). While many historians of pile and knotted textiles seem happy to take Woolley's report at face-value, I think it is unwise to suppose that a generalized excavator with no particular textile training had the specialist knowledge necessary to distinguish between woven pile, knotted pile, embroidered tassels, or simple warp fringe, particularly when studying an object so fragile it did not even make it out of the excavation camp. The above excerpt is the only description of the fragment given and no drawings or photographs

were made; even Woolley is not sure whether the structure is pile or tassels! While these may seem interchangeable to a non-specialist, they are distinctly different things. Similar mistakes in attribution were made on other fragments recovered by archaeologists with similar backgrounds working in a similar era (see below), and so I am skeptical that Woolley's single-sentence description is viable evidence for pile textiles in the First Dynasty of Ur (mid-3rd millennium BCE).

It may be that the kaunakes garment was woven, or that natural and artificial versions existed contemporaneously (Hirsch 1991:108). Houston's supposition is that a naturally-occurring product would be depicted less rigidly, but we cannot dismiss the homogenizing and stylizing effects of an artistic zeitgeist. These garments certainly may represent the first iterations of pile textiles (Barrelet 1977:83; Reifstahl 1944:22), and if Aristophanes' faux-fleece garments are, in fact, the same as those that appear in reliefs, figurines, and seals of proto-Dynastic Mesopotamia, that would push the invention of pile textiles back by at least a thousand years into the late 4th mill. BCE. Ultimately, however, the links to the drawn kaunakes garments is supposition: there is no firm evidence that the depictions represent a pile textile, or a man-made object at all.

The earliest confirmed remnants of pile textiles in the Near East are a set of objects from Deir al-Bahri, Egypt, dating to the 11-12th Dynastic periods (2150-1800 BCE) (Winlock 1945:32) (Fig. 5.3). These pieces are made with looped pile: the weft is woven across the warp as normal, but excess yarn is pulled out between warps to create loops across the surface. This is an intentional version of what occurs when a cat's claw snags an article of clothing and pulls a thread (Fig. 5.4). Towels are the best-known modern use of looped pile: it is suggested that the Deir al-

Bahri fragments are also towels (based on apparent shrinkage from repeated contact with water) (ibid.), although I find this assertion dubious.

Similar textiles appear in Egyptian burial contexts through the rest of the 2nd millennium BCE. A notable set of objects was recovered from the Tomb of Kha & Merit by Italian archaeologists in 1906. The tomb was built for a married couple and was likely sealed under the reign of Amenhotep III (early 14th cent. BCE). However, exact dating of the objects cannot be given as they may have been added several decades earlier: Merit died young and was interred 20-50 years before her husband. Relevant objects include three bedcovers and chair/throne covers (Fig. 5.5). These items were described at the time, and still in most of the modern literature, as looped pile like that at Deir al-Bahri (Riefstahl 1944:22; this same citation is given in nearly all modern carpet literature). However, a short and apparently unnoticed article in the carpet journal *Hali* suggests that this technical description is incorrect (Hirsch 1991). Hirsch's paper is not commonly referenced in the modern western or English-language carpet literature, but does contribute to the work of Russian and post-Soviet textile historians and archaeologists (see the various publications of E. Tsareva and E. Gyul). Hirsch viewed the textiles from the Kha & Merit burial in-person at the Museo Egizio in Turin, Italy, and determined that all were produced with knotted pile, not looped or otherwise woven pile (1991:110) (Fig. 5.4c). Indeed, this seems apparent even from Kirsch's more detailed photographs published in the article – this is clearly not a looped textile. Hirsch draws the same conclusion about a textile from another Theban site too, the Tomb of Madja, now held in the Louvre (catalogue number E14500) (Fig. 5.4b). The Madja piece is slightly older, dated to the mid-15th cent. BCE, but uses a similar technique and is also made

entirely of linen (ibid.). These major misattributions of technique, which went unnoticed for nearly a century, were originally put forth by early 20th century European generalist archaeologists. If a mistake of this scale could happen when the textile survives, it reinforces my skepticism of Woolley's assertions about the lost cloth at Ur.



Figure 5.5: Early Egyptian Knotted Textile

Chair cover from the Tomb of Kha & Merit, Thebes, Egypt, 18th Dynasty.
Inv. No., Museo Egizio (Turin): Suppl. 8529. See also Suppl. 8528, Suppl. 17328
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The Kha & Merit textiles use symmetric knots and a very long pile, which creates a much shaggier surface than usually appears in knotted textiles today. The rows of knots are not consecutive but rather are separated by many rows of plain-weave weft up to 15 cm wide. This style is still used in textiles today: they are known in Turkic languages as *filikli* and *tülü*, in the north Caucuses as *rytu* or *kiiz,* in the Transcarpathian region as *guni,* and in Scandinavia as *rya*

(Geijer 1963:79; Tsareva 2012:1).[6] These words are widely considered translations of the Greek *kaunakes*, already discussed, but they often reference the long-pile technique rather than a specific style of garment. The Central Asian жұлқышы [zhylkishi, Kazakh] and julkhir [Uzbek] could also be considered part of this group, although they do not necessarily have the large gap between rows of knots. Many of the historic carpets analyzed in this study could be considered kaunakes, including most of the Al-Sabah carpets collected from eastern Iran and north Afghanistan (samples MU-AS) and the pieces collected by Aurel Stein in the Taklamakan and now held at the Victoria & Albert Museum (samples MU-VA-3, 4).

Despite being the first irrefutable physical remains of a knotted textile currently known, the Egyptian pieces are not considered to be a local innovation. Instead, scholars suggest that the technique was imported from the Fertile Cresent, possibly Syria. This conclusion is based on two main lines of evidence. First, the depictions of kaunakes garments, and the Ur fragment if we accept it as true pile, predate the Egyptian pile pieces by a thousand years. This suggests that pile weaving potentially enjoyed a long history in Mesopotamia before reaching Egypt (Reifstahl 1944:33, 35). Secondly, the military campaigns of Thutmose III and the capture of Syria in the mid-15th century BCE resulted in an influx of Mesopotamian migrants to the Nile zone (Steindorff & Seele 1942:56). These groups brought other textile industries with them including wool fiber and dying methods, so it is not unreasonable to think they may have brought pile technologies as well (Tsareva 2012:2-3). Although there is reasonable context to suggest that the knotted pile

[6] Tsareva (2012) lists *киизы (*kiizi) as a long-pile knotted technique; this word and its variations are more widely used for feltwork in the Caucasus and Central Asia.

technique could have been imported, it is important to note that there is no definitive evidence for that, or for the idea that it was not a local Egyptian invention.

Secondary evidence in the form of written documents suggests that a pile-knotting technique existed in Mesopotamia in the 2nd mill. BCE too. This evidence is drawn almost entirely from the inventory of Kar-Tukulti-Ninurta, dated to c. 1225 BCE (CDLI 2024). This tablet was found in the palace at Kar-Tukulti-Ninurta and is a record of items sent as tribute from Assur to the Assyrian king Tukulti-Ninurta I (Barrelet 1977:56). It includes various references to textiles and floor-coverings, as well as to many other fabulous and exotic riches. The primary translation of the tablet is from Akkadian into German by Franz Köcher (1957), and was re-examined for textile reference in French by Marie-Thérèse Barrelet in 1977. The text provides several words which may be indications of pile technology in the Middle Babylonian period. First are words for floor coverings, including *mardalu* / *mardatum* / *martauhlu*. (Barrelet 1977:85; Hirsch 1991:107). *Mardalu* is translated into English as rug or carpet: Köcher uses the German *teppich*, but that language does not duplicate or differentiate rug/carpet in the same way as English does. His word choice could therefore be reasonably translated from German into English as either carpet or rug, and should not be interpreted as an intentional reference to pile or knotted carpets in the way we use those terms here (Dalley 1991:118).

Although modern English does not particularly differentiate weavers by their techniques, Akkaddian delineates crafts more precisely to regulate craft specialization (Barrelet 1977:59). Two separate words for ‘weaver’ appear in the inventory: *isparu* / *ispartu* and *kāmidu* / *kāṣiru* / *kasirtum* (ibid.; Hirsch 1991:107). Köcher translates them into German with two different words:

weber and *wirker* respectively. In modern German, these two words would both be translated to English as ‘weaver’. However, Köcher’s choice to translate the two words differently presumably is meant to indicate a connotative difference (Barrelet 1977:59). As *kāṣiru* more literally translates as “to attach or bind”, Barrelet proposes that it may be a reference to the tying action of knotted pile, and therefore should be interpreted more like ‘knotter’ (ibid., pg. 60). A particular line in the inventory uses both the rug/carpet word and the knotter word together, emphasizing they are conceptually related and that *kāṣiru* is a textile term:

r iii 27’ [1 ^{tug_2}mar-du-tu] ša ši-par$_2$ ka-ṣi-ri u$_3$ [...]
[one rug] of the work of the knotter and […]

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Finally, the word *hala / halu* is translated as woolen cloth in the tablet (Hirsch 1991:107). While the presence of wool cloth in this period is neither surprising nor notable, the word for it is. Note the similarity to the modern Turkic-Iranian *haly*, used today for knotted carpets. This may suggest a technological-linguistic link between knotted pile and ancient Mesopotamia, and reinforce the possibility that the technique was developed there.

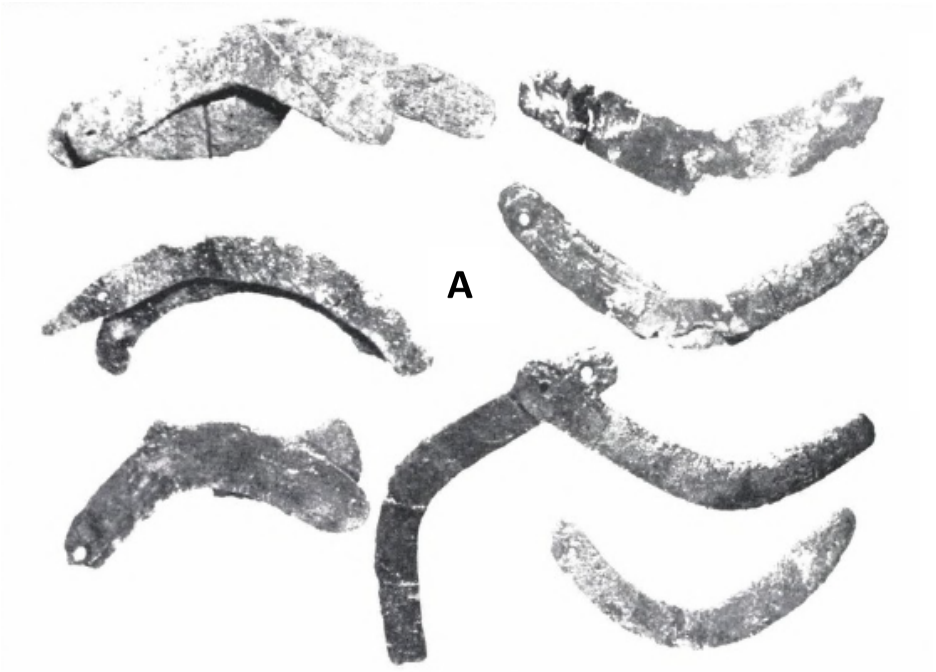
Around the same time that the Mesopotamians and Egyptians were making both looped and knotted pile, the Hallstatt peoples of central Europe were decorating textiles with a non-pile, but knot-like technique (Collingwood 1968:183). *Soumak* uses supplementary wefts to create a raised texture through twists and knots (Burnham 1980:127). A completed soumak can have a similar appearance to embroidery or tapestry, but differs structurally from both. Fragments from a site in north-central Switzerland near Irgenhausen have simple soumak decorations, dating to

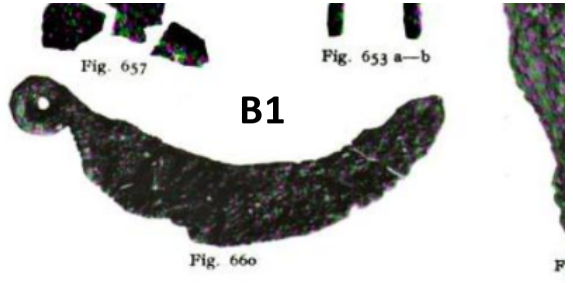
the Early Bronze Age (1700-1440 BCE) (Rast-Eicher & Dietrich 2015:55, 143; Vogt 1937:76-90; both quoted in Banck-Burgess 2017:14). The soumak threads, while slightly dimensional, do not create a true z-axis, and therefore it is not considered a pile technique. However, the structural similarity of soumak twists to pile knots is striking: you could "hack" a pile textile by cutting apart the weft twists in a soumak. As true knotted pile is being produced at the same time in Egypt, I believe it is reasonable to propose that an intersection of the two techniques, or even a derivation of one from the other, is possible. The requisite skills and technical diversification for knotted pile certainly existed in wider western Eurasia by the mid-2nd millennium BCE, and possibly earlier.

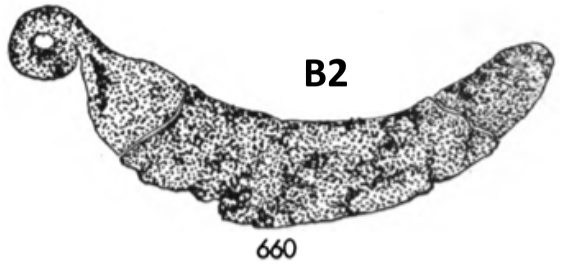
Northeast of Mesopotamia lies another piece of tantalizing evidence recovered near the city of Magtymguly (formerly Kara-Kala). The site sits in the valley of the river Sumbar (Sara-su) in the foothills of the Kopet Dag Mountains. It lies just inside modern Turkmenistan, on the northern edge of the Iranian plateau. The site was excavated by Soviet archaeologist S.I. Khlopin as part of the wider South Turkmenistan Complex Archaeological Expedition organized by the Turkmen SSR in the mid-20th century. The expedition focused on Neolithic to Bronze Age sites across the width of the country. It was as part of this expedition that Uzbek SSR-born archaeologist Viktor Sarianidi identified and named the Bronze Age culture now known as the Bactria-Margiana Archaeological Complex (BMAC) (Sarianidi 2002:87).[7]

[7] Sarianidi dislikes the often-used "Oxus Civilization", as *civilization* implies some sort of intentional cohesion which was lacking between the oasis settlements, and there is no evidence that the Oxus (Amu Darya) river was especially culturally significant to the population (Sarianidi 2002:87)

Khlopin's excavations around Magtymguly in 1972 focused on a BMAC (10-14th cent. BCE) cemetery. Among more than 200 burials, eight held distinct, crescent-moon shaped knives (Fig. 5.6). (Khlopin 1982:116). These knives are 6-7 cm long, with a hole drilled in one end and sharpened along the outer edge. They were always accompanied by other textile items, including needles and spindle whorls. Sixteen knives were found in total, usually in pairs or trios and threaded on belts. The eight graves containing the crescent knives also contained carved wooden cylinders with oxidization stains indicating contact with metal (ibid.). Although it took some time for the function of these objects to be identified, the excavation team eventually linked them to the carpet knives still in use by living carpet-weavers in the area. Khlopin proposed that the distinctive blades were slotted into the wood cylinders as handles, and then secured with a tack through the drilled hole (ibid.) (Fig. 5.7). Similar items have been recovered from other sites of the same period, including at Shah Tepe in northern Iran near the southeastern coast of the Caspian Sea (Arne 1945:305, fig. 660 [pg.304], and pl. LXXIX). These items were also found in a grave but with earthenware rather than wood handles, and the excavation report lists them as "razors" (see Fig. 5.6). More blades were recovered at Tepe Hissar, also in northern Iran near the Caspian Sea (Schmidt 1937:208, object H-3863, and pl. LIV). These excavators did not know what to make of the blades, and they are published as "presumably ornaments" (ibid.; see Fig. 5.6). Evidently, consensus on these objects was low before the link to carpet knives was made. The striking similarity between the Bronze Age blades and the modern carpet knives, coupled with the distinct and unusual shape, is strong evidence that carpet-making or a similar process was practiced in the Bronze Age Kopet Dag (see Fig. 5.7).







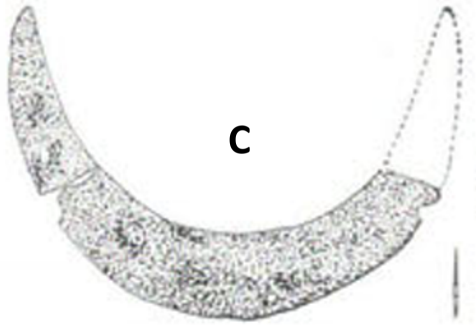


Figure 5.6: Bronze Age Carpet Knives

Cresent-shaped knives recovered from Bronze Age burials.

A: Magtymguly, Turkmenistan. Figure from Khlopin 1982: fig 1.

B: Shah-Tepe, Iran. From Arne 1945: fig 660 [illustration], photo [pl. LXXIX]

C: Tepe-Hissar, Iran. Figure from Schmidt 1937: pl. LIV

Even further from the proposed homeland of the pile technique in Mesopotamia, looped pile textiles are found in burials in China's Tarim Basin. The 'Beauty of Loulan', a very well-preserved female mummy associated with the Qäwrighul cultural complex excavated in 1980, is wearing a wrap or cloak made of looped pile (like that of the Deir al-Bahri towel) (Figs. 5.4a, 5.8).[8] She wears the cloak with the pile-side inward, presumably as insulation against a chilly winter (Barber 1998:648). Her death has been dated to c. 1800 BCE, making her garment approximately contemporaneous with the Deir al-Bahri cloth and one of the oldest known pile textiles in the world. In addition to her significant cloak, she was also buried with a comb. While combs are usually assumed to be beauty implements in archaeological contexts, Barber suggests that this comb's morphological similarity to combs from the Levant may point at a different conclusion. According to a study by T. Schick in 1995, microscopic analysis of the wear pattern on combs from Judea matches more closely to weft-beating than personal grooming. Although the Loulan comb has not been studied in a similar way, it is an intriguing idea.

A similarly relevant kaunakes fragment (long-haired, wide-set knotted pile) from the Tarim Basin was dated to the 12th century BCE by carbon dating; unfortunately, this object is in a private collection and not available for widespread analysis (Tsareva 2012: footnote 11).

Between these early fragments of pile-woven textiles, it is evident that the Tarim Basin had woven/looped pile technology from at least the early 2nd mill. BCE. This aligns with the timeline of the Egyptian looped pile. The knotted pile evidence lags a little behind the looped

[8] Not to be confused with the Loulan Beauty, another well-preserved mummy excavated nearby in 2004, or the Beauty of Xiaohe, excavated in 2003.

remains in both places, suggesting that the technology started with the simpler (and more intuitive) looped version and complexified over time to include knots by the mid-2nd millennium. If we accept that the Ur fragment (c. 2700 BCE) was a true pile textile, I will hazard a guess that it was looped rather than knotted based on the apparent evolutionary progression of the technique elsewhere.



Figure 5.8: Beauty of Loulan

A female mummy wearing a woven-pile wrap. Loulan, Xinjiang, China, c. 1800 BCE.
Photo © Gilles Sabrie, published in Wong 2008

Firm evidence for knotted textiles in Egypt, Mesopotamia, and the Taklamakan arises in the mid-late 2nd mill. BCE, which aligns with the specialty BMAC knives recovered along the north Iranian Plateau. The specialism of the knives, however, does not suggest a nascent technology but rather one that has been trialed and perfected over time. We should therefore assume that the practice is older than the knives themselves. It is worth pointing out that knives are not required for looped pile, but are a specialist advancement for knotted pile.

The objects discussed so far suggest that carpet production was a settled activity, not a nomadic one (Khlopin 1982:117). All the evidence described has come from sedentary, even urban environments. Even when including evidence from the 1st mill. BCE and into the early parts of the common era (described below), the evidence is still predominantly from settled communities living in hot, arid climates. The technology does not appear among the nomadic-pastoralists of the cold northern steppe for close to a thousand more years after it appears in the desert zones, and even then it may have been an import from the arid south rather than being a local product. Absolute evidence for nomadic or pastoral production of knotted carpets is not available until the post-Medieval period, when records improved and more carpets survive. Although traditionally and popularly associated with nomadic cultures, the combination of this evidence and the difficulty of weaving a cumbersome, heavy, months-long carpet in a mobile setting would seem to indicate that the technology probably arose in the sedentary southern steppe, and not the mobile north where felt seems to have been more popular (ibid.; Doumani Dupuy et al. 2018:9). Admittedly it may be more difficult to locate and excavate the remains of pastoral groups than those building complex urban centers, but their kurgans dot the northern steppe zone in the hundreds of thousands (CAAL 2025). For knotted pile technology to not appear in nomadic settings in any form until the mid-1st mill. BCE is telling.

The enormous distances represented here (5,500 km from Loulan to Thebes) make it difficult to explain the innovation and spread of knotted textiles; many combinations of single invention, multiple/independent invention, and cultural transmission between groups could explain the available data. Without confirmation of the Ur fragment, which predates the rest by

such a margin that it could reasonably be used as a focal point for invention, it may yet be premature to claim to know, as so many scholars do, where knotted textiles originated.

Mesopotamia, Egypt, and Bactria-Margiana are (relatively) close together and their connections and material trade in the Bronze Age are well established. Afghan lapis lazuli and Bactrian turquoise appear in Near Eastern sites, Sogdian beads are spread among the Andronovo nomads in the Ural mountains, and Indus seals reach as far as Iraq (Kuzmina 1998:64; Langdon 1931:697). It is not difficult to imagine that carpet technology, like so many other materials, was transmitted between these communities at the same time. Regardless of which specific location is favored as the origin, cultural transmission rather than independent innovation seems likely in wider southwestern and south-central Eurasia. The Taklamakan finds are less easy to link, and it is therefore possible that the pile technology used in the Tarim Basin may have been an independent innovation. There are counts both for and against this theory.

In order to fully grasp the problems with the Tarim evidence, we need to look at its history and geography. While a full summary of the extensive and somewhat contentious work on this region is beyond the scope of this paper, a summary can be given. The Tarim Basin is in China's Xinjiang Uyghur Autonomous Region (XUAR), sitting on the country's western edge and bordering Mongolia, Russia, Kazakhstan, Kyrgyzstan, Tajikistan, Afghanistan, and the disputed districts of Ladakh, Jammu & Kashmir, and Tibet. The XUAR is composed of two basins: Tarim in the south, and Zhunge'er in the north (Xie et al. 2016:168). The basins are divided by the Tian Shan mountain range and bounded by other ranges on the north, south, and west, and by the Gobi desert to the east. These geographic obstacles make the XUAR one of the most inaccessible regions of the

world, and one of the last places to be permanently settled by humans (Chen & Hiebert 1995:247). Of the two basins, the northern Zhunge'er is more hospitable to human life: it is slightly wetter and can sustain some plant life and dry agriculture. The Tarim Basin, to the south, is more arid and is almost entirely covered by the Taklamakan, a gravel desert with exposed bedrock and minimal topsoil (ibid., pg. 245). Climate change in the last several thousand years has slightly shifted the position of resources between the Bronze Age and today.

Although research places hunter-gatherers in the wetter Pamir and Tian Shan mountains by 9000-8000 BCE (Thornton & Schurr 2004:84), archaeological investigations over the last century have shown that there was minimal human settlement in the Tarim Basin before the Bronze Age. The dry, unforgiving, and geographically inaccessible environment supported only small hunter-gatherer groups, and little more than occasional microlithic remains have been found (Jia et al. 2009:171-172). The community who buried the Beauty of Loulan arrived by at least the early 2nd mill. BCE, and was generally cut off from neighboring societies until the end of the 1st millennium BCE (Jia et al. 2009:170). In that period, the Tarim peoples lived predominantly on a sedentary oasis model, relying on alluvial soil and mountain run-off along the Basin's rim (Høisæter 2017:343-344).

The Tarim Basin has been an archaeological curiosity since the early 20th century. It was brought to the attention of Western scholars when the explorers Aurel Stein (British) and Sven Hedin (Swedish) uncovered remarkably well-preserved human remains in the Basin's Taklamakan Desert. Initial investigations of the remains, their facial structure, coloring, and associated material culture concluded that the mummies were Europoid, perhaps one of Israel's "lost tribes"

or an offshoot of the mythological Amazon. This general belief that the Tarim peoples emigrated from the far west (Li et al. 2010:1) has survived the last century. Their textiles are particularly featured in this attribution, as not only is it the "largest cache of prehistoric textiles in the Old World" (Good 1998:656), but the finds include many examples of tartan with remarkable similarity to that being produced by the Celts of west-central Europe at a similar time. Dissatisfied with this seemingly unlikely early conclusion of European origins, modern archaeologists, historians, geneticists, and linguists continue to work on the identification and cultural attributions of the Bronze Age Tarim people.

The cultural and genetic origins of the Bronze Age Tarim peoples has been an archaeological quandary for a century (see Allentoft et al. 2015; Chen & Hiebert 1995; Hemphill & Mallory 2004; Høisæter 2017; and many more). For many years, two primary explanations have been proposed: an origin in the Kazakh-Siberian steppe, or in the BMAC (Romgard 2008:13).

The Kazakh-Siberian steppe hypothesis suggests that the Tarim population were a Europoid offshoot of the Andronovo or Afanasievo groups living in the Central Asian and south-central Siberian steppes. This theory was based initially on phenotypic characteristics of hair color, face and eye shape, height, etc., which indicate a tall, fair-skinned, light-eyed, light-haired community more similar to those living in Europe and the western steppe than to those in eastern or southern Asia. Additional similarity in textile technology and decoration further strengthened associations to central European Celts. Researchers who support a Europoid background suggest that the group may have broken off from the Afanasievo or Andronovo groups in Central Asia and the south-central Siberian steppe, possibly via a pass in the Tian Shan range and travelling through

the Zhunge'er Basin to the north to access the Tarim Basin (Allentoft et al. 2015:169; Hemphill & Mallory 2004:202). This migration likely occurred in several waves. Linguistic evidence also seems to link the Tarim Basin to European populations. Documents found in the Taklamakan dated to the 7-8th centuries CE are in Tocharian, an Indo-European language most closely related to the Italo-Celtic branch of that family (Blench & Dendo 2004:17). Although it is impossible to say whether the Bronze Age population spoke a proto-Tocharian language, the physical similarity between depictions of Tocharians in their 1st mill. CE art (tall, fair-skinned, light-haired) suggests a continuity between the similarly Europoid Bronze Age mummies (Hemphill & Mallory 2004:202). The northern steppe Afanasievo and Andronovo both spoke Indo-European languages as well, while the BMAC groups spoke an Indo-Iranian language.

The BMAC (or often, the Oxus) theory places the Tarim people's ancestors in the Bactria-Margiana region of Turkmenistan and northern Afghanistan, along the northern edge of the Iranian Plateau and sitting in the lowlands of the Kopet Dag and Pamir mountain ranges. The main evidence for this link is the similarity of environmental subsistence systems in the form of oasis agriculture. Both zones are arid and hot without possibility of widespread intensive agriculture. Groups in both places relied on a complex system of irrigation channels along fertile mountain river deltas to generate reliable resources for permanent settlement (Li et al. 2015:9; Thornton & Schurr 2004:85). This similarity in subsistence pattern is paired with the presence of woolly sheep in the Tarim Basin; all woolly sheep are known to have descended from an original stock domesticated in the Zagros mountains in western Iran (Barber 1998:648). The textiles associated with the Bronze Age Tarim populations is made from this Iranian stock, which was widespread in

Bactria-Margiana but not the northern steppe at this period (Hemphill & Mallory 2004:203). It is against this debated backdrop that the pile remains must be viewed.

While there is a scattering of foreign imports found in Bronze Age sites in the Tarim Basin, they are rare and seem to suggest that direct or indirect contact with far-flung groups across the continent was minimal (Høisæter 2017:347). Indeed, the distinct burial practices and material culture of different Tarim groups settlements suggest that they may not even have interacted consistently with each other, rarely venturing further than one or two settlements away (ibid.). This is likely due to the harsh environment of the Taklamakan desert, where drifting too far from the oasis settlements would have been risky and transit along the alluvial basin rim would have been slow and indirect. A lack of consistent contact (or an impressive disinterest in non-local material culture) would explain the general dearth of foreign goods in Bronze Age Taklamakan sites, and therefore suggests local innovation rather than foreign-born transmission for the pile technologies which appear in Xinjiang by 1800 BCE. The idea that the early Tarim inhabitants imported a single weaving technology with enough enthusiasm for it to appear in the perishable archaeological record but imported nothing else is improbable.

The striking technological and aesthetic links between the Tarim and west-central European Celtic textiles might also suggest an independent invention of pile technology. The similarity between the tartans recovered in the Taklamakan and those found in European contexts was one of the original lines of evidence suggesting a European origin for the Tarim people. Soumak is a non-pile technique that has conceptual and structural similarities to knotted pile (see Fig. 6.2), and direct physical evidence for soumak appears in central Europe by the mid-2nd

millennium BCE. I propose that the technological and conceptual jump between soumak and knotted pile is smaller than between other types of weaving and knotted pile. If we accept a Kazakh/Siberian steppe origin for the Tarim population, both the Hallstatt soumak and the Tarim pile technologies may share a common Europoid ancestor in the north steppe zone. Or, if we assume that the earliest surviving piece of soumak is not necessarily representative of the technique's first appearance, it is possible that soumak evolved into pile weaving somewhere along the Tarim population's eastward migration in the early-mid Bronze Age.

Despite this evidence for an independent origin in the Tarim Basin, it is difficult to overlook the contemporaneity between the western and eastern textile evidence. Even discounting the linguistic and artistic secondary evidence, the two groups both have primary evidence for looped textiles in the early 2nd mill. BCE, and both have primary evidence of knotted textiles a few hundred years thereafter. It seems unlikely that these two disparate groups, separated by 4,000 km (Ur to Loulan) and some of the world's highest mountains, developed not one but two matching technologies on an identical timeline. Of course, it may be that the timelines were substantially different and this is an example of sampling problems rather than of independent innovation. If we include the Ur fragment as a true pile textile, this mirrored timeline does fall apart as there is no hint of pile textiles in the Tarim Basin in the 3rd millennium BCE (remember, the Ur fragment was dated to c. 2700 BCE). But we should be wary of confusing coincidence for fact, particularly when archaeological preservation is so poor and sample sizes are so small.

It is also important to consider the possibility that pile technology didn't originate in Mesopotamia, Egypt, the BMAC, or the Tarim Basin, and instead was transmitted to all these areas

from a fifth location. Modern genetic testing has not been able to establish a firm link between the Tarim people and any other region. Links to both the north steppe and the BMAC area exist, but are weak at best. In fact, some of the better evidence links the Tarim groups to eastern Asia (Høisæter 2017:346). It is therefore possible that rather than pre-supposing an eastward expansion of knotting technology out of Mesopotamia, we should consider a westward expansion out of eastern Asia. This link to the east may be supported by Tarim trade connections which preferentially developed to the east: by the 3rd millennium BC, a "jade road" ran between Khotan and Yarkand in the Tarim Basin to Longshan in east-central China (Kuzmina 1998:64). Similarity of ceramics found in central China and the Tarim oases suggests a "pottery road" by the middle Bronze Age (Høisæter 2017:346). In the late Bronze Age and early Iron Age, central and eastern Chinese markets increasingly drew exports of Xinjiang tin and copper (Høisæter 2017:345). If jade, pottery, and other goods moved along these routes, perhaps pile-weaving did too.

While these links are tempting hints at an east-Asian origin for pile technology, a few counter points need to be addressed. First, these routes appear to be mostly east-bound: very little reciprocal Chinese material appears in Xinjiang. If the technique originated in eastern China, it seems unlikely that it would have been transmitted westward along these routes when little else was. Second, archaeological, linguistic, and written historic evidence tells us that woolen textiles like those worn by the Tarim mummies were not widespread in early China, making it unlikely that it originated there – woolen textiles were viewed as a novelty well into the Iron Age (Boulnois 1966:19). Admittedly there is no reason a pile textile must be made of wool (the Egyptian examples were linen, and many modern examples exist in cotton and silk), but a

complete lack of evidence for Bronze Age silken pile anywhere in the world is certainly a problem. Even the modern practice of carpet-weaving in eastern China lags more than a millennium behind that of western China, with no firm evidence before the Renaissance (Bidder 1964:29).

Finally, the local and inter-regional connections that would eventually grow into the Silk Roads were already present among both settled and nomadic groups in 3rd mill. BCE Central Asia, Siberia, and Xinjiang (Doumani Dupuy et al. 2018:1). So while the Tarim communities may have had preferential contact to the east and limited foreign influence overall, it would not be correct to say there was no contact at all between Tarim communities and the west. An eastward transmission of pile-weaving technology out of Egypt, Mesopotamia, or the BMAC therefore remains possible.

A potentially South Asian origin is also worth noting (Eiland Jr. 1979:132; Tsareva 2016:20). Curved knives similar to those recovered in the Kopet Dag have been found at Indus sites in Pakistan, but dating to a substantially earlier period between 2600-1900 BCE (Kenoyer 2004:22; the Kopet Dag knives date to the 10-14th centuries BCE). Linguistic ties also exist between Vedic languages and Avestan languages in the Iron Age, suggesting links between south Asian populations and Iranic groups to the northwest (Hiebert 1998:148). Similarly, relationships in language between early Indo-Scythians in the western Indian subcontinent and the Tocharian Tarim Basin peoples (Bidder 1964:15; Zhang 2015:24) could also imply an influx of migrants carrying textiles and textile techniques between the regions. There are no physical fragments known in South Asia until the Mughal period, where it is reasonably clear that the practice was

at least reinvigorated if not wholly (re)introduced by Uzbek conquerors. Yet, the early date of the curved knives is intriguing support for an earlier invention of pile-weaving in the subcontinent.

Other "fifth origins" have also been proposed for pile weaving technology, from along the north Caspian Sea (Barber 1998:2), or from the central Iranian plateau (Tsareva 2016:20). However, these theories are based on general migratory and trade patterns of the Bronze Age rather than direct evidence of pile technology and therefore are not especially persuasive.

While an interesting idea, the lack of direct physical evidence for a "fifth origin" hypothesis, regardless of where that origin might be, clearly makes it a weaker option than a Mesopotamian or Tarim single origin, or a multiple independent innovation in Egypt, Mesopotamia, the Tarim Basin, and/or the BMAC. Nonetheless, we do need to acknowledge the difficulty of preferencing the single-origin vs. dual-origin theories, and the possibility that this difficulty means that neither is correct.

We cannot say with any evidence-based certainty that pile technology was transmitted in a particular direction, especially without confirmation of the Ur fragment. While a Tarim origin theory is not popular in the scholarly literature, I suggest it should be given as much credit as a Mesopotamian origin theory, as neither appears to be based on significantly older, more reliable, or substantially more persuasive evidence than the other. While a Mesopotamian origin may be slightly more likely than an Egyptian or Bactro-Margian origin due to the secondary linguistic and artistic evidence that emphasizes the Fertile Cresent, this is not sufficient to preference the Mesopotamian origin over a Tarim origin, particularly in light of the significant distances involved and the seclusion of the Bronze Age Tarim settlements. The overwhelming preference for a

Mesopotamian origin seems to be based more on a paradigmatic view of what carpets, carpet technology, and carpet history should be, rather than what the evidence suggests they actually are.

The Iron Age

Despite the evidence discussed above, carpets (and knotted pile generally) are almost always quoted as dating to the mid-Iron Age. This is likely due to many factors including romanticism, mistranslation, misunderstanding, and pure laziness, but the finger can be pointed most squarely at one thing: the Pazyryk carpet (Fig. 5.9). Excavated in Russian Siberia in 1949 and dating to c. 300 BCE, the Pazyryk carpet has become to textile archaeology what Tutankhamun's death mask is to Egyptology, or what Plymouth rock is to the history of the American colonial period. It has a wider popular reach than anything else discussed anywhere in this paper and even boasts an individual Wikipedia page (in nineteen languages!). Modern carpet workshops will happily weave you a replica and have the cartoons (designs) ready to go. I saw more than one replica hanging in carpet galleries in Central Asia over the course of this project. Nearly every carpet publication, whether it be from an academic journal, a dealer or trade publication, an auction or museum catalogue, or a hobbyist newsletter, will list the Pazyryk carpet as "the oldest known". So many publications make this pronouncement that it is not even practical to list them, as it would be most of the carpet texts in the bibliography. And because the Pazyryk carpet is the "oldest known" and it dates to the late Iron Age, carpets as a whole must also date to the Iron Age!



Figure 5.9: The Pazyryk Carpet

The knotted pile carpet recovered from Kurgan 5 of the Pazyryk burial ground, 5-4th cent. BCE. Inv. No., State Hermitage Museum: 1687-93. Photo © The State Hermitage Museum, St. Petersburg.

It is unclear what exactly the authors mean when they say that the Pazyryk carpet is the "oldest known" or the "world's oldest". Some seem to mean that the Pazyryk carpet is the oldest known knotted textile. As we have already seen, this is flat wrong. It is not even the oldest known knotted textile discovered in central Siberia, much less from the whole world. The most generous explanation I can give for this blatant inaccuracy is that the authors were reproducing a statement that was true at the time of discovery, but which has since been superseded. What they really

meant was that it was the oldest known carpet *at the time of excavation*. However, as the Pazyryk carpet's age was exceeded by another fragment recovered by the same excavator the very next year, there was only a short window when this statement was true.[9] Its repetition for over half a century is baffling.

Maybe the authors mean that it is the oldest *carpet*, as in the oldest pile-woven object used specifically as a floor covering versus other applications. I suppose I cannot say that this statement is definitely false, but the assertion certainly should raise eyebrows. There is no absolute evidence that the Pazyryk carpet definitely is a floor-covering, or that any of the other fragments already discussed definitely are not (except perhaps the Beauty of Loulan's cloak, wrapped so snugly around her by her family to keep her warm in the frigid desert sand). The wear-and-tear exhibited by the Pazyryk carpet is given as evidence that it was used on a floor, but similarly decorative knotted textiles were used as early saddles and saddle blankets in wider central Eurasia (Bunker 2001:6; Polosmak & Barkova 2005:191; Schorta 2001:112; Zhang 2019:40) and it is not unreasonable to think they would have been similarly worn as a floor carpet. The Pazyryk carpet wasn't even found in a human burial, but rather a horse burial! I admit that the large size (1.8 x 2.0 m) of the Pazyryk carpet suggests it isn't a saddle or saddle blanket in the modern sense, but any experience with ranching or riding families will show horses wearing sheet-sized coats to protect them from wind, cold, sun, and insects. Spending more than two thousand years buried in dirty ice may also contribute to its ruffled appearance, and as there are

[9] Technically the statement was not even true on the day of discovery, as the objects from the tombs of Madja and Kha & Merit had been recovered decades earlier. However as discussed already, these objects were misattributed as woven/looped pile until the 1990s.

no similar objects to compare, we cannot say that the Pazyryk carpet is or is not worn out in any definable way.

Some authors might mean that it is the oldest *complete* carpet. The Pazyryk carpet certainly is remarkably well-preserved, far better than many other pieces. This and its beautiful design have undoubtedly contributed to its fame. However, it absolutely is not the only complete or near-complete ancient pile textile: the Deir al-Bahri towels, the covers from the tombs of Madja and Kha & Merit, and the Beauty of Loulan's cloak are all similarly whole, and a millennium older. In fact, some of the Egyptian pieces are truly whole, while only ~80% of the Pazyryk carpet survives.

All of this is to say that a discussion of carpets' Iron Age history cannot begin without an understanding of the Pazyryk carpet. Despite the older and equally-well preserved items found elsewhere, the Pazyryk carpet is still by far the most widely-researched and published ancient knotted textile in the world. The carpet was recovered during an excavation in the Altai Republic, a Russian state with a modern indigenous Turkic population of about 40% (other main ethnic backgrounds are Russian and Kazakh). It is situated in south-central Siberia, at the point where China, Kazakhstan, Mongolia, and Russia meet. The site sits on the Ukok (Укок, Russian) Plateau, a steppe highland area created by uplift during the formation of the nearby Altai and Tian Shan mountain ranges. The site is within the Ulagan (Улаган) Valley, one of many tributary valleys carrying mountain run-off onto the plateau plain. The specific gully is known locally as Pazyryk (Пазырык).

The valley is home to a series of kurgans, the name given to Iron Age burial mounds of the northern steppe. Many assume that the gully where they sit (Pazyryk) gave its name to the kurgans, but it may be the other way around. In Tuvan (the Turkic language of the neighboring Tuvan Republic), *pazyryg* means a pile or heap; likely this name was given to the gully in acknowledgement of the kurgans, which appear as large piles of stone (Ochir-Goryaeva 2017:331). Despite being part of a different language family, *pagórek* is also used in Polish for a small mountain or hill (A. Sluka 2025). This suggests a wider cultural-environmental association across the Eurasian steppe. Although the name 'Pazyryk' was originally used just for this specific collocated group of kurgans, the wealth of now-iconic material that was recovered from the site has led it to become the archetype for the nomadic Saka cultural complex of the Iron Age trans-Altai. The whole cultural complex is therefore often known as the Pazyryk culture today.

One of the Pazyryk kurgans was excavated by Russian archaeologist Mikhail Griaznov in 1929, and the rest were excavated by Sergei Rudenko, a Ukrainian archaeologist, from 1947-1949. The kurgans start with a rectangular pit, 4-7 meters deep. Inside the pit a structure similar to a log cabin is built, with stacked trunk walls and plank floors generally made of locally-sourced larch (British Museum 1978:23; Rudenko 1968:8). Coffins and grave goods are placed in the room, then a brush and larch-wood roof is constructed to enclose the burial. Dirt is piled on top to create a mound, up to 60 meters in diameter. Finally, a cairn is built at the top of the mound, and the entire earthwork can reach up to 5 meters high. While not an absolute rule, kurgans are usually constructed in groups, and usually in approximately north-south lines – the Pazyryk kurgans follow this pattern (Rudenko 1968:7; Fig. 5.10). The kurgans and all their contents have

been variably dated to the 3-6th centuries BCE (Aruz et al. 2000:241; Hajdas et al. 2005; Rageth 1999; xRudenko 1968:12), based on carbon dating of the trees used in the burial construction.

The Pazyryk kurgans have single or double burials (Rudenko 1968:8). When double, they were always in male-female pairs, presumed to be spouses or other relatives. The bodies themselves were subjected to an embalming or mummification ritual in which their skulls were trepanned and their brains removed, their skin cut open and their muscle tissue flayed out, the cavities filled with grasses and reeds, and the skin re-stitched with sinew (Rudenko 1970:293; Aruz et al. 2000:244). Some of the bodies have incredible tattoos in the Scythian Animal Style iconic of this period (Rudenko 1968:25; Fig. 5.11b). The burials are accompanied by a wide variety of grave goods whose quality and diversity suggest that the larger Pazyryk burials were important or wealthy people, possibly chieftains or warlords (British Museum 1978:24). These include furniture, textiles, weapons, animal trappings, cooking utensils, and musical instruments (Rudenko 1968:8). The walls of the burial chambers were originally draped in felt hangings, still an integral part of the north steppe material culture.

In addition to the human burials were extensive horse burials. Every human burial in this cultural complex, regardless of age, gender, or apparent social status, is associated with horse burials, ranging from one to more than twenty horses in a single kurgan (ibid., pg. 19). Deposited in a separate chamber, the horse burials have various goods of their own including trappings, armaments, and even a carriage.

The remarkable survival of human remains and grave goods in the Pazyryk kurgans is due to two factors: the natural environment and the laziness of Iron Age looters. In the summer

months, water easily seeps into the unsealed burial chambers and causes flooding. When the temperature drops, the water freezes. Even when summer returns, an insulating ice box effect is created where the chamber maintains its low temperature and the ice never gets warm enough to fully melt. This results in an "artificial permafrost" in an area without natural tundra (ibid., pgs. 10-11). This freezing, which would have happened in the first few winters after burial, was an effective defense against decomposition.

All of the Pazyryk kurgans (and most others in the trans-Altai) were looted in antiquity. Because the bodies appear to have still been articulated when rummaged through, it must have taken place relatively soon after burial (Rudenko 1970:9). The thieves dug their way into the central chamber and then would have had to hack out the ice to access some of the treasures frozen within. The difficulty in extracting the materials meant that the looters were rougher than looters generally need to be – heads were cut off to access necklaces where the ice obscured the clasp at the neck, and wall hangings were cut apart when the lower halves could not be extricated quickly (ibid., pg. 30). This was the fate of fine white felts lining the walls in Kurgan 5. While the looters undoubtedly caused horrible damage to the burials, their opening of the chamber and sudden exposure of it to the open air is part of the reason the un-looted objects survive so well. The exposure to open air led to condensation, which flooded any remaining open space inside the tomb and froze that too. Rudenko remembers that the two ice layers were easily distinguishable, as the earlier water had filtered through the ground and was relatively clean, while the second layer was clouded by the dirt and rubble dislodged by the looters in summer months.

Fortunately, the looters apparently decided that the horse burials, which had a similar artificial permafrost, were not worth digging into and they were left completely untouched. This is where the Pazyryk carpet (and many other incredible objects) was found, buried in Kurgan 5's horse pit (Fig. 5.9).

The carpet measures 1.83 x 2.00 meters and has approximately 1,250,000 knots (35 k/cm^2) (compare to the density of the modern and historic pieces included in this project's experiments in Appendix C). The knots are symmetric, and the pile has an average length of 2mm (Rudenko 1968:49) (Fig. 5.4e). This on the shorter side but within the range of a modern knotted carpet, and would not be considered a kaunakes. It is generally accepted today that the carpet was imported rather than locally made (Rudenko 1970:304; Aruz et al. 2000; Aslanapa & Edmonds 1988:10; Böhmer & Thompson 1991:30; Jones 2009:26; Tsareva 2009:76). The most common source of the carpet is suggested as the Achaemenid empire, which extended as far as the Aral Sea in southern Kazakhstan and reached within 1,000km of Pazyryk at its height. The evidence for an Achaemenid source is based on two main points: the design and the quality.

First and most notably, the similarity of the Pazyryk carpet's design to Achaemenid motifs of similar age is striking. The horsemen riding along the outer border (Fig. 5.12) are very similar to those lining the walls in Persepolis (Rubinson 1990:55). A particularly useful comparison can be drawn to a series of reliefs in the Persepolis Apadana (a large hypostyle hall used for audiences and other public engagements), constructed in the early 5th century BCE. Carvings show delegations from around the empire arriving, in their native dress, to deliver tribute from their respective homelands. Delegations include Syrians, Ethiopians, Arabians, Indians, Bactrians,

Parthians, and many others. Relevant here is a procession of Saka (east steppe Scythians) (University of Chicago 2025) (Fig. 5.13). A horseman walks alongside his steed, who has a docked tail and a decorative tuft at the forehead. The men wear short robes or tunics with leggings or pants underneath for riding. They also wear a distinctive, Phrygian-style cap. The horsemen circling the Pazyryk carpet are drawn in a similar style, although some of them are mounted rather than walking (see Fig. 5.12).

The rosette motifs in the central field of the carpet are also linked to the Near East. In the 8th century BCE, a fashion arises in Asyrian palaces and ceremonial buildings where intricate designs are carved on floors (particularly in thresholds) (Albenda 1978:4; Spooner 1986:211) (Fig. 5.14). These carvings are thought to imitate (knotted) textiles: we know that large textiles were used in this period because they appear in depictions (Fig. 5.15). There is also continued use of the specialized "knotter" word (*kāmidu*) already discussed (ibid., pg. 1; Barrelet 1977:60-62), indicating continuity of the knotted/pile technique. Fringes on the threshold carvings indicate that they are meant to replicate textiles rather than be independent decoration, although there is no way to guarantee that they are intended to imitate specifically knotted textiles, rather than flat-woven kilim, embroideries, or other techniques (Kawami 1992:14). The complexity of the design, while not technically impossible to weave as a kilim or tapestry, would certainly be tricky and not very durable (especially under foot). I think we can discount that theory. Embroidery is more realistic, although embroidered panels tend not to have fringes: they would usually be worked on a flat-woven sheet which would have loom-finished or hemmed edges, and therefore no need for fringes which get dirtied, snagged, and ruffled by feet. The best evidence that these

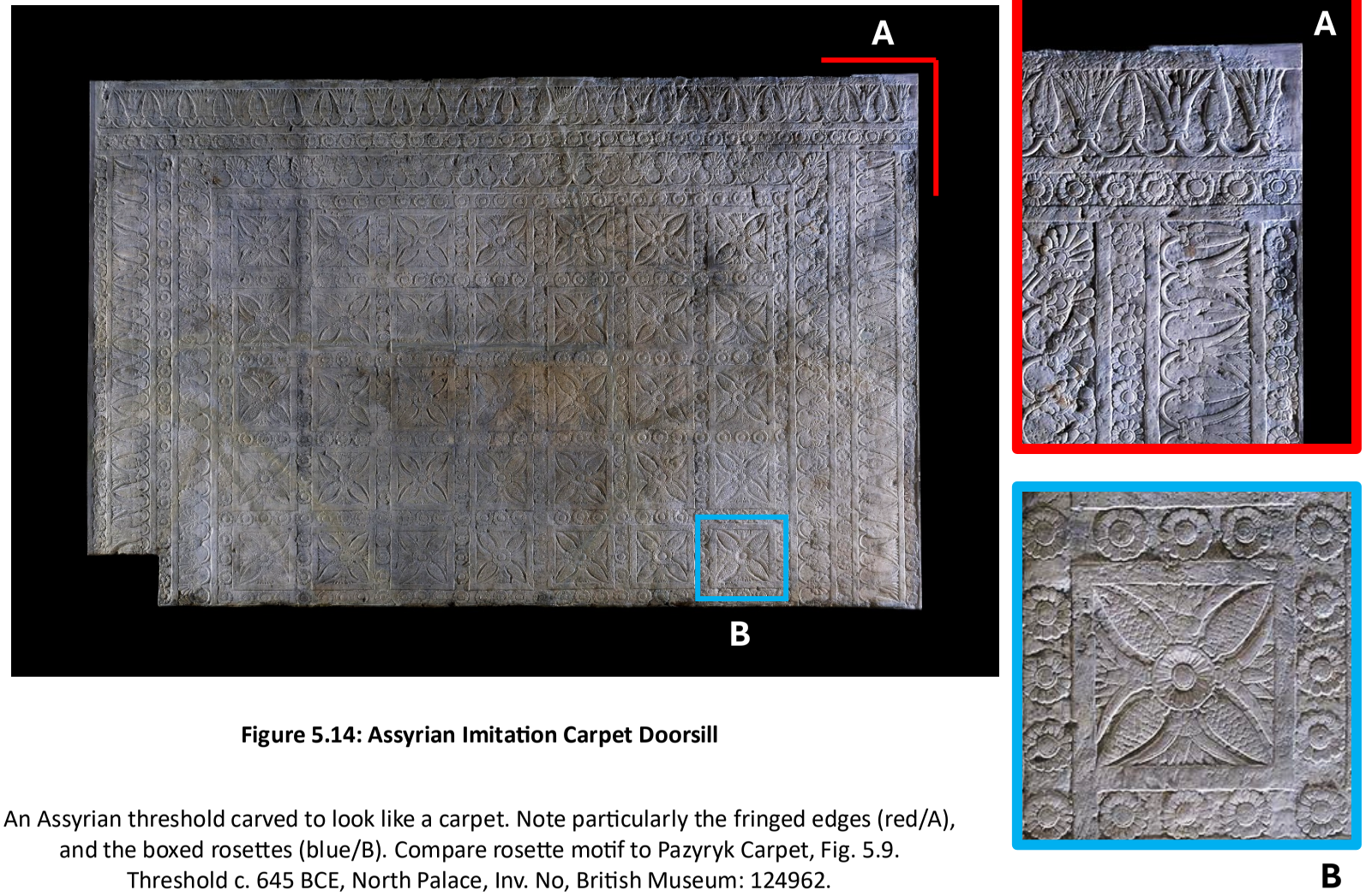


Figure 5.14: Assyrian Imitation Carpet Doorsill

An Assyrian threshold carved to look like a carpet. Note particularly the fringed edges (red/A), and the boxed rosettes (blue/B). Compare rosette motif to Pazyryk Carpet, Fig. 5.9.
Threshold c. 645 BCE, North Palace, Inv. No, British Museum: 124962.
See also 118913, 124943; Photos © The Trustees of the British Museum. Shared under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license.

floor carvings represent knotted textiles is the similarity of their boxed rosettes to those that make up the central field of the Pazyryk carpet (Rudenko 1968:52) (compare Figs. 5.9, 5.14). Clearly this motif is associated with knotted carpets, even if it is not exclusive to them.

In addition to the design similarities to Achaemenid art, the high quality, fine colors, and careful symmetry of the Pazyryk carpet does not suggest nomadic production – as we have already discussed, the idea that nomads were weaving large, time-consuming carpets on mobile horizontal looms is unlikely, and that they were disassembling and transporting heavy, awkward vertical looms repeatedly while weaving is equally so. While certainly nomadic weavers were and are skilled craftspeople and perfectly capable of producing fine works, it seems unlikely that they would do so regularly given the logistical and practical limitations of their lifestyle. The good quality of the carpet and its very large size (around $4m^2$), with even tension and attention to detail throughout, does not seem to imply it was a rush-job crammed into a nomadic stop-over either. It seems more likely, therefore, that the Pazyryk carpet was produced in a settled, possibly even urban environment. The combination of the similar designs, logistical concerns, and fine quality leads most researchers to believe the carpet originated within the sedentary Achaemenid empire.

The Achaemenid empire was a big place, spanning more than 5.5 million square kilometers at its height in the mid-late 1st millennium BCE (around when the carpet was woven). Although the designs are most similar to carvings found in the Near East and Persia, most scholars suspect that the carpet was woven further north, likely near the empire's edge in Central Asia (modern southern Kazakhstan, northern Kyrgyzstan, or possibly Uzbekistan). The Asyrian and Achaemenid designs suggest significant southern influence, but there are strong northern

influences too, particularly in the line of deer that act as the inner border (see Fig. 5.9). These are spotted fallow deer (*Dama dama*), which are native across large parts of Eurasia, but which feature as the primary iconic motif of Scythian art of the northern steppes (Rubinson 1990:54; Rudenko 1968:29) (Fig. 5.11). [10] Similar deer appear in the locally-produced felts, woodwork, metal ornaments, and even the tattoos of the Pazyryk burials. The presence of the animals on the carpet suggests more local production with local environmental and cultural influence, rather than production in a court or urban workshop further south.

Although most scholars today tend to favor production by Central Asians under Achaemenid control, it must be acknowledged that definite proof does not exist. The blending of Achaemenid/Near Eastern imagery with steppe imagery cannot be said to absolutely preference one source over the other. It is possible that the carpet was woven by Achaemenid subjects anywhere in the empire specifically for the steppe market, or by steppe peoples copying Achaemenid designs they had seen elsewhere (Böhmer & Thompson 1991:34). The quality of the carpet, while good for the period, also shows some small errors and asymmetries that seem out-of-place for a specialized craftsperson working in an urban environment. For instance, despite seven horsemen lining each border, there is no consistent pattern in how many are mounted vs. walking, or in what order they occur (Rudenko 1968:45). The complexity of the horsemen makes it seem very unlikely that they were worked from memory, but their inconsistency also does not suggest close attention to a drawn cartoon or a rigorous production standard (Böhmer &

[10] Carl Linnaeus gave two names to the species in his original 1758 classification: *Cervus dama* and *Dama dama*. Rudenko references *Cervus dama*. Modern zoologists use *Dama dama*. (EEA 2025)

Thompson 1991:32). The fibers and dyes, although they have been tested, do not link to any environmental product that distinguishes the two places. Overall, unless a miraculous clue is found, it is likely that we will never know for sure where the carpet originated; however, the general consensus is that it was not a local nomadic Saka product.

The carpet was not the only pile textile recovered from the Pazyryk kurgans. A looped fragment, possibly also from a carpet, was recovered in kurgan 2 (British Museum 1978:25) (Figs. 5.4f, 5.16). This piece is usually presented as a local product, as it is coarser and the looped technique is more realistic for mobile populations (ibid.), eligible for manufacture on the more mobile horizontal loom and even backstrap looms. A larger division between all the Pazyryk textiles emerges, where more colorful and finely-worked pieces are mostly believed to be imports from elsewhere (including silks from China and tapestries from the Middle East), while coarser and more monochrome objects are presumed to be local (ibid.; Rubinson 1990:56; Rudenko 1968:6). Despite a smattering of foreign luxury fabrics and other items, including a Chinese mirror (Rudenko 1970:296), the vast majority of textiles placed in the Pazyryk graves were felt, a common material of north steppe nomadic groups to this day. There is no other textile paraphernalia present in the Pazyryk kurgans (whorls, needles, beating combs, carpet knives, loom components, etc.) – a single whorl was found in a simpler in-ground cemetery nearby at Biysk (Rudenko 1970:304). This may indicate that weaving and textile work was not a common chore for the wealthier people buried in the kurgans, and certainly reinforces that felts rather than woven textiles were the primary fabric of this community. Whorls are not required for feltwork.

Only a year after excavating the Pazyryk burial ground, Rudenko moved approximately 160 km west to work on another cluster of kurgans at Bashadar (Башадар, Russian). These have a similar environmental setting as those at Pazyryk and would be considered part of the same nomadic Iron Age Scythian culture. In form and content, they are generally similar, although the Bashadar burials are not as wealthy as the Pazyryk ones. However, the group at Bashadar date to the 6th century BCE, up to three centuries before Pazyryk (Rudenko 1968:59). One small fragment of knotted textile was removed from a burial chamber at Bashadar. Unlike the Pazyryk carpet's symmetric knots, the Bashadar fragment uses asymmetric, left-opening knots (Fig. 5.4d). This is notable, as even today, communities usually use the same knot style – it is one of the conservative "techno-gestures" of carpet-weaving. For these two groups to use different knots reinforces the idea that the Pazyryk carpet and/or the Bashadar fragment are imports, and not representative of a cohesive local knotting tradition.

The Bashadar fragment is also considerably finer than the Pazyryk carpet, with approximately 70 knots/cm^2 (Pazyryk carpet is 35k/cm^2; compare to the density of the experimental samples in Appendix C). The fragment is listed as from a saddle cloth (Eiland Jr. 1976:4), recalling our earlier discussion on the difficulty in distinguishing floor textiles from other utilities based only on apparent wear. Because the Bashadar fragment is very small (only 8 x 8cm), far less analysis has been performed on it and fewer conclusions can be drawn. It was also, unfortunately, sewn to a backing board shortly after discovery. Nevertheless, based on the same lines of thinking applied to the Pazyryk carpet, it is likely that this fragment was produced by

skilled craftspeople in an urban environment, possibly also on the settled edges of Achaemenid Central Asia (Rudenko 1970:302) as that was the major urban power in the area at the time.

Another fragment of similar age (3-6th cent. BCE) came from Verkh-Kaldzhin (Верх-Кальджин, Russian), about 150 km south of Pazyryk and Bashadar. This fragment is of cut pile which has then been twisted into shaggy fringes (see Fig. 5.4g). Like all the other pieces associated with the Pazyryk culture, it is entirely wool and was recovered from a kurgan. Like the looped pile at Pazyryk, the coarse and drab Verkh-Kaldzhin fragment is believed to be a local product (Polosmak & Barkova 2005:191).

Both the Pazyryk carpet and the Bashadar knotted fragment represent a fine, well-honed, and time-consuming craft, reinforcing the idea that knotted textiles must have existed, either in the northern steppe or elsewhere, for a considerable period before the 5th century BCE (Spooner 1986:204). While four pieces is not enormous evidence, the presence of both imported and local, knotted and looped pile, and symmetric and asymmetric knots in culturally compatible burials in a similar timeframe is notable. It suggests that the technique has not only been refined at the small and local scale, but has permeated and diversified across the wider Eurasian community in a way not apparent in the Bronze Age.

The central Tarim Basin sits about 1,300 km south-southwest of the Saka kurgans at Pazyryk, Bashadar, and Verkh-Kaldzhin. Although some scattered pile textiles have been found in the Tarim from the Bronze Age, most notably the Beauty of Loulan's wrap, the bulk of the pile finds here are from the Iron Age. First recovered by famed British explorer Aurel Stein in his 1900-1901 expedition, these pile fragments would have briefly held the title of oldest-yet-known,

predating the excavation of the Tomb of Kha & Merit by five years (Zhang 2019:36). A robust collection of pile textiles is now known from the Tarim Basin – too many to list individually here (but see a more robust summary in Zhang 2019). A few individual pieces are worth bringing to attention. There are two Stein fragments included in this study: MU-VA-3 and MU-VA-4 (see their structural diagrams in Appendix B). Both are now held in the Victoria & Albert Museum in London, and both were recovered in Loulan, a settlement on the eastern edge of the Tarim Basin. They date to 150 BCE – 60 CE, both are made entirely of wool, and both use symmetric knots. Both are also examples of the kaunakes type, with many picks (6-7) of weft separating single rows of knots. Unfortunately, degradation over the last two thousand years means that the long pile does not survive. We assume that the long pile existed to cover the excess wefts – this is a guess, however, and the pieces may have been short-pile with an intentionally ridged appearance, like corduroy. Either way, they fit the more ancient style of separating the pile knots by many rows of weft, and are a visible departure from the carpets most are familiar with today.

Another group of seven important pieces was recovered by Chinese teams in the last twenty years at Yanghai on the northeastern edge of the basin. Unfortunately, these fragments have been published exclusively in Chinese (Jia et al. 2009, Jia 2015; both quoted in Zhang 2019:40). Only brief summary information is available in English. The fragments are symmetrically knotted, have been classified as saddle blankets (like the Bashadar fragment), and date variously from 1100-700 BCE. The Chinese sources state that these are therefore the oldest knotted textiles known in the world. We know this to be untrue as they are edged out by the Egyptian pieces of the 14-15th centuries BCE, but can agree that they are currently among the oldest known in Asia

and certainly predate the Pazyryk carpet.[11] As mentioned already, a fragment held in a private collection and also collected (likely looted) in the Tarim Basin was recently carbon-dated to the 12th century BCE, making it contemporary with the oldest of this group, or slightly older (Tsareva 2012: footnote 1). Regardless of which piece holds the ultimate title, the presence of knotted textiles in the Tarim Basin is comfortably established throughout the full 1st mill. BCE and into the early common era.

The Tarim Basin carpets in the Iron Age are all made of animal fibers. This is predominantly sheep and goat wool, although some yarns of cow and horse occur too (Zhang 2019:38). While the selection of fragments described above all use symmetric knots, pieces with both asymmetric and wrapped knots appear in similar contexts too. The textiles include both short-pile (what we would think of as a standard carpet), kaunakes (long-pile), and double-sided versions where knots are tied from both the front and back of the warp. Most of the fragments still use a plain-weave weft, but in this period there is an occasional twill as well (ibid., pg. 40). One of the two known twills is also the earliest evidence of the asymmetric knot form in the Taklamakan (Xinjiang Museum cat. no 96QZIIM2:9) (ibid., pg. 41). Some of the pieces of this period use more than one knot form in the same item, a practice which still occurs in modern Central Asian carpets, particularly in eastern Turkmenistan (see the well-preserved saddle blanket recovered in Shanpula, Xinjiang Museum cat. no. 84K2:1, Schorta 2001:112). Like with the fragments recovered in the steppe kurgans, the sharp increase in the number of knotted textiles and the

[11] Remember that although the Beauty of Loulan died in c. 1800 BCE, her cloak was looped pile, not knotted pile.

impressive variety of structures and applications suggests a craft that has permeated the area, rather than one just finding its feet.

To date, no direct evidence for looms has been discovered in the Tarim Basin. Of course, this does not mean they didn't exist: a loom would be necessary to weave a knotted textile. The question then is not whether they had looms, but rather what style their looms took.

Without any direct evidence, we cannot say definitively that the Iron Age Tarim oasis people used either vertical or horizontal looms (or both). However, as already discussed, the discomfort and the physical size limitations usually imposed by horizontal looms make them less practical for large items like carpets. Unlike the Saka and other Central Asian nomads, the Tarim people were sedentary at this period: their survival in the harsh, dry Taklamakan relied on proximity to the oases that dot the basin's rim (Hong et al. 2003:546). A sedentary lifestyle does lend itself better to carpet weaving, as it eliminates the need to dismantle a loom or roll up a months-long project for transition periods. Some of the Taklamakan fragments are also double-sided, meaning that the weaver tied knots on both sides of the warp – this would require access to the back of the warp, which is not possible on a horizontal loom where the warp runs parallel to and usually only a few inches above the ground. Finally, there is no evidence that horizontal looms were ever used for carpets in the Tarim Basin (Bidder 1964:11; Eiland Jr. 1979:14). There has never been any record of it, even into the modern period (unlike in Iran and Central Asia, where use of horizontal looms for carpet-weaving is documented from the Renaissance into the 20th century) (Bidder 1964:11; Eiland Jr. 1979:14). Overall, it is reasonable to assume that the Iron Age Tarim carpet weavers worked primarily if not exclusively on vertical looms. This does

not discount the possibility that other textile types were woven on horizontal looms in the same communities.

Material analysis of non-carpet weavings found at the same sites have structural indications of not only loom use, but beamed and mechanically-shedded looms. A particular flat-weave twill fragment from Qizilchoqa, at the western end of the basin, has the same weaving mistake replicated throughout the pattern (Barber 1991:146). This suggests that the shedding system was set up wrong: every time the weaver had to repeat a particular pick in the weaving sequence, the mechanism placed it incorrectly. It is possible that the weaver didn't notice the mistake or that she decided it was not worth trying to fix, as shedding mistakes can be difficult and time-consuming to correct once weaving has begun. If the weaver was hand-counting the twill without a mechanical system, she would not make the same mistake in perfectly repeating intervals, as appears in the fragment (ibid.). We can therefore assume that by the time of this fragment at least (c. 1200 BCE), the Tarim weavers had access to mechanized sheds. As a carpet shedding mechanism is simpler than that needed for a twill, we can reasonably extrapolate that they had both, and that carpets were probably not hand-picked.

Various flat-woven fabrics from Qizilchoqa also have four selvedges (one on each side).[12] Experiments with warp-weighted looms have shown that regular and symmetric edges like this are not generally possible on a warp-weighted loom, as the warps are not held in tension or with consistent horizontal spacing in the way required. Therefore, a multi-selvedged piece like this

[12] In flat-weaves, "selvedge" refers to any finished edge where the weaving is secure and cannot ravel, and can include both the horizontal and vertical sides. Carpets distinguish between the vertical (bindings) and horizontal (selvedges) because they take very different structural forms.

would have to be made on a beam loom (Barber 1991:146). Again, if they were using beamed looms for other textiles, it is reasonable to suppose that they could have used them for carpets as well, as is done today. Overall, this evidence tells us that by the end of the 2nd mill BCE (if not much earlier), Tarim carpet-weavers were likely working on vertical, beamed, and mechanically shedding looms very similar to those used in Eurasian carpet weaving in the 21st century.

While no pieces or depictions of looms survive in the Tarim Basin, other tools do. Stein's original excavations, as well as subsequent ones through the 20-21st centuries, have recovered many weft beating combs. Examples have been excavated at Niya on the south-central rim of the basin (Zhongri Niya 1996, quoted in Zhang 2019:38), and at Kaladun (Yue 2009, quoted in Zhang 2019:38) and Shanpula (Wang & Xiao 2001:65) in the south-west (Fig. 5.17). These combs are not the shape generally associated with personal grooming, and their weighted bodies mean that they create extra force when used for beating. The morphological similarity to modern carpet combs is striking (see Fig. 6.42e). These combs date from the end of the 1st mill BCE and into the early common era. Their relative frequency in archaeological contexts in the western part of the basin has led some to suggest that the area was a carpet production center during the Khotan period, which started c. 300 BCE and ran the duration of the first millennium CE (Zhang 2019:36-37).

Despite their geographic seclusion in the Bronze Age, the settlements in the Tarim Basin transitioned into cohesive urban kingdoms in the Iron Age. Populations increased, settlements became more stratified, urban economies took over from egalitarian ones, and inter-regional and trans-continental trade flourished (Høisæter 2017:352). A likely cause of this major social change

is the arrival of a "steppe package" (Frachetti 2012:17-21) from the north-west. The rise of mounted steppe nomads occurred around the turn of the first millennium BCE. While horses had been domesticated for thousands of years by this point, the transition from using them as meat, milk, and pack animals into using them as a primary mode of transportation did not occur till the late Bronze Age (Linduff & Rubinson 2013:359). And when it did happen, it caused a rapid shift in social and economic organization: a similar phenomenon occurred in the North American plains when horses were introduced there by the Spanish in the 16th century (Sherratt 1981:261). Groups that had previously been restricted to land within short distance of rivers and lakes (like the Tarim people and their oases) suddenly had the option for rapid travel and expansion into previously under-utilized grassland. This expanded sphere provided access to new environmental resources and increased trade contact with neighbors. Particularly relevant for textiles, it also allowed for the management of ever-larger sheep and goat herds.

The short-distance local and regional trade networks which had existed in central Eurasia for over a thousand years were accelerated by this increased contact and faster mode of transport. Although the Silk Roads as a concept are usually given a start date c. 100 BCE, it is incorrect to imagine that the routes were a new system set up, supported, or managed by the grand empires at east and west. Instead, contact with those empires brought an influx of cash into an already established network, incentivizing merchant and craftsmen classes and reprioritizing resources for the groups along the central routes (Frachetti 2012:21; Høisæter 2017:340). It was along these expanding trade routes that the Taklamakan oasis communities grew into powerful, wealthy city-states. By the time Chinese military expansion campaigns

reached the basin in 204 BCE, thirty-six independent kingdoms were reported there (ibid.). The material repertoire of these cities also expanded greatly with increased access to foreign materials, techniques, and styles: the introduction of iron, horses, silk, and other foreign objects is apparent in drastically wealthier grave assemblages and in a sharp rise in grave-wealth differentiation. This increased technological complexity sees increased diversity across textiles too, with complicated brocades, tapestries, samits, twills, and carpets appearing in vast arrays of new colors and styles (Barber 1999:63-71). As textiles become finer and more consistent, it may be that they are becoming increasingly specialized to meet growing demand for exotic foreign goods and tastes among the expanding upper classes. An unusual fragment of tapestry (c. 500 BCE) recovered at Chärchän in the south-central basin is similar to contemporaneous Middle Eastern pieces in style but not structure, suggesting a craftsperson incentivized to backwards-engineer a foreign product without direct instruction (Barber 1999:63-64). Carpet-weaving would surely have been caught up in the same material revolution.

By the time the Chinese arrive at the end of the millennium, the Taklamakan kingdoms were Scythian, Indo-European-speaking settlements (Bunker 2001:45; Samolin 1958:52). This included both Indo-Iranian Saka languages and the Tocharian or proto-Tocharian brought by the mysterious original settlers. Whether the Scythian influence is due to population replacement, migration and mixing, or a less direct cultural influence is unclear (genetic evidence from Iron Age Tarim burials does not show a major influx of new genes) (Høisæter 2017:353). Regardless of how it happened, the cultural and linguistic similarities plus the known trade contact between the

Tarim populations and contemporaneous Indo-European Scythian groups further west suggests they may have a shared knotted-pile technological system.

While the Tarim knotted objects show an explosion of technique, color, and design in this period, the woven quality (measured by knot density) remains generally low, particularly in comparison to the fine Pazyryk carpet and the even finer Bashadar fragment. There are few Iron Age fragments from Xinjiang that approach what is considered a mid-range carpet today (~20 k/cm^2 [Hodjamukhamedov & Dovadov 1982:22]), while the Pazyryk carpet and Bashadar carpets would both be considered quite high-quality today. Some scholars have suggested that this sharp difference in quality indicates a hard break in technology in the Tarim Basin at some point before the mid-1st mill. BCE, when the western Eurasian weavers continued to perfect and diversify their Bronze Age pile textiles, while the eastern weavers had to "start over" for some reason (Aslanapa & Edmonds 1988:207; Eiland Jr. 1976:4). However, there is no direct evidence for a major technological break or re-setting event. The (comparatively) low-density designs remain the default type in the Taklamakan through the first half of the 1st mill CE, more than a millennium after they established regular contact and substantive trade relations with the north steppe communities and the Achaemenid weavers of Central Asia. There is no reason to think that the Tarim weavers, clearly skilled and technologically creative in their own right, would not have been capable of adopting the Central Asian or Near Eastern methods and styles for finer weaving, if they wanted to. The fact that the knot density remains generally low for such a long time suggests either a cultural or artistic preference for lower-density objects, an economic aversion to labor-intensive high-density weaves, or a simple sampling error in the archaeological record (tombs in

both regions were thoroughly looted). There are also no equally-fine pieces in the northern steppe for close to two thousand years after the kurgan pieces, so it may be more accurate to view the Pazyryk carpet and the Bashadar fragment as outliers, rather than seeing the Tarim pieces as representatively sub-standard.

As the Tarim kingdoms produced ever more complex carpets, their Chinese counterparts start to notice them. While intricate silk brocades and samits were travelling west along the Silk Roads, wool carpets are flowing east (Jones 2009:24). Bright, colorful, and nearly complete, a set of 4-5th century CE carpets excavated at Yingpan cemetery on the northeast edge of the Tarim Basin show a distinctively Central Asian lion (Li 2006:255; Fig. 5.18). In fact, it seems that the production and export of lion carpets was very efficient: one of the Yingpan carpets has been cut along its selvedges, suggesting that it may have been woven with others in a long bolt and cut apart for sale after removal from the loom (ibid., pg. 256). These carpets also use the simpler wrap-style knots, and the knots do not occur on every warp (see Fig. 5.4j). I suspect that this was a cost-saving measure, designed to speed production and maximize sales to foreign buyers who couldn't tell the difference anyway (a practice still occurring today!).

"Yingpan" literally means "military camp" in Chinese, and the settlement was an outpost of the Chinese imperial state. The presence of the lion carpets (and many others) in Chinese outposts in Xinjiang prove that they were part of the cultural landscape for the Chinese as well as the local Scythian populations. However, they do not seem to have permeated much further east, or into the wider Chinese consciousness. There are some scattered records of wealthy Chinese families purchasing wool textiles from Xinjiang at the end of the 1st millennium BCE, and



Figure 5.18: Yingpan Lion Carpet

A lion carpet with a Central Asian style excavated at Yingpan cemetery,
Xinjiang Uyghur Autonomous Region, China, 4-5th cent. CE.
See also 89YYC3:1. Inv. No., Xinjiang Museum: 95YYM15:1
Image from Yue 2009.

the high cost listed suggest that they are labor-intensive pile rather than flat-weaves (Eiland Jr. 1979:10). This long-distance ordering seems to be relatively rare though. Carpets remain, for the most part, a western product and a novelty souvenir for the Chinese soldiers garrisoned in the borderlands (Eiland Jr. 1979:10).

While the Chinese do not play a huge role in carpet-weaving, the linguistic evidence suggests that there are complicated relationships unfolding between other groups. The local Tarim peoples used the Kharosthi language through the 1st millennium BCE (Zhang 2019:39), and their records include the rug/carpet words *kojava* and *tavastaga*. When communities began to transition away from the local language and into Saka (aka Khotanese) in the early common era,

they started to use *gahāvara* and *thauracaihä*. Meanwhile, Sogdians across the Pamir mountains in Central Asia were using *faspā* and *parštarn*, and the Chinese records use *qushu* and *tadeng* (ibid.). The carpet/rug issue in modern English seems to be reflected in these historic terms, as each language has a pair, but it is not entirely clear how the words are distinct. Like in modern English, the frequent use of both words in the same documents and in slightly different settings suggests a distinction: whether it was a subtle distinction or a clear-cut one to the ancient Central Eurasians, and whether it was based on technique or material or some other characteristic, we cannot say for sure. Original translations of Kharosthi documents performed by British Indologist and translator Thomas Burrow (1940, quoted in Zhang 2015:1-2) for the Stein expedition materials uses *kojava* as "rug" and *tavastaga* as "carpet". *Tavastaga* is usually given with dimensions (eg., a tavastaga measuring 2x4 meters), while *kojava* is usually given without measurements. This suggests that *kojava* come in a standardized size which does not need to be reiterated in every sale (ibid., pg. 22). This could be comparable to purchasing a bolt of fabric: a unit that is the full-width of the loom with loom-woven selvedges on both sides, in a pre-determined and standardized length. This might be a logical way to market flat-weaves (like tartans, brocades, or samits), which could be purchased in bulk and then cut down by a tailor or household member to produce garments, furnishings, or whatever else was required. Because carpets are usually woven as a one-off and their bulk limits how many can be wound together as a "bolt", it makes sense that they would be treated as individuals with extra size details.

While the evidence for knotted carpets, and pile textiles generally, explodes in central Eurasia during the mid-late Iron Age, it makes only a half-hearted showing in the Near East and

Iranian Plateau. Considering so many believe that the technique was invented in Mesopotamia, and Iran is today thought of as the global carpet leader, it is interesting that there is no physical primary evidence from the southwestern quarter of the continent until the early common era, nearly two millennium behind Egypt and the Tarim Basin. Beyond occasional use of *kāmidu* ("knotter") under the Achaemenids (Barrelet 1977:60-62) and the decorative similarity to the Pazyryk carpet, there is no explicit or definitive mention of carpet weaving or carpet economies under the Achaemenids, Seleucids, or Parthians (Edwards 1953:2). While of course it is possible that the lack of evidence is a fluke of the archaeological record rather than a mirror of reality, it is worth considering why no pile textiles survive here, where they supposedly originated, but appear with persuasive regularity through the Iron Age in other parts of the continent.

The earliest-known physical fragments of knotted textiles from Mesopotamia or Iran are from the al-Tar caves in central Iraq (Tsareva 2012:3; Fig. 5.19).[13] Excavated by Japanese teams in the 1970's, the caves are both naturally occurring and dug-out in the mesas and buttes of Iraq's central desert, and have evidence of human use from at least the Middle Assyrian period (c. 1000 BCE) (Matsumoto 2019). A particular locus, Cave 16 in Hill C, produced eight knotted pile fragments (Fujii & Sakamoto 1990:45). These are dated to the late Parthian-Roman period, 2-4th centuries CE. The fragments, like those in the north steppe and the Tarim Basin, are made with many knot types and weaving structures and are much more diverse than a cultural sample you'd be likely to collect in a single community today. The pieces use symmetric, asymmetric, and wrap

[13] The name is also given as at-Tar or Attar, referencing the common practice of Arabic speakers to elide the article *al* (ال) into an *ah* sound.

knots, as well as examples of double-sided knotting (ibid., pg. 49; Fig. 5.4h). They also have both tabby and twills in the ground weave. They have relatively wide weft shots, requiring longer pile than is used in knotted carpets today, but not as long as would generally be called a kaunakes, filikli, or julkhir (ibid., pg. 49). The analysis notes that the pile is uniform and well-spun, while the warp and weft are made with a grandrelle yarn (a yarn where two or more colors have been plied together) (ibid., pg. 46). Today, grandrelles are usually intentional and used to introduce variety, texture, and dimension into fiber arts, but the exclusive use of the grandrelle yarn in the warp and weft here suggests that it was considered cheap or lower-quality. Because the warp and weft are completely hidden in a dense pile textile, their appearance is less important, and therefore it is reasonable to use whatever happens to be on-hand rather than investing high-quality or limited resources. This practice is still used to cut costs today. The pile is the part that is visible, and the pile in these fragments is made of uniform, single-color yarns. Despite the difference in quality and structure, all the al-Tar components are wool.

More fragments of similar age were discovered at Dura-Europos in eastern Syria (Fig. 5.20). This site had a long history under successive Seleucid, Parthian, Roman, and Sassanian control, but the textiles date to the end of the city's habitation, likely the 3rd cent. CE and therefore are attributed as Sassanid (Pfifster & Bellinger 1945:1). Most of the pieces recovered are tapestries, although there are more than ten pile fragments of various size. There are also a few pieces of silk compound weaves, indicating a trade relationship with China (ibid., pg. 2-3). Overall, the Dura-Europos pieces are very similar to the al-Tar pieces. They display an array of knotting forms including symmetric, asymmetric, and wrap knots. Some pieces use both traditional weft-

looping and a variation which the author of the report calls “Sehna loops” (ibid., pg. 47-49) but could also be called soumak. The presence of this soumak style alongside knotted pile reinforces my suggestion that the techniques are conceptually and technologically related. Many of these pieces also trend towards the long-haired technique, although again perhaps not quite long enough to be called true kaunakes/filikli. The pieces are made exclusively of wool. Based on the availability of sheep’s wool, the relevant dyes, and vertical-loom weaving in the early-common-era Near East, there is no reason to think that the textiles from al-Tar or Dura-Europos were not woven locally (Pfifster & Bellinger 1945:1). However, the presence of other imported textiles at Dura-Europos means we cannot fully eliminate the possibility of foreign manufacture (Tsareva 2009:3).

The Middle Ages

For most of the 20th century, the Medieval history of carpets was unknown. A few scattered fragments trail off from the late Iron Age, and a few early examples appear just before the rise of the Renaissance, but there was nothing substantial known from c. 500-1300 CE. This has started to change in the last few decades, and new objects and observations are illuminating a hazy picture. However, even with this new information, this period is still overwhelming dark.

A few Iron Age-Medieval transitional pieces were recovered at Shahr-i Qümis in north-central Iran, a Parthian-Sassanian site dated to the 6th century CE (Hansman & Stronach 1970a:29; Kawami 1992:16) in the 1960s. These pieces are looped pile and were associated with Zoroastrian burials (Metropolitan Museum of Art inv. nos. 69.24.34a-c, 69.24.37, 69.24.37). The pieces are

too fragmentary to determine if they were clothing, burials cloths, grave goods/furnishings, or other items. This same assemblage contains the first piece of silk identified in Iran (MET inv. no. 69.24.30), indicating a trade relationship with China. While notable for their date, this group is not technologically remarkable and is in-line with what was produced at al-Tar and Dura-Europos. Like those sites and despite the contemporaneous presence of silk, there is no evidence that the Shahr-i Qümis knotted textiles are not a local product.

One particular set of carpets is providing the most detail on the missing eight hundred years between the Iron Age and Renaissance. Known as the "Bactrian group", a collection of around thirty pieces is perceived as a distinct unit by some scholars, primarily Russian-language ones. The group includes both complete carpets and fragments of varying size. Spread across museums and (more often) private collections, these pieces are only recently being associated with each other as a cohesive group (Tsareva 2009:76). A notable number were discovered as random single finds in caves along the Hindu-Kush during the Afghan wars of the last 50 years; unfortunately, these have mostly disappeared into private collections without study (ibid., pg. 77). Others were recovered earlier in the 20th century, but were not recognized as notable and were packed away into museum storerooms or auctioned to collectors without serious scientific analysis. These carpets are from the 8th cent. BCE to the 10th cent. CE, although few have been carbon dated, and were recovered in Bactria, the east Iranian Plateau, the Hindu-Kush, the Pamirs, the Tian Shan, the eastern part of Central Asia, and into the western Tarim Basin. They are variably associated with the Sogdian, Khotan, Sassanid, and/or Kushan cultures (ibid., pg. 75; Gyul 2016:6). These carpets are grouped together based on their structural and aesthetic

similarities, but were mostly not discovered in shared deposits. They are unusual for using multiple types of knots in a single piece, although they favor asymmetric left-opening knots (Tsareva 2009:78). They tend to be rectangular, with a general aspect ratio of 2:1, and are always almost always double-sided. They have bright, rich colors, and combine Hellenistic and Central Asian motifs, possibly suggesting ties to Parthia. They heavily feature animal decorations and asymmetric compartment compositions. Many of the Tarim fragments recovered in the early 20th century are included in this group, as are most of the Al-Sabah Collection pieces included in this study (MU-AS-1, 3-5, 7-12, 14, 16-18; see structural diagrams in Appendix B).

Scholarship on this group is preliminary, and almost exclusively published in Russian and Chinese. Eminent Russian textile scholar Elena Tsareva favors Bactria as the origin, under Kushan or Sassanid control. Her advocacy for detailed research on the group and her belief of a Bactrian origin are what provide the group its name. She prefers a Bactrian origin because many were recovered within the borders of Bactria, along the Pamir and Hindu-Kush mountains in what is now northern Afghanistan. She also points to the "Bactrian lion", a motif that appears throughout the history of the region and which features on many of the carpets (see the Yingpan carpet, Fig. 5.18). Uzbek scholar Elmira Gyul favors a Sogdian origin further northwest, pointing to the Sogdian's strategic position on the main Silk Road route, their role as the main suppliers of textiles along the route, the stylistic similarity of the carpet designs to Sogdian motifs, and a tendency towards realism more reminiscent of Turkic (Sogdian) art than Sassanian (Iranian) or Bactrian art (Gyul 2016 6-7). Both scholars believe that most if not all of the group were produced by the

same community due to their similar technological and decorative style, and then were traded around the wider region.

Most of what little is published on this group, and almost the entirety of the English-language offerings, is the collection catalogue assembled for Kuwait's Al-Sabah Collection by Friedrich Spuhler (2014). He acknowledges that these carpets do not seem to fit the fine-quality and careful craftsmanship of an urban or court carpet (2014:16), which he suggests the Pazyryk carpet must have been based on its careful symmetry and forethought (although as we have already noted, the Pazyryk carpet's symmetry is only surface-level and falls apart with closer inspection). Spuhler thinks these "Bactrian group" carpets are rough works produced by nomads or peasants, and that should be classified as utilitarian rather than art pieces (ibid.). While I agree that there is no evidence that these carpets came from a court or specialized urban workshop and that their very thick, double-sided knotting suggests concerns of water-tightness or cold, I take offense at the idea that these carpets are not fine art, or that only luxury workshops working for the elite can produce art. These carpets are vibrant, playful, joyous, and full of life, and produce a more guttural reaction than the grand Ardabil carpet, even in fragments on dusty tables in an off-site storeroom. One particularly well-preserved piece (Al-Sabah Collection inv. no. LNS 67 R a-h) is without a doubt the most incredible of the hundreds of carpets I saw in the course of this project, drawing a notable reaction even with only the border remaining (Fig. 5.21). Based on the Al Sabah fragments' find locations in the Khorasan region of northern Afghanistan and eastern Iran, Spuhler supports a Sassanid origin.



Figure 5.21: Author's Favorite Bactrian Carpet

Fragments of a carpet recovered from a cave in Samangan Province, Afghanistan.
Inv. No., al-Sabah Collection: LNS 67 R a-h. Project Carpet ID: MU-AS-15
Photo by author, courtesy of the al-Sabah Collection, Dar al-Athar al-Islamiyyah, Kuwait.

While there is little yet to say about this group as an analytical unit, they do play an important role in bridging the gap between the Iron Age and Renaissance. For many years, scholars believed that there were no examples of carpets from between the time of Pazyryk in the 4-5th cent. BCE to the appearance of carpets in Konya, Turkey around the year 1200 CE (discussed in the next section). Clearly, the many fragments from al-Tar, Dura-Europos, Shahr-i Qümis, and the Tarim Basin should fit in that gap, but perhaps they are overlooked for their very small and fragmentary nature. These "Bactrian group" carpets, coming out of the woodwork from forgotten storerooms and private collections in the last quarter century and comprising many

complete or nearly-complete pieces, are finally helping to fill the hole. It will be fascinating to see what kinds of conclusions can be drawn about the movement and development of the pile-knotting technique in the next few decades.

Apart from the "Bactrian group", some of which are late Iron Age and not Medieval, there is little other primary evidence for carpet manufacture in the Middle Ages. Carpet history therefore relies on secondary evidence in the form of descriptions and depictions to provide clues in this period. The journals of Buddhist pilgrim Xuanzang note intensive production of carpets in Kashgar on the western edge of the Tarim Basin in the 7th century CE (Bidder 1964:18-19). This and other similar records, plus the plethora of "Bactrian group" carpets and beating combs recovered in that area from the late Iron Age, may suggest that the "Bactrian group" should consider a Khotanese origin. 8th century Palestinian geographer al-Muqaddasī notes carpets in central Iraq (al-Muqaddasī 1897:107) and Israel (ibid., pg. 296). An anonymous (but likely Afghan) chronicle dated to the 9th century, the Hadud al-Alam, notes carpets made in various parts of Iran (Minorsky 1930:100, 126, 129, 137, 142), Turkey (ibid., pg. 156), Uzbekistan (ibid., pg. 112, 114), and the south Caucuses (ibid., pg. 143).

The anonymous Afghan author is particularly useful, as he differentiates between flat-weaves and pile-weaves using the kilim vs. haly distinction already discussed. The work of the other writers is less clear, and they may be referring to flat-weaves instead of pile carpets. According to these 7-9th century writers, Turkey, Iran, Azerbaijan/the south Caucuses, and a cluster of land in the Asian interior around modern Tajikistan are the primary carpet hotspots at the end of the 1st millennium CE.

Decorative floor textiles appear in many murals of the Mogao (Dunhuang) caves just outside the eastern edge of the Tarim Basin. Representing a thousand years of Buddhist art and culture, carpet murals appear regularly here with dates from the 4th-14th centuries (Zhang 2019:49). Similar murals appear at Afrasaib, a Sogdian private home under control of the Western Turkic Khaganate in the 7th century CE (Gyul 2016:3). The site would historically have been just outside Samarkand to the north, but it now sits within the city's central sprawl. Several floor textiles are shown, and similar examples appear at ancient Panjikant 50 kilometers away in Tajikistan and at Sogdian sites of similar age elsewhere (ibid.; Fig. 5.22). While it is impossible to say with certainty that these objects are knotted textiles and not some other type, the strong tradition of Tarim and Khotanese carpets, the general proximity of the "Bactrian group" find spots, and the likelihood that the fine Pazyryk carpet was woven by Achaemenid weavers in arid Central Asia suggest that carpet production continued in eastern Central Asia from the Iron Age into the 2nd millennium CE. The lack of physical remains from the late-1st to mid-2nd millennium may have more to do with political upheaval, warfare, shifting economic and production centers, or a simple preservation bias than with a lapse in Central Asian carpet production.

Carpets make a scattered appearance in the written record of Europe at this point too, suggesting that the carpet trade to that continent stretched back much further than the extant Renaissance carpets would suggest. They are referenced occasionally in Byzantine texts and the Copts were known for their pile textiles. The invasion of the Iberian Peninsula by Moorish armies likely brought weaving to that area, as indicated by our association of "Spanish" knots. *Tapis sarassinois* (Saracen carpets/rugs) are referenced in 13th century French texts discussing the

spoils of war. Eleanor of Castile arrived in London in 1255 with an assortment of household goods, including both tapestries and carpets made in her Spanish homeland (King & Sylvester 1983:11). However, while it is possible (and maybe likely) that some of these references are to knotted carpets, others may refer to flat-woven rugs or other pile techniques. The Coptic pieces, many fragments of which still survive, are woven loop.

The Renaissance

Somewhere in the hazy 1000 years between the boom in Tarim carpets and the 12th century Konya carpets, knotted-carpet technology transitions from the inconsistent, coarse, weather-proof materials already discussed into the very consistent and fine work we imagine as knotted carpets today. From about 1200 CE onward, carpets have homogenized and the total number of techniques and combinations has consolidated on a smaller core. Besides the degrading effects of time, we would not note a particular difference between a carpet woven in 1221 and one woven in 2021. Of course, technological variations remain and stylistic and artistic expression are free as they ever were. But carpets have settled on a reduced set of form factors that make them iconic and recognizable, even within their field of variation. I suspect that if you could snatch a new carpet out of 1221 and roll it out for inspection by Dr. Tsareva, Ms. Bier, or Mr. Eiland, they would not know that it was anything special. A little odd? Perhaps. Done a bit carelessly, and a bit out of touch with modern fashions? Maybe. Perhaps they would think it was made by a student, but I doubt they would see an object out-of-time. Like the looms that make them, carpets have generally plateaued. The variations seen between carpets in the last

millennium are ones of cultural attribution and fashionable style, rather than intensive technological diversification, invention, or refinement.

By this I mean that the different techniques and materials used in the last thousand years are almost always associated with socio-cultural groups and/or geographic areas. They are variations, not inventions – they do not represent a complexification or simplification of process, or a notable change in function or efficiency. They would generally be considered interchangeable, the "stylistic choice" of material cultural specialists and evolutionary archaeologists. While significant changes in technique and application are present between the historic pieces already discussed (to the point that the untrained eye might not even recognize all these objects as knotted carpets), that is not the case today. At this point, the number of variations is generally fixed, although their distributions continue to shift.

This is not to say that there is no creative experimentation happening anymore: of course there is! Innovative artists and tinkerers continue to play with the technique and push the boundaries like they always have; the Azerbaijani artist Faig Ahmed is a relatively well-known example in modern art (Fig. 5.23). However, these are fine art pieces that are intended to be original and boundary-pushing additions to galleries. They do not represent the "normal" experience of producing or owning a knotted carpet. A useful comparison can be drawn to music: the violin has changed very little in the last several centuries. The normal violinist, in the sense that people imagine a violinist, is not changing the underlying structure of the violin or the method by which it is played, even at the elite level. Instead, he expresses his skill and creativity by the combination of notes and his mastery of the movements. Similarly, carpet weaving has

generally solidified into a common core of technique and material, and the weaver shows her skill and creativity by the combination of knot colors and mastery and speed in the technological gestures.

This consolidation of technique plus the Western carpet fads that have cropped up occasionally in the last century and a half have resulted in an expansive body of literature (academic, artistic, and mercantile) on the structure of carpets, their designs, and their regional-cultural attributions since the Renaissance. This type of work is so overwhelmingly disproportionate that it is incredibly difficult to find firm information on carpets that *aren't* from the last millennium, or even the last half-millennium. Except for the repeated (and incorrect) assertion that the Pazyryk carpet is the oldest known, it would be hard for a novice to know that the technique was not invented in the late Middle Ages, or that it may originate somewhere other than Turkey or Iran. Because these newer carpets are so widely and thoroughly discussed elsewhere, an in-depth analysis of modern cultural attributions, identifying characteristics, and classification schemes of the type used by appraisers and cataloguers is not needed here. A brief survey of the major points will suffice.[14]

The gap in knotted textile history, only recently filled by the so-called "Bactrian group", was for most of the last century seen to end with a group of carpets recovered in 1905 from a mosque storeroom in Konya, central Turkey. The Alaeddin Mosque was the principal mosque during the city's time as the Seljuk capital from the 11-14th centuries CE (Erdmann 1970:44;

[14] Interested parties should see Bidder 1964; Aslanapa & Edmonds (ed) 1988; Edwards 1953; Eiland Jr. 1976, 1979; Eiland III 1993, 2004; Erdmann (ed) 1970; Helfgott 1994; Moshkova 1996; Thompson 1993; Tsareva 1984, 2016, and any of hundreds more.

Thompson 1993:67). The carpets themselves date from the middle of that period, 12-13th centuries CE. The group includes three complete carpets and five large fragments, all in relatively good condition. Although impossible to confirm, the fine quality and their presence in a major religious institution in the capital city suggest that these carpets were made in an urban, professional setting, if not a court workshop, possibly for use in this specific mosque. This group of eight pieces is generally known in the literature as the Konya carpets; it should be noted that this name is also sometimes used for carpets produced in the local decorative style, regardless of age.

The Konya group is joined by a handful of other Seljuk pieces recovered elsewhere, including three from Beyşehir, Turkey, and seven from Fustat, Egypt (Aslanapa & Edmonds 1988:13). The presence of more Seljuk carpets in Beyşehir, not even eighty kilometers from Konya, reinforces Marco Polo's observation that the region was a hub for fine carpet weaving in the 13th century (Polo 1844:206). The Arab geographer and poet Ibn Sa'id al-Maghribi makes a similar note a few decades earlier, stating that "in Aksaray are made the Turcoman carpets which are exported to all the countries of the world" (quoted in Erdmann 1970:44; Aksaray is approximately 145 kilometers from Konya). All of these Seljuk-period carpets are produced with a wrap knot similar to what we now call a Spanish knot (Aslanapa & Edmonds 1988:32). There is no reason to suspect that any of these carpets were imported, and so it is assumed that all were produced in or near the city where they were found. Of course, we should not discount the possibility that either Turkey or Egypt was the source of the entire group, considering the relatively small distance and strong trade relationship between the regions in the late Medieval

period and early Renaissance. It is also possible that the whole group or some part of it was imported from an unknown third location. This seems like an unnecessary complication to me, considering the strength of the carpet industries in Turkey and Cairo from the Seljuk period into modern day.

These seventeen Seljuk pieces, plus a few of the "Bactrian group", are the only extant carpets widely known from the first few centuries of the 2nd millennium CE. We know from other travelers that carpets were present elsewhere too, though. 14th century Moroccan traveler Ibn Battuta notes carpets in several Iranian cities, including those under control of the Turkic atabeg (Edwards 1953:2; Erdmann 1970:44; Ibn Battuta 1829:32). He also notes them along the east-central African coast (Mogadishu, ibid., pg. 56), India (including Delhi [ibid., pg. 139] and the south-western coast [ibid., pg.173, 192]), the Maldives (ibid., pg. 182), and Java (ibid., pg. 204). 13th century Abbasid writer Yaqut al-Hamawi records production in Azerbaijan (quoted in Edwards 1953:2). As in the Medieval chronicles already discussed, it is hard to say whether these writers are referring explicitly to knotted textiles, general pile textiles, or to some other class altogether. Particularly in the more far-flung regions where there has been no evidence of knotted textiles before this point (east Africa, Maldives, Java), it seems likely that the author refers to flat-woven rugs, or to an entirely separate technique that might resemble knotted pile. Tufted and embroidered pile, for instance, have a long history in Africa and produce a similar effect to knotted and woven pile, including the reasonably well-known Kuba cloth embroideries. India, although it does not itself have direct evidence for carpets in the Bronze or Iron Ages, has a well-documented history of trade, migration, and linguistic transfer with Central Asia, the

Iranian Plateau, and the Arabian peninsula, where early knotted fragments likely produced in India were discovered (Cohen 2026). We might therefore accept the possibility that carpet technology arrived in India during or before the Medieval period, as the chroniclers suggest.

These notes present an interesting map of carpet production in the late Medieval and early Renaissance periods, and perhaps an even more notable map of where carpet production *wasn't*. No written evidence appears for more northerly Central Asian carpets, and little for western Chinese ones. Kashgar, on the west edge of the Tarim Basin, is the only site mentioned in modern China. Both the northern steppe and the east Tarim Basin definitely had pile and knotted textiles by the Iron Age, suggesting either that the chroniclers did not produce an exhaustive record, or that the earlier pieces identified in those places were not a local product. Incompleteness in records seems more likely to me: Xuanzang (the 7th century Buddhist pilgrim) notes production in Kashgar, but Marco Polo does not. While these two men lived more than four hundred years apart, it seems unlikely that a city producing carpets in notable quantities both before and after the 13th century boarded up its workshops only when Polo was passing through. The deep antiquity of the Beauty of Loulan and other early pile fragments would seem to discount the idea that the Iron Age finds were imported rather than locally made, at least for Xinjiang (the origin of the north steppe finds at Pazyryk and Bashadar is very much up for debate). We are therefore still faced with the impossibility of fully understanding where carpet technology originated, to and from whom it spread, and if it was innovated multiple times by separate groups. As in the Bronze and Iron Ages, carpet technology seems to wax and wane in many

regions contemporaneously, with no distinct hub disseminating outwards, and no clear priority in date or technical skill.

Fortunately, the picture becomes much clearer once the Seljuk Konya carpets are woven in the late Medieval-early Renaissance. Increased production, improved preservation, and more detailed and reliable written records paint a picture of intensive elite carpet production through the Renaissance, both for use in the carpets' homeland(s) and in the far reaches of the withering Silk Roads. We assume that non-elite production intensified at this time too (Helfgott 1994:25): unfortunately, the increased wear-and-tear and relatively lower economic value of village and domestic carpets mean that few survive, and we are left to focus instead on luxury pieces preserved in palaces and mosques as heirlooms and state treasures. Village or "tribal" carpets do not appear in notable quantities until the 19th century, and are not popular or widespread outside of the originating villages for another century after that.

The Konya, Beyşehir, and Fustat carpets tell us that there was a substantial industry of fine carpets in the Seljuk period. The notes of the earlier chroniclers indicate that the Seljuks did not bring carpet-production to Turkey when they arrived in the 11th century: it was already present (Edwards 1953:2). It is possible that Turkey is one of the independent innovation centers, or that their industry arrived in an earlier wave of immigration or conquest by the Turks, Persians, or other groups. Other than the physical remains of the Seljuk carpets, there is little other information about the weaving industry at that time, and it seems that whatever industry existed in Anatolia, Persia, and Mesopotamia suffered badly under the Mongol conquest in the 13th century (ibid., pg. 3).

Following this miniature "Dark Age" under the Mongols, consistent reference to carpets, interest in a substantive industry, and notable extant pieces do not reemerge until the relative calm of Timurids a century and a half later. While Timur (born c. 1336) himself shows no direct interest in carpets or carpet-weaving while ruling, his son Shah Rukh (b. 1377) sponsors state carpet workshops in his subsequent reign (ibid.). Rukh's 3x great-nephew and Timur's 3x great-grandson, Babur (b. 1483), establishes the Mughal empire in India the following century. In the reign of Babur's pro-arts grandson Akbar (b. 1542), weavers from the Timurid homeland in Uzbekistan were brought to perform the first (to date) confirmed carpet production in India (Bier 1996:75). Unfortunately, only a small fragment survives from Timurid Central Asia itself, held now in the Benaki Museum in Athens (inv. no. 16147) (Fig. 5.24).

The so called "golden ages" which flourished first in Central Asia under the Timurids and then in India under the Mughals both prioritized art and science in a state making the most of conquest wealth. Carpets, like many other skilled crafts, were emphasized and elaborated upon, and carpet ubiquity and quality is evident in miniature paintings of the period (Briggs 1940:20). In fact, not a single surviving Mughal carpet is *not* a luxury court piece (ibid., pg. 78); they have a standard density of more than 50 knots/cm^2, which would be considered a high-quality piece even today. The Mughals also produce the first surviving silk carpets, one example of which achieves an incredible density of more than 390 k/cm^2 (Metropolitan Museum of Art, inv. no. 14.40.722, 1630-1640 CE) (Fig. 5.25)! It seems likely that a similar flourishing in carpets may have occurred in the Islamic "golden age" of c. 800-1260 CE under the Abbasid Caliphate, who

controlled much of the southwestern Eurasian carpet zone: without direct evidence however, this cannot be confirmed.





Figure 5.24: Timurid Carpets

Left: Only known extant fragment of a Timurid carpet, 14-15th cent. CE, Uzbekistan or Iran. Image courtesy of the Benaki Museum of Islamic Art, Athens

Right: A silk carpet produced at the Silk Carpet Workshop in Khiva, Uzbekistan, using the Benaki fragment's design. This is one of many designs re-created by the workshop weavers & designers based on Timurid, Mughal, and Persian miniatures, carvings, and other media. Photo © Christopher Aslan Alexander

During the early Renaissance, a near-constant stream of Turkic people were entering Iran under the Seljuks, Mongols, and Timurids. While the physical evidence of Magtymguly, al-Tar, Dura-Europos, and Shahr-i Qümis tell us that carpet technology was already present in and around the Iranian Plateau before the Seljuk conquests, the influx of Central Asians in the first half of the 2nd mill. CE may still have contributed to the proliferation of the carpet industry in that area (Helfgott 1994:33). The substantial industry mentioned in Kashgar and western Uzbekistan by the chroniclers, the role of the Central Asian Sogdians as the primary textile merchants along the Silk Roads, and the strong ties between the "Bactrian group" carpets and the Khotanese empire suggest a robust carpet industry there unlike anything linked to Persia at the same period – whether the Khotanese/Sogdians learned their craft from Tarim or Mesopotamian populations or derived it themselves is immaterial. Regardless of where they got it from, it seems likely that the influence of the Turkic immigrants contributed significantly to the establishment of knotted carpets as a cornerstone of Persian material culture, even if a more rudimentary version predated their arrival.

Despite what was probably a notable carpet industry from at least the beginning of the millennium, the earliest extant Persian carpets date to the 16th century (Briggs 1940:20; Eiland Jr. 1976:5; Erdmann 1970:168). This is the Safavid period, when Persia returned to native rule after centuries of Turkic influence and control. The carpet industry booms under the new regime, and centralized court workshops are established under Shah Abbas (b. 1571) in Isfahan. Artisans from other fields, such as wood-carving and tilework, were hired to produce new carpet designs. The Shah is said to have even tried his hand at drawing cartoons himself (Edwards 1953:4, Erdmann

1970:187)! It is at this time that the traditional, blocky, geometric designs that could be worked from memory with a basic grasp of mathematics are replaced by more elaborate, natural, and curvilinear designs that rely on a drawn reference (ibid.; Bier 1996:75). These designs, now collectively known as arabesques, are associated with Persian-produced carpets to this day. Safavid carpets usually use asymmetric knots, which are widely believed to be more square and to pack together more tightly than symmetric knots, which allows for finer control over curves and complex shapes (Bier 1996:75).

The Safavid carpet boom, like the smaller booms of the Timurids and Mughals, left behind only court/luxury pieces. However, we have moved past the age of having only single samples and disparate evidence: as many as 2,000 Safavid carpets are extant, including many complete and nearly-complete pieces (Edwards 1953:7). A few Safavid carpets are included in this study (MU-AS-13, MU-SO-4, MU-VA-2). A small selection of Safavid carpets are even 'signed', where the date and/or place of manufacture is integrated into the knotted design (Erdmann 1970:168). This practice continues today, and a luxury silk carpet, like those woven in Uzbekistan and included in this study, will often include integrated provenance information.

The "great period" of Iranian carpet production lasts for the duration of the Safavid empire, but ends when repeated incursions from the Ottomans from the west, the Russians from the north, and the Afghans from the east eventually topple the state in the early 1700's (Edwards 1953:5; Seager 1964:120). Workshops close, economies shift, weavers retrain in other professions, and Iran's carpet industry would not return to global prominence until the late 19th century (Edwards 1953:6; Erdmann 1970:27).

At a similar time that the Persians were experiencing their carpet boom, the Ottomans oversaw a similar explosion in Anatolia, Egypt, the Caucuses, and the Near East. As under the Timurids, Mughals, and Safavids, the expanding Ottoman state had the resources and cultural interest to support skilled craftspeople. Building on the carpet-weaving centers that already existed in the area, Ottoman weavers produced fine carpets on-par with what was produced under the Safavids. Like in Persia, only high-quality and court carpets survive from the 12-18th century Ottoman empire, but the quantity of extant pieces explodes compared to what was available before this time. Several are included in this study (MU-DY-1, MU-SO-1, MU-SO-3, MU-VA-1), and an example or two can be found in most major art museums. the designs certainly diversify here like they do in Persia, the forms generally remain slightly stylized and geometric. Most Ottoman carpets use symmetric knots, reinforcing their ties to Anatolia (symmetric knots are still sometimes called “Turkish knots”). The master weavers of Ottoman Cairo are a notable departure from those of Anatolia: Cairene carpets are characterized by asymmetric knots that are nearly if not perfectly square. This means that Cairene carpets of this period have equal vertical vs. horizontal density, an impressive feat even among modern weavers (Bier 1996:70). This allowed the Egyptian masters to produce very balanced and precise designs, and in turn increased their value and prestige.

The boom carpets, particularly those of the Ottoman empire, drew increased attention from the royalty of Europe. The 14-17th centuries could be considered the first of three major fads for carpets in Europe and the wider west. By the 15th century, they start to appear in formal portraiture and fine paintings (Bidder 1964:26; Eiland Jr. 1976:4; Erdmann 1970:27; King &

Sylvester 1983:14; Helfgott 1994:14; Spooner 1986:215; Thompson 1993:33). They become so ubiquitous in European art that the designs used in Turkish/Persian carpets of this period are often named after the European artists who depicted them, rather than by a Turkish/Persian or descriptive name (Fig. 5.26a-d). This is particularly the fate of Turkish carpets, which were considerably more popular in Europe due to proximity (King & Sylvester 1983:17). These include Lotto, Holbein, Memling, Crivelli, Bellini, and Ghirlandaio carpet types, although Lotto and Holbein are the two names most used today (Bier 1996:74). This tendency to name designs after European associations rather than their traditional name or place of origin has resulted in a few confusing misattributions. Of course, Lotto, Holbein, and the rest had no relationship at all to the manufacture of the carpets they painted, and association with those names should not be interpreted as correlation of date, nationality, or culture to the artist. Other misleading associations exist too. The "Transylvanian" carpets were produced in Turkey, not Transylvania, and draw their name from the popularity the design style enjoyed in the Balkans (Bier 1996:74). The "Polonaise" carpets were produced intentionally for a Polish market and in a Polish decorative style, but were made in Safavid Iran by Persian weavers (Edwards 1953:8). Neither Transylvanian nor Polonaise carpets even necessarily transited their eponymous countries.

A notable portion of the extant Renaissance carpets are those that came through Europe. Gifts to ambassadors and distant rulers, private purchases by stately families and class-hopping merchants, even as the spoils of war, it is likely that tens of thousands of Asian carpets entered Europe in this period. This is both a blessing and curse for carpet research. The extreme cost to import carpets to Europe and their position as an exotic status symbol placed them firmly in the

category of antiquities and heirlooms. This meant that they were passed on and cared for a bit more generously than their counterparts in Asia, where a worn-out carpet was more easily discarded and replaced. Their popularity and status also drove their inclusion in paintings, which, like the Persian and Mughal miniatures of a similar period, allow us to study designs, color schemes, and contemporary uses in the household.

Unfortunately, a lack of reliable record-keeping means that it is not clear when, where, or from whom individual carpets were acquired. As already discussed, carpet weaving generally plateaued by the Renaissance, so changes in technology can't be used to establish conclusive timestamps. Where records do exist, they are often vague or dubious, and many inventories source the carpets to Venice, Genoa, or other major European ports of entry rather than to their actual location of manufacture. The household inventory assembled in 1547 by the staff of Henry VIII following their lord's death is a sobering example. It is the largest and most detailed inventory of the any English king's holdings and includes more than 800 carpets. His immense collection, unusually large even for a king, may have contributed to the popularity of carpets in England and across European royalty (Thompson 1993:33). Many of these carpets are attributed to "beyond-sea making" (King 2012:133), which is less than helpful. A recent study of the collection identified that 13 carpets attributed to Venice are actually Cairene. Up to 400 carpets listed from Turkey should be better described as Ottoman, and may have originated in any part of that empire (ibid., pg. 138; Thompson 1993:34). At the time, the Ottomans controlled both Cairo and the Caucuses, where substantial carpet-production was taking place. To call this entire group Turkish is probably both reductive and inaccurate.

This is complicated further by a burgeoning European carpet industry (trying to profit on the valuable trade in Asian carpets). The "Sun King" Louis XIV granted a royal monopoly to a recently-opened, Levantine-founded carpet factory outside Paris in 1627. This company, the Savonnerie, produced carpets in the French decorative style using Asian techniques (Thompson 1993:23). Axminster, the famous British manufacturer, opened its doors on a similar business model a century later in 1755. While neither of these iconic carpet houses had yet been founded when Henry VIII died in 1527, they were a continuation of smaller-scale production that already existed in his lifetime, with Italy being the hub of European-manufacture at the time. This means that when his inventory says that certain carpets are French, English, or Italian, we cannot assume they were only imported through those countries: some may really have been produced in Italy, France, or England (Helfgott 1994:14; King 2012:135). As many of these carpets are now lost and few are recorded in drawings, it will probably never be possible to clarify which are which. To top things off, it seems that some objects described in the inventory as 'carpets' are actually rugs, embroideries, or even sheets of velvet! The same linguistic imprecision that confuses modern carpet studies is equally prevalent in Tudor England.

Renaissance carpets are today provenanced mainly by two factors: knot shape and design. The common use of symmetric knots in Turkey and asymmetric knots in Iran provides a quick way to divide carpets. While it would be incorrect to say that there is no correlation between knot type and location, it would also be incorrect to view that relationship as an absolute one. There are examples of Turkish-made asymmetric knots, and Iranian-made symmetric ones: the Egyptian-Ottoman Cairene masters weaving with asymmetric knots are an

excellent counterpoint, as are the Turkic Seljuks using “Spanish” wrap knots. This system also glosses over other carpet centers in Egypt, the Caucuses, the Near East, Central Asia, and Xinjiang.

Carpet patterns are the second main method for determining origin, matching similar motifs and styles to carpets with known provenance, written descriptions, or painted depictions. This method is risky for similar reasons. It is particularly worth noting that the demand for European carpets seems to have slightly shifted the designs used in the Renaissance, causing some more traditional designs to go extinct or be orphaned while the designs popular in Europe took over (Erdmann 1970:27). Similarly, this system of tracking origin based on the design of surviving pieces and comparative media necessarily relies on there being both surviving pieces and comparative media: weaving communities who had less global trade and fewer extant works have less to go on, and less popular designs may be invisible in comparative media.

Of course, there are some Renaissance carpets whose origins are well-established. King Sigismund III Vasa of Poland (b. 1587) took a personal interest in carpet production and sent a delegation to Safavid Iran to commission carpets featuring his coat of arms for Wawel Castle in Krakow in 1601. His representatives not only placed the order but remained on-site to document the production process: this group are the only surviving Renaissance carpets whose individual manufacture is documented (Edwards 1953:8). Less than a century later, Poland-Lithuania’s decisive defeat of the Ottomans at the Battle of Vienna (1683) added carpets, grand war tents, armaments, and other items to the national collection, now housed in the Wawel Royal Castle Collection (Erdmann 1970:92). Those carpets, even when sold in the interim, can generally be traced to their source. The enormous Ardabil carpet, one of the most famous knotted carpets in

the world and now held in the Victoria & Albert Museum in London, has a knotted inscription dating it to A.H. 946 (1539-40 CE).[15] This makes it possibly the earliest dated Iranian carpet known (Beattie 1986). Wonderfully, the inscription also gives the name of the weaver and a location: Maksoud, Kashan. While it is unclear if Kashan is the carpet's place of manufacture or a reference to Maksoud's individual origin (e.g., woven by Maksoud *of* Kashan or woven by Maksoud *in* Kashan), the inscription plus the technique and design are enough to place the carpet firmly within 16th century Safavid Iran.

Despite the problems of provenance, the vastly expanded carpet sample in the Renaissance allows for more robust conclusions to be drawn. This has been particularly useful for studies of design and motifs, but technological and cultural research is also possible. An interesting observation by museum staff in the 20th century noted that five carpets held in major collections (the Museum of Islamic Art in Berlin, the Victoria & Albert Museum in London, the Musée Jacquemart-André in Paris, the Metropolitan Museum of Art in New York, and the Museum of Applied Arts in Budapest) all appear to have been worked from the same unique cartoon before being sold independently (Fig. 5.27). This is the first physical evidence of a cartoon being used repeatedly as a method for multiple or mass manufacture (Erdmann 1970:187).

Although the vast majority of Renaissance and early modern carpets are from either Turkey or Iran, other areas were known production centers too. Europe itself has two centers of

[15] The Ardabil Carpet was acquired by the V&A in pieces in the 19th century. Their restoration team tried to re-assemble the original, creating a Frankenstein piece which left out some large fragments. These extra pieces were purchased by American industrialist J.P. Getty, who had them re-assembled into a second Ardabil Carpet now held in the Los Angeles County Museum of Art.



Figure 5.27: Cartoons for Mass Production

The earliest known example of a workshop reusing an identical pattern for multiple- or mass-manufacture.

A: Ottoman carpet, Cairo, 1600-1650 CE. Inv. no., Museum of Islamic Art: I. 6355.
Image © State Museums of Berlin, Museum of Islamic Art / Christian Krug.

B: Ottoman carpet, Turkey, 1500-1600 CE. Inv. no., Victoria & Albert Museum: 491-1899.
Image © Victoria & Albert Museum, London.

C: Ottoman carpet, Cairo, 1550-1600 CE. Inv. no., Museum of Applied Arts: 14800.
Image © Museum of Applied Arts, Budapest.

D: Ottoman carpet, Cairo, c. 1550 CE. Inv. no., Metropolitan Museum of Art: 1971.263.2.
Image courtesy of The Metropolitan Museum of Art, New York; Gift of Joseph V. McMullan, 1971.

what might be called “traditional” knotted carpet production, wherein the pieces were woven as a native cultural product rather than as an intentional imitation of a popular foreign good (as was the case in France, England, and Italy). Moorish weavers established an industry in Spain and produced some of the oldest surviving Renaissance carpets, dating to the 15th century. Spanish carpets are distinct from their Asian counterparts due to their use of a style of wrap knots now commonly known as the Spanish knot (Bier 1996:70). Scandinavian weavers, particularly in Norway and Sweden, were producing a similar product known as a *rya*. When complete, a rya is not readily distinguishable from a knotted carpet but they are produced a different way. Instead of tying the knots during the weaving process, a rya’s knots are “embroidered” on the finished weft base after weaving is complete. The ultimate result is the same. Rya pile is usually left long, like the kaunakes pieces already discussed. The origin of rya is unknown: it could be an independent Scandinavian invention, a technique transmitted from another group possibly across the northern steppe or riverine contact between Vikings and the Near East, or an attempt to copy pile textiles made elsewhere. They are known from the 15th century CE, and likely predate that time (Geijer 1963:79).

A few Renaissance carpets survive from Central Asia, primarily associated with Turkmen whose identity was coalescing into the ethnicity we know now under the Oghuz and Seljuk conquests (Tsareva 2016:20). While their modern ethnic group took shape, so too does the now-iconic character of their carpets. Following the devastation of the Mongol conquests, the Turkmen were faced with an ever-shifting set of foreign and local overlords and loyalties, including the Timurids, Safavids, Khanate of Bukhara, Khanate of Khiva, and ultimately tsarist

Russia and the Soviet Union. Despite this upheaval, three distinct centers of carpet weaving emerge, likely influenced and supported at least partially by the imperial carpet booms happening elsewhere and the power of the Silk Roads' final years. These regions were in the Aralo-Caspian are of the Central Asian Southern Desert in the western part of modern Turkmenistan and Uzbekistan, the middle Amu Darya along the central border between those two countries, and in the southern part of Turkmenistan around the Merv (Mary) oasis (ibid., pg. 21). Merv itself had been a major regional trade power before it was devastated by the Mongols in 1221: some contend that it was the world's largest city in the 12-13th centuries, home to 500,000 to 1 million people (Eiland III 2004:255). Capital of the carpet-producing Seljuk empire for part of the 12th century and believed to have knotted textiles by the late Bronze Age, it is likely that the Turkic-Iranic populations of this area had been producing knotted carpets for a considerable period before the Renaissance. Indeed, contact between Central Asian and Persian weavers is so significant in the late Middle Ages and early Renaissance that Central Asian languages call their carpet motifs *guls* to this day, deriving from the Persian word گل (gul), meaning flower (Spooner 1986:212).

Unfortunately, there is little direct evidence through the 1st mill. CE and the oldest extant Turkmen carpets date only to the 15-16th centuries (ibid., pg. 21). Early Turkmen carpets face a similar attribution problem as many of those passed through Europe. For example, Bukhara carpets (a popular historic and modern attribution) were only traded through Bukhara in Uzbekistan: they were woven by Turkmen, likely in the Merv oasis some 320 kilometers southwest based on comparison to 19-21st century weaving styles in surrounding areas (Aslanapa

& Edmonds 1988:207; Seager 1964:122; Spooner 1986:197). But all is not lost! Although early chroniclers do not mention carpet production in the southern part of Central Asia that is the Turkmen homeland (Moshkova 1996:9), they do repeatedly describe the Turcomans of Turcomania. Many scholars, in both English and Russian, seem to interpret these terms as referring to the modern concepts of Turkmen ethnicity and Turkestan, e.g., Central Asia, but this is not the case. The early notes on Turcoman carpets are all referring to the work of Turkic weavers in modern Turkey (see a brief summary of Turcomania and its people in Polo 1844:206).[16] However, as Anatolia had only recently been conquered by the Seljuks, an Oghuz Turkic empire originating south of the Aral Sea in modern Uzbekistan, Kazakhstan, and Turkmenistan and from whom the modern Turkmen ethnicity is derived, we might consider the chronicles to be records of Turkmen weaving, to the extent that it existed at the time. Turkmen carpets tend to have a medium-high density of 39+ knots/cm^2, consistently surpassing those of the earlier but approximately co-located "Bactrian group" and the nearby Caucuses, but generally less fine than the court products of empirical Iran, Turkey, or India (Bier 1996:75).

The primary evidence for Renaissance carpet production in the north steppe zone of Central Asia and in western China/Xinjiang is limited to a few scattered carpets, most of which are held in private collections and not well-studied. Although the presence of knotted textiles in these regions in preceding centuries make it likely that some were being produced at this point, little can be said about them or their production as a cohesive group.

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[16] To avoid confusion, I use spellings with '*c*' to indicate the historic groups of invading Oghuz Turks in Anatolia. Spellings with a '*k*' indicate the modern concept of the Turkmen ethnic group, and the areas in and around modern Turkmenistan that make up the modern geopolitical region of Central Asia.

After the notable production levels represented by Stein's late Iron Age finds and the "Bactrian group" of the Middle Ages, carpet production does not pick up again in/around Xinjiang until the Qing Dynasty (1641-1911), when extant Khotanese carpets reappear in the historic record (Bier 1996:51). These late Renaissance/early modern carpets sourced their wool from trade with Kyrgyz pastoralists transiting the Tian Shan mountains (Bidder 1964:37). Written records, primarily Chinese and often associated with the imperial government, suggest that weaving was a predominantly male profession at this time in Khotan, although we should be wary of assuming that a foreign writer would necessarily have been witness to domestic labor. Both horizontal and vertical looms were used, with vertical looms producing better-quality carpets but horizontal looms producing larger ones (ibid., pg. 40). A record from the turn of the 19th century provides extra detail, stating that carpets produced in Lop county (just east of the Khotan oasis) used wool warp and cotton weft, as well as more luxurious carpets of entirely silk (ibid., pg. 26). By the mid-1800's, at least 200 carpet masters are recorded in Khotan.

Beyond a few scattered references to individual purchases by Chinese soldiers garrisoned in Xinjiang during the Han dynasty (202 BCE – 220 CE), there is no evidence to suggest that carpets were a common import among the imperial Chinese. There is similarly no evidence that carpets were ever given as tribute or tax to eastern overlords (Bidder 1964:22; Bier 1996:79). Even wool weaving is not explicitly mentioned before the Ming dynasty, when a brief (and somewhat disdainful) description of wool fiber processing and loom weaving is given by writer Sung Yingxing in his 1637 encyclopedia Tiangong Kaiwu (天工開物 or *The Exploitation of the Works of Nature*) (Sung 1997:69-70; Bidder 1964:29). After 30 pages describing, with fine detail and excellent

drawings, the process of silk cloth production, wool-weaving is described in one page as having been brought to west China by “barbarians”, that all woolly-sheep products are coarse and used exclusively by the poor, and that no Chinese take part in the work. The *ch’ü-yü* carpets, which may refer to knotted pile as they are set in contrast to rugs, are mentioned but not described in production or product at all (Sung 1997:70). This association of carpets and wool textiles with “barbarians” and western China reinforce the writing of provincial gazetteers of the subsequent period. These Qing records include product lists using Turkic and Mongolic words for various textile classes, suggesting foreign imports or works by non-Chinese weavers on the western fringes of the empire, and a cultural othering of wool textiles in eastern China in the late Renaissance/early modern period (Bier 1996:80).

This is not to say that no one in eastern China was interested in carpets. Like Sigismund III Vasa in Poland-Lithuania and Akbar among the Mughals, Chinese emperor Qianlong (b. 1711) took a personal interest in carpets in the late Renaissance/early modern period. The source of his interest is not clear: some suggest that he was exposed to carpets when trying to furnish accommodations for a new consort, a princess from Kashgar. In sourcing Turkic items and art to make his new bride feel at home in the palace, he develops a personal affinity for her people’s fine carpets (Bidder 1964:25). This likely-mythical story may draw from legends of the “Fragrant Concubine” (香妃), who in turn may be based on the real life of empirical consort Rong (容妃) (b. 1734). Rong was a Muslim Uyghur (Turkic) woman from the Ili river valley in Xinjiang, situated between the Tarim and Zhunge’er Basins near the modern Kazakh border. Despite Qianlong’s

interest, there is limited carpet-weaving in eastern China and the industry remains esoteric into the 19th century (Bidder 1964:29).

The Modern Period

Following the empirical carpet booms of the Seljuks, Timurids, Ottomans, Safavids, and Mughals, carpet production wanes in the early modern period (c. 1750 onwards) (Edwards 1953:5; Erdmann 1970:27; Helfgott 1994:14). Carpets are still produced and many are still extant, but the overall volume and quality diminishes (Tsareva 1984:21). Dynastic collapse, warfare, invasion, and civil war in these regions lead to a mass decline in workshops, refocusing the industry on domestic, village, and tribal weavers (Helfgott 1994:14). Great golden age works, like the Ardabil and Konya carpets, are rolled away in storerooms, sold off to raise money, or left to disintegrate. The collections of Europe similarly get packed away or forgotten in grand houses and museums. The carpet industry doesn't regain global momentum until the late 19th century, when an exhibition at the 1873 World's Fair in Vienna brought Asian carpets suddenly back into the European public consciousness (Helfgott 1994:15).

The transition from luxury furnishing for the elite to global commodity for the middle classes is almost instantaneous. Boastful stories and purchases from the World's Fair couple with Victorian Orientalism, the growing middle class, the burgeoning concept of the department store, a growing fad for handmade and artisanal goods among the industrial output of factories, and an American and Canadian upper class desperate to be seen as cultured and well-traveled caused a sudden and immense uptick in carpet demand (Thompson 1993:35). The Axminster company,

which had been established in England a century earlier but was crippled by a disastrous fire in 1828, is suddenly overrun with new orders. The famed father of the Arts & Crafts movement, William Morris, sees an opportunity and sets up a new carpet workshop to compete with Axminster and Asian imports in Hammersmith, west London, in 1879 (ibid., pg. 38): the influence of Persian scrollwork and arabesques on his designs (both in carpets and other media) is evident. This sudden European and North American demand for exotic carpets funded the establishment of many new professional workshops in Iran, Turkey, and the Caucuses, where the existing domestic and cottage industry that had survived the 18th century collapse could not keep up (ibid.). The Victorian carpet boom particularly favored these regions, likely due to distance and diplomatic relationships with Europe (Bier 1996:66). The other carpet regions in Central Asia, west China, and India do not reach nearly the same level of Western popularity. The late Victorian era likely saw the all-time peak in global handwoven carpet production, and the vast majority of extant Asian carpets date to 1860-1920 (Bier 1996:66, 70). It is likely because of the Victorian boom that so many English-speakers use the terms "Persian" or "Oriental" carpet as generics today.

Other than to reinvigorate carpet production generally, a notable outcome of this global carpet boom is the rise of a truly Chinese carpet industry. Although some limited weaving had taken place since the 17th century, almost if not exclusively for court use, it becomes a more substantial public industry in the late 19th (Bidder 1964:29). Production is focused in the north, particularly around Ningxia and Beijing (Bier 1996:78; Eiland Jr. 1979:3; Zhang 2019:51). Lacking a historic or cultural *raison d'être* for specific technologies, Chinese carpets are distinct for their

hodge-podge technique. They often use multiple knot types in the same piece, apparently to improve fidelity of designs and/or to speed production (Bier 1996:79). There are any number of explanations for this, from an attempt to reproduce symmetric or balanced designs, to speed production by using simpler knots, to force patterns to fit in spaces not appropriately sized for them by using extra/fewer warps than a knot normally calls for, or simply due to a lack of investment in the knotted consistency or an openness to experimentation. Other aspects are inconsistent too, with both single- and double-warping, wrap and woven bindings, and different numbers of picks all being common (see Bier 1996, Eiland Jr. 1979). While similar inconsistency appears in Iron Age and Medieval carpets elsewhere in the continent, those regions are practicing internal consistency by the early Renaissance.[17] Ningxia carpets are also often "carved", where the pile of different design elements is trimmed to different lengths to create texture and depth (Bier 1996:78). The quality of Chinese carpets is generally low, often less than 10 knots/cm^2 (Eiland Jr. 1979:14). Their pile is also often on the long side, 1-2cm (compared to <5mm in Central Asia, Iran, and Turkey). Despite their long history of sericulture, silk carpets are rare even among modern Chinese hand-weavers. A few Chinese carpets are included in this study (MU-CH-5:7).

The sheer number of Victorian carpets allows for more analysis and comparison of technique and design than ever before, and collectors and merchants start to build an encyclopedic body of literature with extensive classification schemes on origins, colors, ethnic

[17] A notable exception can be found among Turkmen weavers, who frequently use asymmetric knots in the body of a carpet but symmetric knots up the vertical sides. This is done to strengthen the edges and even out the natural sideways list of the asymmetric knot, creating a neater edge. See carpets TK-MA-1:9 in this study, and Moshkova 1996.

and tribal attributions, symbolism, and value based on information provided by the Asian dealers. Unfortunately, with no way for consumers to fact-check the dealers an ocean away, these schemes do not, for the most part, appear to be based on fact (Thompson 1993:44). Like in the Renaissance, mistakes of attribution are common and even preferred. Carpets are attributed to their port of exit or place of purchase, not their actual geographic origin (ibid., pg. 34). Designs believed to be the exclusive output of one group are actually copies made by another group to corner the market (Baker 1995:370). Motifs and symbols, which probably once had a symbolic or cultural meaning, are re-combined and reimagined in meaningless ways by unrelated groups to feed the Western hunger for the unknown and exotic (Spooner 1986:209). This phenomenon mirrors the meaningless strings of non-Latin characters used in modern Western clothing and tattoos. Origin is decided based on quality, as Victorian sensibilities made it difficult for Western buyers to accept that a fine-quality carpet could have been made by savage, untamed nomads: high-quality work had to be from a city, and low-quality work had to be nomadic and therefore less valuable (Baker 1997:363). Romantic (and largely imagined) classification schemes are still the de-facto system used in carpet authentication, valuation, and study today. Even more concerningly, attributions linked to 19th century regions and weavers are often cast backward onto earlier works, as if the Victoria and subsequent 20th century systems are grounded in timeless fact.

To make matters worse, the ubiquity of Victorian carpets eventually devalued them and clouded their provenances further. Fringes, tassels, selvedges, and other technologically and culturally diagnostic features were often cut off before shipping to make the packages lighter and

therefore cheaper (Thompson 1993:40). Unwanted or out-of-style carpets were cut up for handbags, coats, and upholstery, and larger works were cut down to fit wall-to-wall in bedrooms and parlors (coincidentally, this practice is likely why modern English associates “carpet” with a fitted and immobile floor textile) (ibid.).

Like any fashion, tastes changed and the Western fad for Asian carpets fades with the onset of World War I (Tsareva 1984:21). Western-supported workshops in Turkey, Iran, and the Caucuses close their doors, and domestic and cottage weavers dominate the industry again. Central Asian weavers are hit particularly hard, as traditionally nomadic and pastoral groups are forced to settle under Soviet rule in this same period (ibid.). This puts additional strain on traditional social organization, trade networks and economies, class and gender divides, etc. Part of this social-restructuring was the disbandment of traditional guilds, unions, and artisan networks (Fitz-Gibbon 2004:129). This in turn destroyed centuries of quality-control systems, artisan education schemes, and valuation and pricing rubrics (ibid.). Manufacture is instead re-focused in state workshops, primarily for export to Russian buyers (Hodjamukhamedov & Dovadov 1982:7). This restructuring regime forced together different technological traditions that did not overlap in the traditional mobile lifeways. Some traditions did not survive the merge, and many aspects that used to be useful markers of cultural identity or location were overwritten or redefined (ibid.). It is at this point that vertical looms start to appear consistently and definitively in Central Asian workshops: believed to be better for the weavers’ backs and therefore conducive to longer and more structured working days, the looms reflect the new emphasis on controlled output and a sedentary lifestyle (ibid.; Moshkova 1996: footnote 104).

The modern classification system for Central Asian carpets, mostly those woven by the prolific Turkmen, is now based on tribal affiliation and oasis geography of the early-mid 20th century (Tsareva 2016:15). More representative of the pro-tribalist attitudes encouraged by the Soviets to keep the population focused on local and tribal dissent instead of regional and national dissent, it would be a mistake to date these technological and aesthetic links to a deep tradition or ancient identity (Eiland III 1993:860; Fitz-Gibbon 2004:130).

Despite the collapse of the Victorian (or really, Victorian-Edwardian) carpet bubble in the early part of the century, the expanding global middle class and the ever-improving global trade network meant that Iran maintained a reduced but respectable cottage industry well into 20th century (Helfgott 1994:11). In fact, aside from petroleum products, carpets were Iran's largest export for the first half of the century (ibid.). It remained a proportionally substantive industry until petroleum value reached a critical level in the 1970s, and weavers were disincentivized to continue their craft (Spooner 1986:216). Although not given the same death blow by oil, the industries in Turkey and the Caucuses followed a similar pattern, retaining a respectable if vastly reduced cottage industry throughout the century.

Possibly due to increased exposure to Iranian art and culture through current events or maybe a simple fluke of the fashion zeitgeist, Asian carpets see another spike in popularity across the West in the 1960's-80's (Eiland III 1993:860; Tsareva 1984:5). The historic precedent favoring finely-woven court, urban, and/or professional pieces is replaced with a fanaticism for pieces that are perceived as rugged, honest, and romantically nomadic (Spooner 1986:202). Being able to trace your carpet to its unfamiliar tribe in an unknown rocky corner of Khorasan or Central Asia

was a major part of the value of these so-called tribal carpets, and ones sourced from tidy, respectable city merchants were looked down upon as "inauthentic" (see Spooner 1986 and Baker 1997 for particularly thorough, and scathing, reviews of this trend). There are even examples of tribes being entirely made up by carpet merchants to push a sale (Eiland III 1993:862)! This movement spread beyond the traditional market centers in Iran and Turkey, sweeping up weavers in Central Asia, the Caucuses, China, and India too (Tsareva 1984:5).

Unfortunately, this new emphasis on domestic and cottage weaving did not correct the long-standing problems of attribution or provenance (Eiland III 1993:862). Wanting an authentic, traditional, and handmade experience in their carpet, buyers expected hand-spun yarns, natural dyes, mobile ground looms, and remote nomadic production, without accepting the corresponding limitations (Spooner 1986:202). Synthetic aniline dyes had been standard in carpets and other textiles for a full century at this point and a lot of the traditional natural dye knowledge was long forgotten (Baker 1997:367). Even when natural dyes were available, the high labor cost to collect and prepare the dyestuffs was not well accounted for in the carpet price, nor was the poor water- and lightfastness of natural dyes well-explained to Western buyers (ibid., pg. 369). Although some weavers certainly did still work on horizontal looms, they were getting progressively bigger, and therefore less mobile (Moshkova 1996:57) – more a technological relic than efficient necessity steeped in meaningful nomadic history.

To make matters worse, there just weren't that many people left living in traditional nomadic or pastoral communities, even fewer of whom were still weaving bulky, time-consuming, and economically impractical carpets by hand. Identifying and visiting these remote,

pre-digital people at the right intervals to generate an export surplus was not realistic in light of the incredibly slow and often-seasonal weaving process. Even where the rare nomadic weaver existed, she would be economically tainted if buyers knew how much interaction modern nomads have with sedentary villages, and how much material, knowledge, and labor is sourced between them (Baker 1995:367). There was no way that the few real nomadic and pastoralist weavers could supply the enormous Western demand, so savvy village and city weavers simply switched to cheaper/coarser wool, redrew their cartoons with a lower knot density, and told unscrupulous dealers that the carpets were sourced from some remote tribe or another (Eiland III 2004:255). Modern carpet classification and valuation schemes for village and domestic carpets are largely built on this invented tribal provenance, despite the almost laughable inaccuracy of many attributions (Baker 1997:363). Even more incredible than the proliferation of fabricated information is the overwhelming disinterest shown in correcting it.

This fad for tribal carpets is what pushes Central Asian weaving permanently from domestic and cottage industry into large-scale commercial production (Fitz-Gibbon 2004). Backed by state-sponsored programs, professional workshops are established, particularly in Turkmenistan and more recently in Uzbekistan (Spooner 1986:216). The strength of the formal carpet market is particularly evident in Turkmenistan, which now has a government agency for the oversight of carpet production, valuation, and export called *Turkmenhaly* (literally "Turkmen carpet"). Today, the majority of Central Asian knotted carpets are produced in those two countries, the same regions that probably had the highest historic production. Carpet-weaving in the other three Central Asian republics and Xinjiang certainly still exists, but the historic, cultural,

and economic landscapes of those countries make it less profitable and less common. Particularly in the more northernly and higher-altitude regions of Central Asia, knotted carpet production has never overtaken that of felted rugs.

Modern carpets, in Central Asia and elsewhere, are primarily made for export. The high labor cost makes them generally unattainable as day-to-day purchases for the local communities, although hand-knotted carpets may still be gifted at milestones like weddings, graduations, or births. One of the Uzbek translators who assisted with this project said she had never seen a new hand-knotted carpet in person before, having been exposed only to antique and vintage pieces in elderly relatives' homes. She considers carpets a machine-made product, and had not given much thought to them as handmade pieces. She did not even know that her city hosted a globally-renowned silk carpet workshop, nor did she have any concept of carpets as a heritage industry. Although her experience was typical of the non-textile people I met in Uzbekistan, the considerably stronger and politically visible carpet industry in Turkmenistan makes carpet-weaving common knowledge there.

Traditional textiles have gained increasing attention in the last few decades under global intangible heritage initiatives: carpets are no exception, and nowhere is carpet heritage more celebrated than Turkmenistan. In an effort to unify the nation following Soviet independence in 1991, Turkmen president Saparmurat Niyazov placed huge emphasis on the proud (and often imaginary) Turkmen identity from before the 18-19th century Russian conquests (Akbarzadeh 1999:272; Clement 2014:549; Denison 2009:1167; Jorayev 2014:53). Backed by dubious claims of ancient origin, many cultural traditions were re-instated and re-invigorated, including music,

dance, art, and craft technologies. Carpets were swept up with other traditions and were granted state status as heritage commodities, overseen by state agencies, glamorized on TV and in published books, celebrated in a dedicated capital-city museum, and even granted their own national holiday (the last Sunday in May). Export is rigorously controlled to ensure that cultural treasures cannot be smuggled or sold outside the country, and it is illegal to remove a carpet older than 30 years from their borders. Younger carpets must be certified by the state carpet authority prior to export. One carpet I purchased in Turkmenistan even had metal pellets sewn into one corner; staff at the Carpet Museum told me that it was sometimes done to ensure the carpet set off airport scanners, so that customs staff know to ask for export papers, thereby making the carpet harder to smuggle out of the country.

Carpet symbology appears in state iconography too: the national flag features carpet motifs, with five medallions representing the five largest tribes of modern Turkmen. Carpet motifs appear on currency, engraved in buildings, laid in marble floors, and on books and souvenirs (Fig. 5.28; see also Wang & Sluka 2022). Former president of Turkmenistan Gurbanguly Berdimuhamedow sums up the government position better than anyone, in a book he wrote about carpets:

> "The Turkmen carpet is like an invariable source of material and spiritual wealth; it always attracts attention of man because it is the endless Universe, its beauty and uniqueness are eternal."
>
> Berdimuhamedow 2016:29

While certainly this nationalized pride has been the cornerstone of the modern trade in Turkmen carpets, it presents its own challenges. The high standards and government-controlled

workshops in which many modern carpets are made have a similarly homogenizing effect as did the collapse of traditional guilds under the Soviets in the 1920s. While an impressive range of techniques, tools, and designs appear in older carpets, they have increasingly homogenized over the last century. V.G. Moshkova, a Soviet ethnologist and carpet expert, produced a veritable tome detailing the techniques and variations extant in Central Asia in the early 20th century. By the time I spoke to weavers in the 2020s, only a handful of those variations were present. In general, the weaving standard in Turkmenistan today was historically associated with the Teke tribe of the Merv (Mary) Oasis: considered master weavers for several centuries, their traditional methods and designs have been prioritized to the detriment of others. Even in a place with a robust modern carpet industry, this loss of variation limits the comparisons that can be drawn and artificially narrows our understanding of variation in the past.

Carpet studies as a cohesive field really begin in the early 20th century as an outgrowth of the Victorian carpet boom, spurred on by Western collectors, enthusiasts, and dealers. The vast majority of the studies produced over the last century have focused on provenance and attribution: knowing where and when a carpet was made has more impact on its monetary and artistic value than its design, materials, or weaving quality. While understanding the origins is certainly a worthwhile goal, the confusing and largely invented mess of information and classification schemes that have been produced for carpets probably do more harm than good. Not only are buyers duped on the origins of their pieces, but serious historical and cultural research is hindered by artificial associations, symbolisms, and ethnic attributions. Without being able to concretely say where any specific carpet came from, it is not realistic to hope we can

make grounded claims about what is/is not standard for a particular community or how techniques, materials, or designs are changed, transmitted, or innovated across time and space. And if we cannot say with reasonable certainty where a carpet from 1970 was made, how could we hope to estimate where or how the Pazyryk carpet or the Bactrian group were produced?

Contributing to this issue is one of the long-term goals of the methodology presented from the next chapter. If carpets of all ages could be A) described with more nuance and B) if those nuances could be used to confirm, expand, or refute attributions, it may be increasingly realistic to position carpets in their correct time and place. The method tested in this dissertation could act as an external validation of other attributions. With a better attributive network, or at least one that is based on the more conservative aspects of technology and gesture rather than the highly changeable aesthetic designs, understanding of carpet movement and technology change should improve. Although commenting directly on the attributions of individual carpets is a longer-term project which will require some additional testing and refinement, the process I piloted here seems to have promising results. These results and conclusions are discussed in more detail in Chapters 9 and 10.

Figures: Chapter 5



Figure 5.2: The Standard of Ur

A box recovered from the Royal Cemetery at Ur, decorated on one side with a parade of wooly sheep, goats, and other livestock. Note the kaunakes garments worn by most people.
Inv. No., British Museum: 121201
© The Trustees of the British Museum. Shared under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license.



Figure 5.3: Earliest Pile Textile

Linen towel fragment from tomb MMA 507, Deir al-Bahri, Egypt, 11-12th Dynasty.
See also MET 31.3.62 and Cairo Museum, catalogue reference unknown.
Inv. No., Metropolitan Museum of Art: 27.3.616. Image courtesy of The Metropolitan Museum of Art, New York; Rogers Fund, 1927

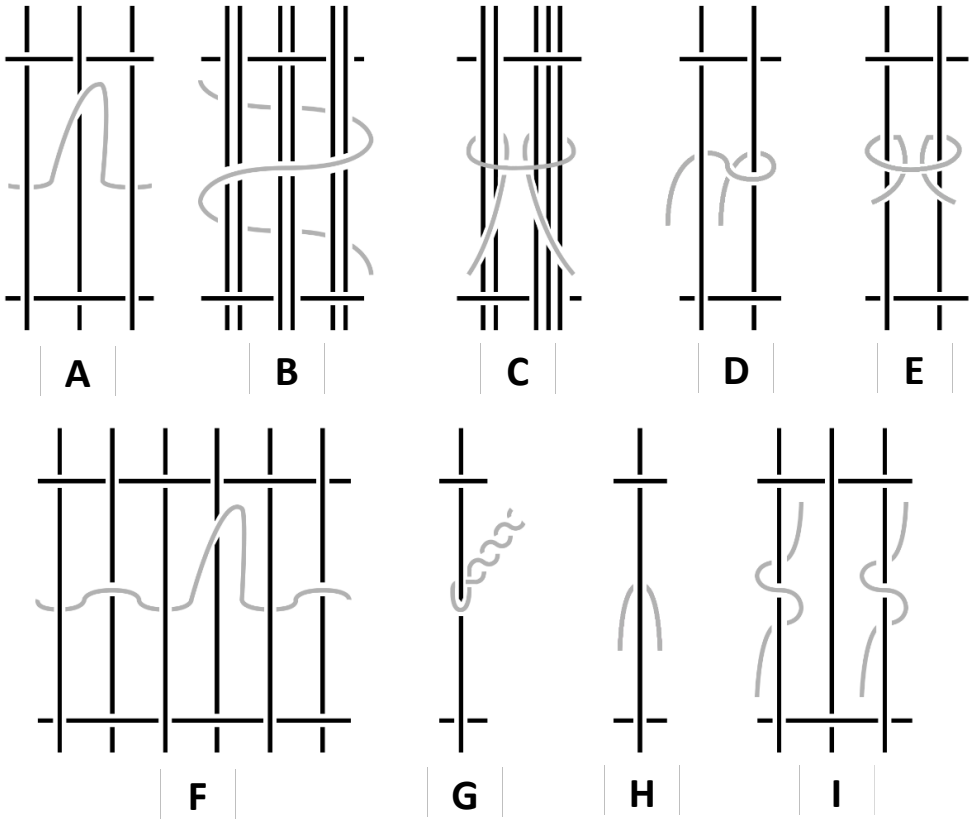

Figure 5.4: Archaeological Pile Textiles

Pile forms of archaeological textiles. Warp and weft shown in black, pile shown in grey. Note that the warp-weft interaction was not considered. Figures by author, based on individual citations.

A: Woven loop, Loulan, Xinjiang, c. 1800 BCE. Adapted from Barber 1999: fig 4.3

B: Warp knot (variation), Tomb of Madja, Egypt,1400-1500 BCE. Adapted from Hirsch 1991:fig 2

C: Symmetric knot (variation), Tomb of Kha & Merit, Egypt, 1300-1350 BCE. Adapted from Hirsch 1991: fig 2

D: Asymmetric knot, Bashadar, Russia, 500-600 BCE. Adapted from Rudenko 1968: fig 44b

E: Symmetric knot, Pazyryk, Russia, 300-500 BCE. Adapted from Rudenko 1968: fig 44a

F: Woven loop, Pazyryk, Russia, 300-500 BCE. Adapted from Rudenko 1968: fig 45

G: Wrap knot (variant), Verkh-Kaldzhin, Russia, 200-600 BCE. Adapted from Polocmak & Barkova 2005: fig 18

H: Woven cut or wrap knot, at-Tar, Iraq, c. 100-400 CE. Adapted from Fuji & Sakamoto 1990: fig 7

I: Wrap knot, Yingpan, Xinjiang, c.400-600 CE. Adapted from Li 2006: fig 199

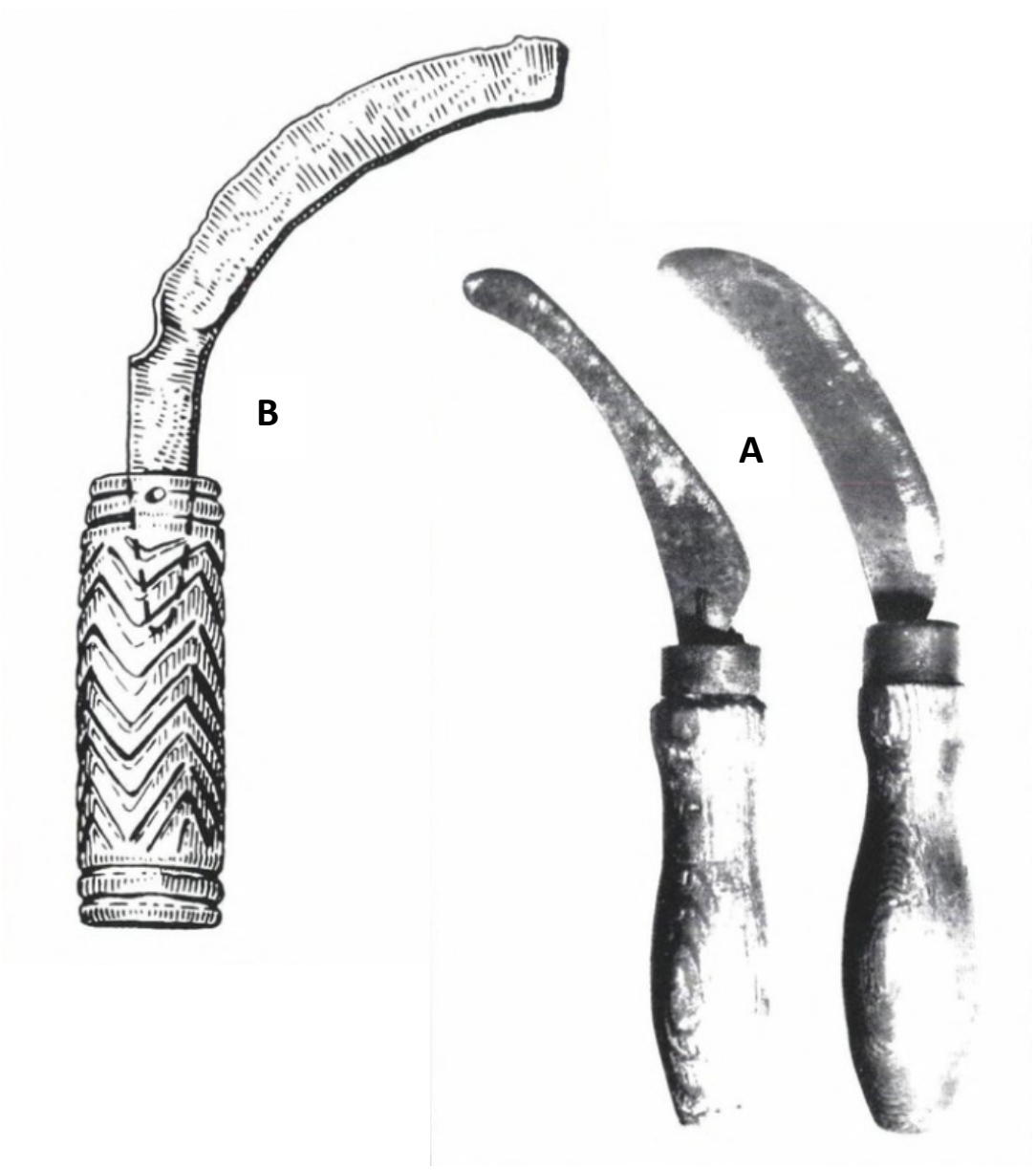

Figure 5.7: 20th Century & Reconstructed Bronze Age Carpet Knives

Figures from Khlopin 1982: figs 2-3.

A: Modern (20th century) carpet knives used by weavers around Magtymguly, Turkmenistan.

B: A proposed reconstruction of the crescent blades and decorated wood cylinders from the Bronze Age burials. Compare to Figs. 5.6 and 6.37.

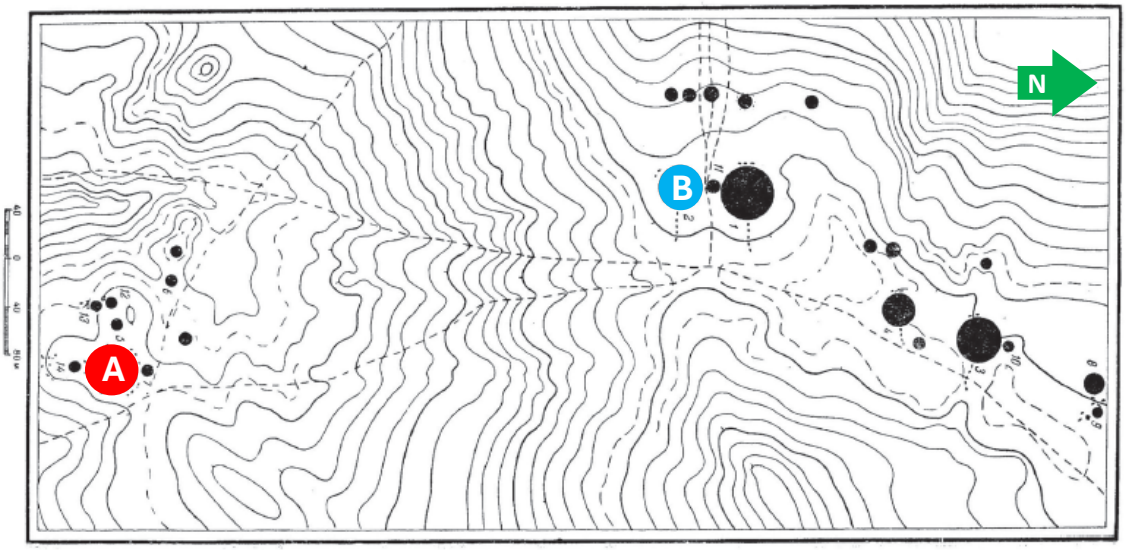

Figure 5.10: Plan of the Pazyryk Kurgans

A plan of the kurgans excavated by S. Rudenko in 1947-1949 in the Ulagan Valley. Kurgan 5 (red/A) produced the famous knotted-pile carpet. A looped-pile carpet fragment was found in kurgan 2 (blue/B). The distance between kurgan 8 in the north and kurgan 14 in the south is approximately 860 meters.
Figure from Rudenko 1953; fig. 2. Color added by author.



Figure 5.16: Looped Pile from Pazyryk

A piece of a looped pile textile recovered in Kurgan 2 of the Pazyryk burial ground, 5-4th cent. BCE.

Inv. No., State Hermitage Museum: 1684-3.
Photo © The State Hermitage Museum, St. Petersburg.



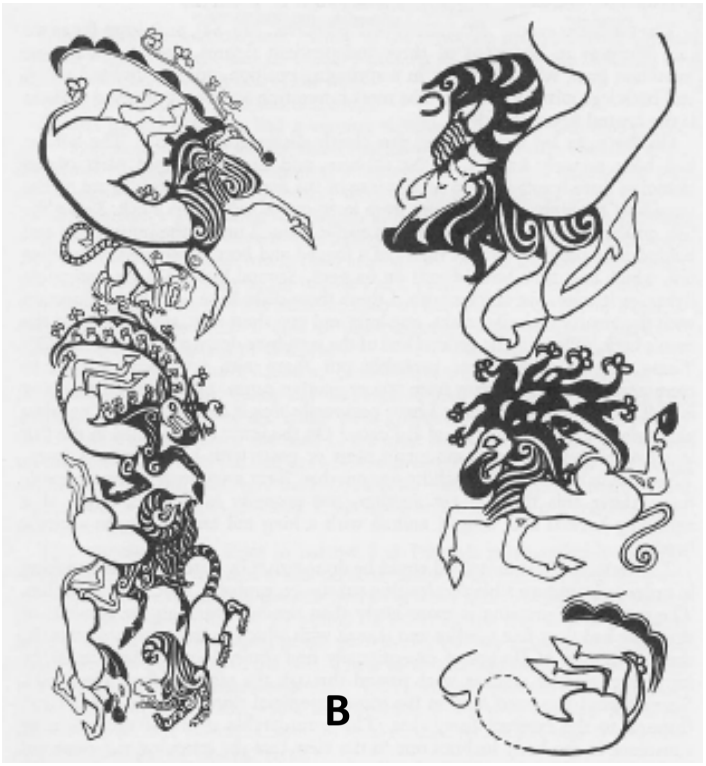



Figure 5.11: Saka "Animal Style" of the Northern Steppe

A: Stag plaque, Eleke Sazy, Kazakhstan, 6-8th cent. BCE. Photo © Fitzwilliam Museum, Cambridge.

B: Tattoos of man buried in Kurgan 5, Pazyryk, Russia. Figure from Rudenko 1970: fig 53.

C: Saka horsemen with antler regalia in front of the National Museum of the Republic of Kazakhstan, Astana. Photo by author, Sep 2018.

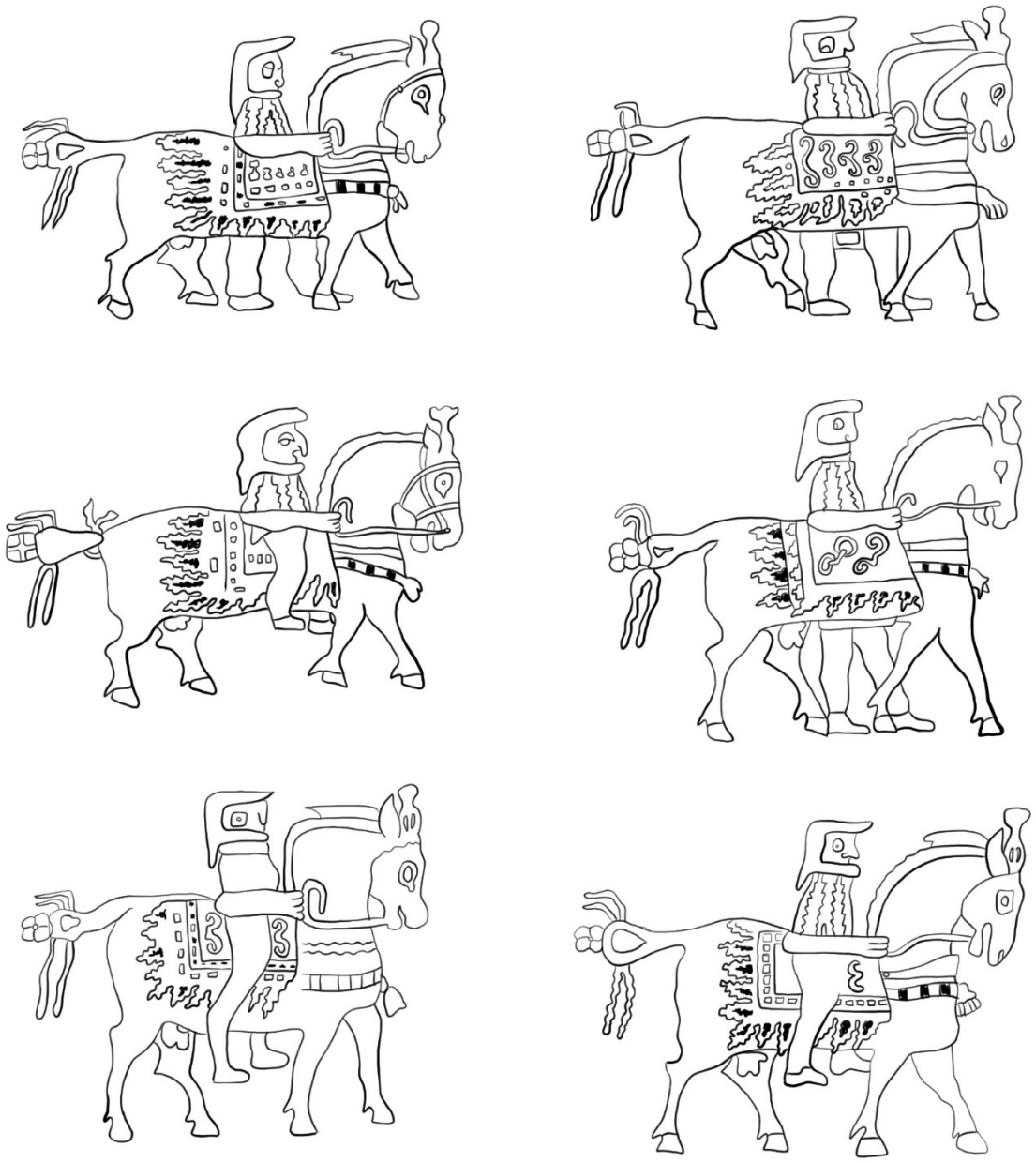

Figure 5.12: Pazyryk Carpet Horsemen

Reproductions of some of the horsemen depicted on the Pazyryk carpet. Note their similarity to those depicted in the Saka delegation at Persepolis in Fig. 5.13.
Figure by author, redrawn from Rudenko 1968:34.

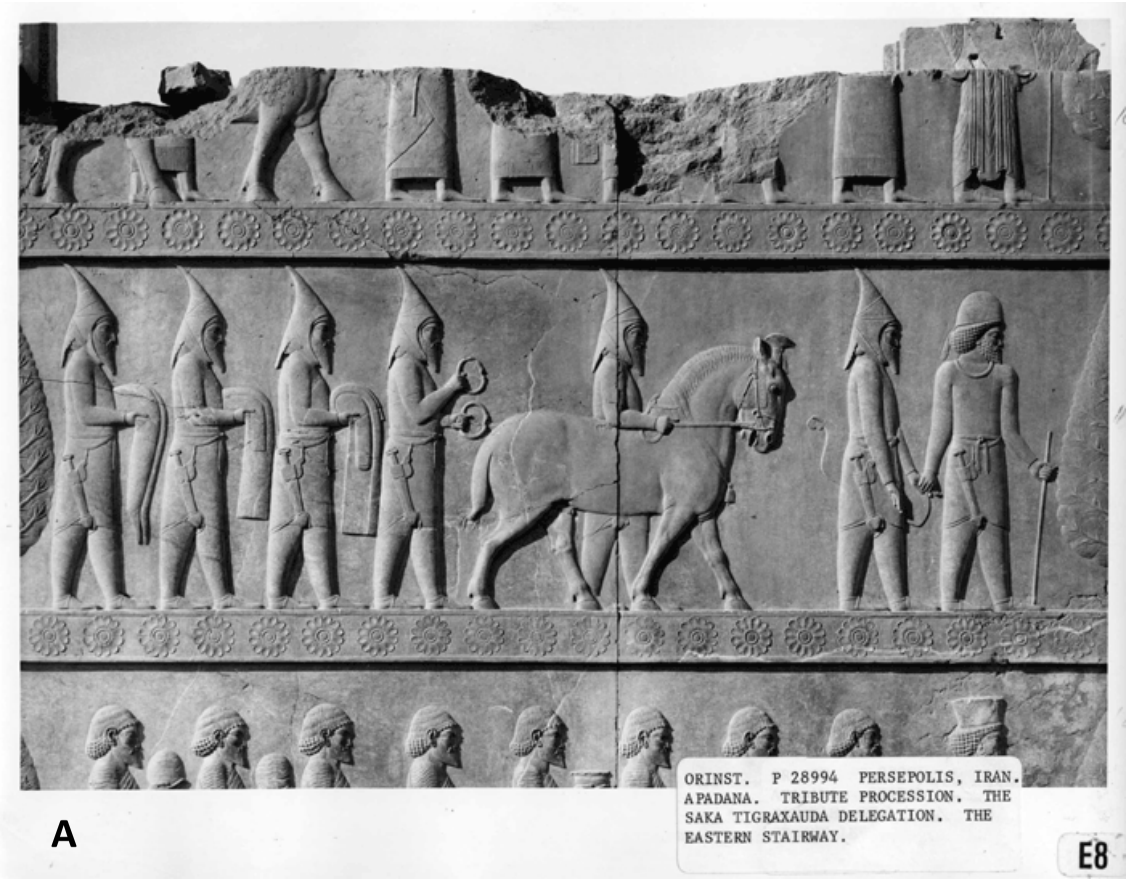



Figure 5.13: The Saka Delegation, Persepolis

A: Relief showing a delegation of Saka (steppe Scythians) delivering tribute to the city.
Relief on east stairway of the Apadana, southern Iran, early 5th cent BCE.
Photo © Institute for the Study of Ancient Cultures, University of Chicago.

B: Felted wool hat like that worn in the Persepolis relief.
Buried in Tomb 5 at Zaghunluq, Chärchän, Xinjiang Uyghur Autonomous Region, China, c. 800 BCE.
Image from Sheng 2010: fig 4.

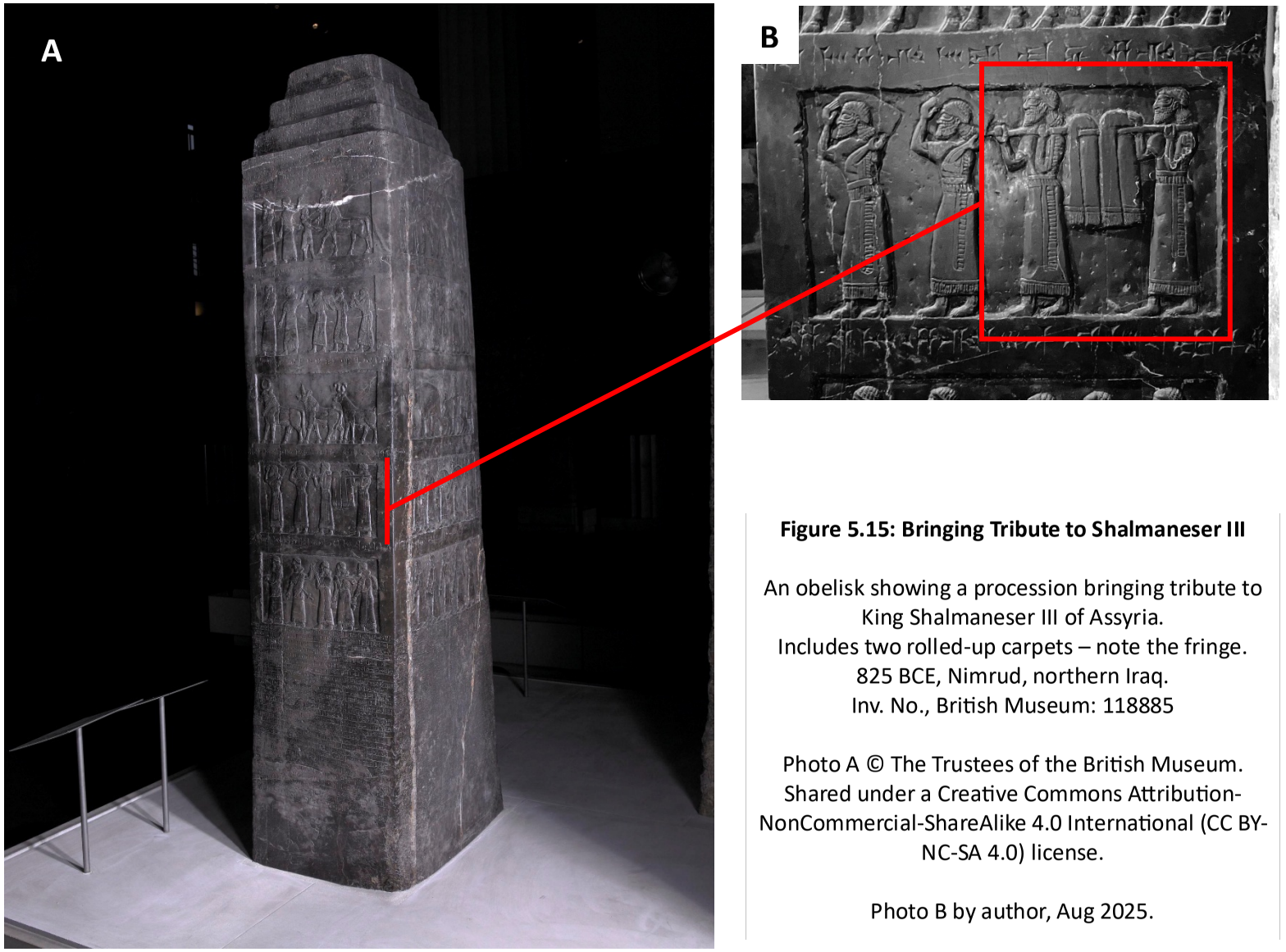

Figure 5.15: Bringing Tribute to Shalmaneser III

An obelisk showing a procession bringing tribute to King Shalmaneser III of Assyria.
Includes two rolled-up carpets – note the fringe.
825 BCE, Nimrud, northern Iraq.
Inv. No., British Museum: 118885

Photo A © The Trustees of the British Museum. Shared under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license.

Photo B by author, Aug 2025.



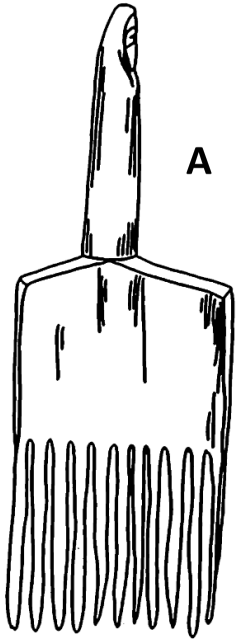





Figure 5.17a: Tarim Basin Combs (continues to next page)

Wooden beating combs recovered at Iron Age and Medieval Tarim Basin sites.

A: Shanpula, c. 100 BCE – 400 CE. Figure from Wang & Xiao 2001:65.

B: Niya, c. 300-500 CE. Figure from Zhang 2019.

C: Niya, c. 300-500 CE. Figure from Zhongri Niya 1996.

D: Niya, c. 100 – 350 CE. Inv. No., Victoria & Albert Museum: LOAN:STEIN.530. Photo © Victoria & Albert Museum, London.



Figure 5.17b: Tarim Basin Combs (continued)

Wooden beating combs recovered at Iron Age and Medieval Tarim Basin sites.

E: Niya, c. 200-300 CE. Inv. No., British Museum: 1907,1111.97

F: Niya, c. 200-300 CE. Inv. No., British Museum: MAS.554

G: Kaladun, c. 200 BCE – 200 CE. Image from Yue 2009.

H: Mazar-toghrak, c. 700-800 CE. Inv. No., British Museum: MAS.472

Images E, F, H: Photos © The Trustees of the British Museum. Shared under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license.

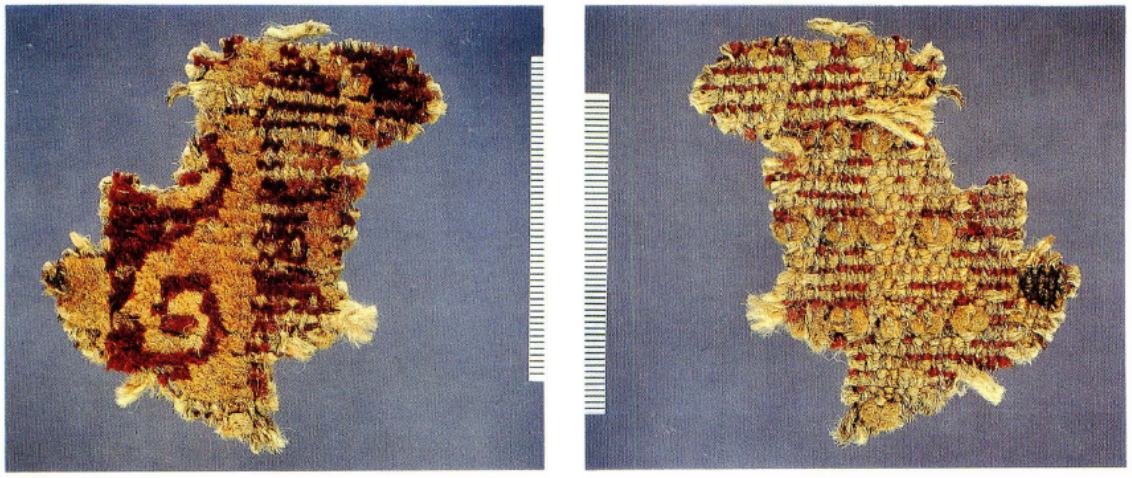

Figure 5.19: Al-Tar Fragment, Object 7

A fragment of knotted pile textile from al-Tar, Iraq, 2-4th cent. CE.
Obverse (left) and reverse (right).
Image from Fujii & Sakamoto 1990: pl. 3ab.



Figure 5.20: Dura-Europos Fragment, Object 231

A fragment of knotted pile textile from al-Tar, Iraq, 2-4th cent. CE.

Image from Pfifster & Bellinger 1945: pl.XXIII.

Figure 5.22: Afrasiab Murals

Turkic delegates meeting the governor of Samarkand, sitting on personal carpet.
Afrasiab, west wall.
Photo courtesy of the Northeast Asian History Foundation, via Wikimedia Commons

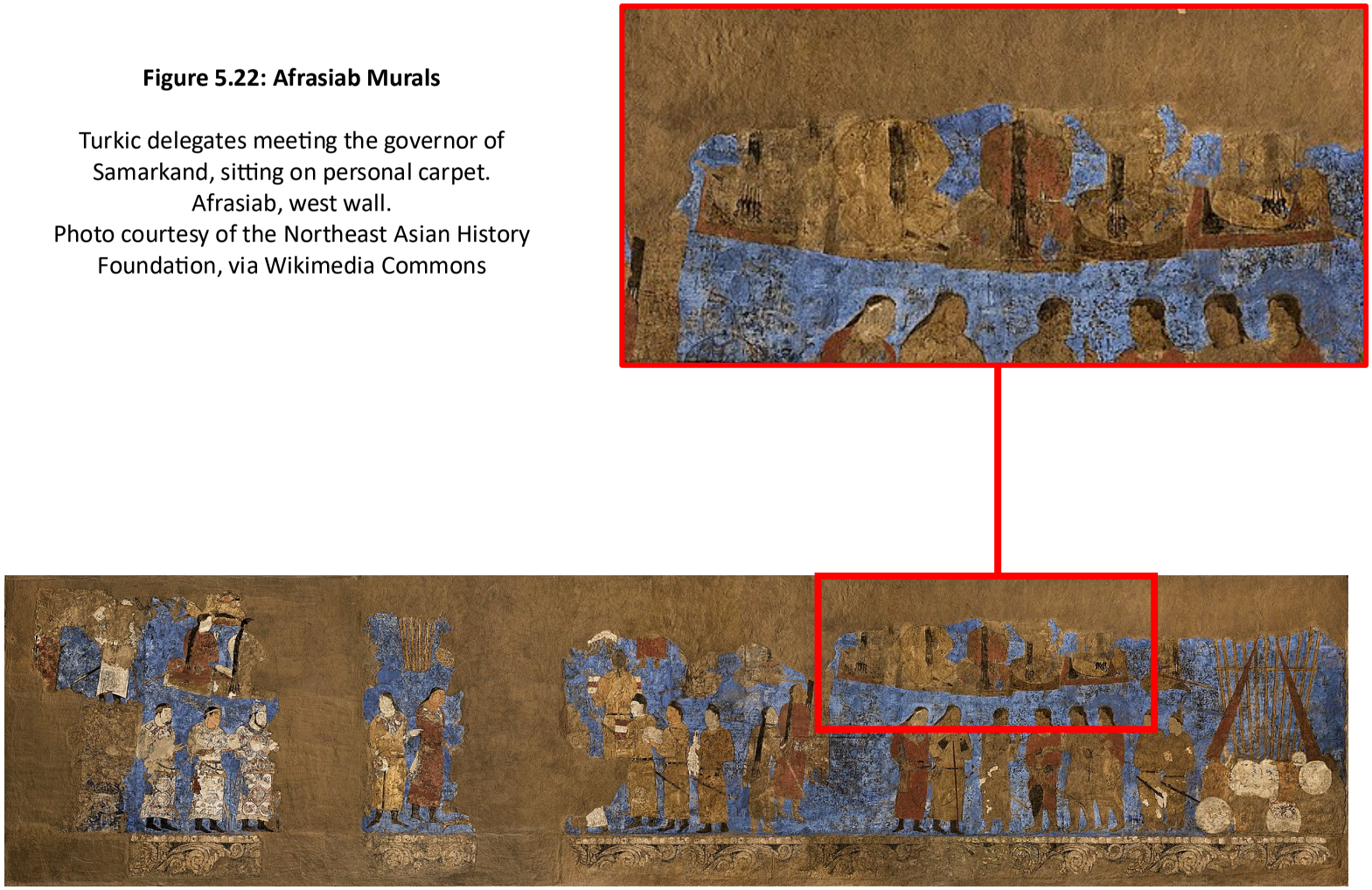



Figure 5.23: *Osho* (2015)

Art piece by Azerbaijani artist Faig Ahmed, pushing the boundaries of the knotted-pile technique and the carpet form-factor. Held in the collection of the Palm Springs Art Museum. Image © Faig Ahmed Studio



Figure 5.25: High-Density Mughal Carpet

A corner fragment of an astoundingly high-quality silk Mughal carpet, with a density of 396 k/in2.
Inv. No., Metropolitan Museum of Art: 14.40.722
Image courtesy of The Metropolitan Museum of Art, New York;
Bequest of Benjamin Altman, 1913

A1



A3



A4



A2



Figure 5.26a: Turkish Carpet Designs Named for European Painters - Lotto

A1, A2: Lotto carpet, Ushak, Turkey, 16th century CE.
Inv. no., Victoria & Albert Museum: T.348-1920.
Image © Victoria and Albert Museum, London.

A3, A4: "Portrait of Giovanni della Volta with his Wife and Children",
Lorenzo Lotto, c. 1480 – 1556/57. Image © National Gallery, London.





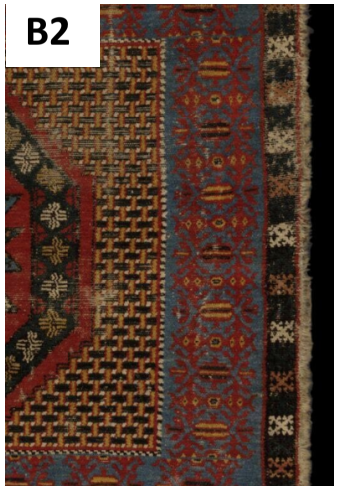



Figure 5.26b: Turkish Carpet Designs Named for European Painters - Holbein

B1, B2: Holbein carpet, Alcaraz, Spain, 1450-1500 CE.
Inv. no., Victoria & Albert Museum: 784-1905.
Image © Victoria and Albert Museum, London.

B3, B4: "The Ambassadors", Hans Holbein the Younger, c. 1497-1543.
Image © National Gallery, London.







Figure 5.26c: Turkish Carpet Designs Named for European Painters – Memling

C1, C2: Memling carpet, Caucuses, c. 1875 CE.
Inv. no., Victoria & Albert Museum: 402-1880.
Image © Victoria and Albert Museum, London.

C3, C4: "The Donne Triptych" (only middle pane shown),
Hans Memling, c. 1430-1494.
Image © National Gallery, London.





D1



D2



D4



D3

Figure 5.26d: Turkish Carpet Designs Named for European Painters - Crivelli

D1, D2: Fragment of a Crivelli carpet, Turkey, 15th century CE.
Inv. no., Museum of Applied Arts: 14940. Image © Museum of Applied Arts, Budapest.

D3, D4: "The Annunciation, with Saint Emidius", Carlo Crivelli, c. 1430-1495.
Image © National Gallery, London.



Figure 5.28: Turkmen Carpets in State Iconography

A: 1 manat note (approximately $0.29) decorated with carpet guls. Photos from private collection.

B: National flag of Turkmenistan, with carpet guls representing the five largest Turkmen tribes.

C: Study carpet TK-MA-4, designed to mimic the national flag.
The design was selected for this project by the weaver. Interestingly, she wove the design upside-down (starting with the flag's top gul at the bottom of the loom). Photo by author.

D: Turkmen State Institute of Culture building, decorated with carpet guls.
Photo by author: Ashgabat, Turkmenistan, May 2023.

6. Carpet Structure

Carpet Construction

A basic textile has threads running in two directions: x and y (Burnham 1980:151; Good 2001:211). The threads running actively in the x-axis are known as *wefts*, while those running passively in the y-axis are known as *warps* (ibid., pgs. 170, 179; Textile Museum 2025). The two groups interlace to create a solid, 2D surface (Fig. 6.1). This is the basic structure that is generally understood by the terms "weave" or "woven" (Burnham 1980:151). Any decoration, color change, or pattern in the textile's surface is the result of physical changes in the warp and/or weft yarns and/or their patterns of interaction. Variable choices about the fiber, the yarn gauge/weight, the weaving pattern, and the positioning and compaction of the warps and wefts can change the appearance, texture, strength, weight, porosity, and translucency of the finished textile. Rugs fall into this category, as they are textiles woven with warps and wefts in two dimensions.

Carpets fall into a subclass of textiles that are characterized by a third dimension: the *pile*. While the warp and weft work in the y- and x-axes respectively, the pile works in the z-axis to create a raised, plush, textural surface (Bier 1996:70; Burnham 1980:100). Carpets, therefore, are three-dimensional in a way that rugs are not. This third dimension could be considered non-structural: the object would hold its general form and still be a textile even if the pile was removed

(although removing a carpet's pile would leave behind a very sad textile indeed) (Bier 1996:70). A carpet which has lost its pile becomes a rug; a rug that has lost any of its main components is a heap of loose yarn. The visible surface of a pile textile may be mostly or entirely made up of the pile, with the warp and weft only visible from the back (Fig. 6.1).

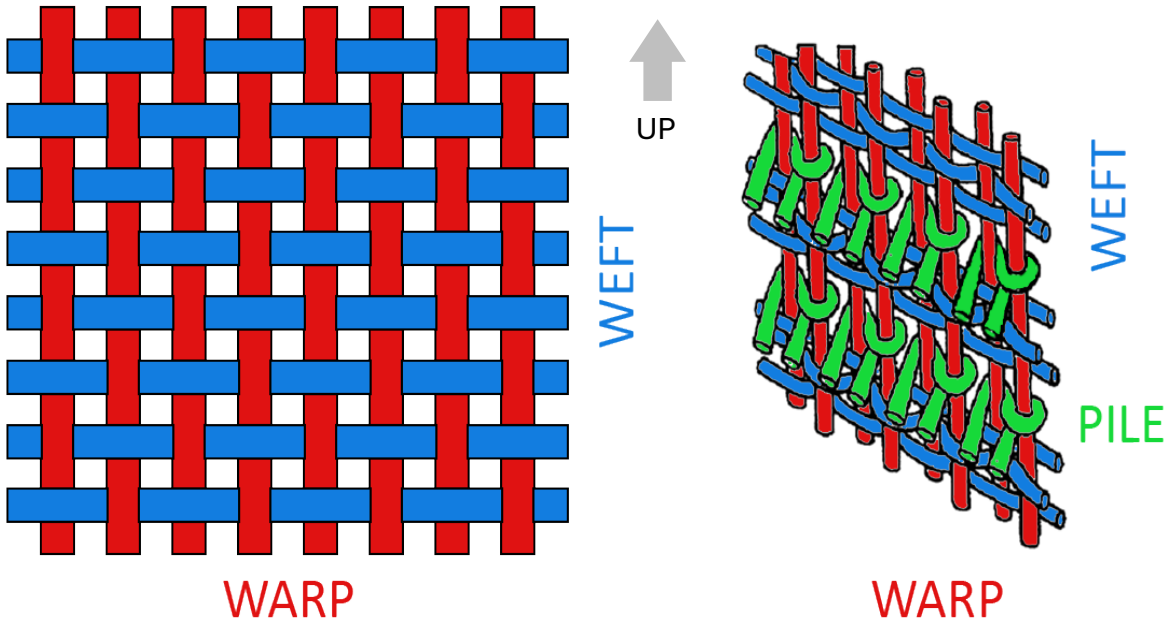

Figure 6.1: Flatwoven vs. Pile Textiles

Surface of a rug (left) and a carpet (right), in loom orientation. The rug warp and weft work together to form the surface, while the warp and weft of the carpet become invisible behind the upright surface of the pile knots. Figures by author (left) and Milton Sonday in Bier 2000:129 (right), modified by author.

Pile textiles are a large category of textiles with many variations used around the world and throughout history (Fig. 6.2). Common types include velvet, corduroy, and toweling: all have a raised, plush surface that differentiates them from satin, denim, and other fabrics (Burnham 1980:100; Textile Museum 2025). Carpets fall into a specific subclass known as *knotted pile*. In

these pieces, the z-dimension (pile) is created by tying individual knots to the underlying warp-weft grid. The body of the knot wraps around individual or pairs of warp threads, and the loose tails of the knot stick upright ((ibid., pg. 78; see Figs. 6.1, 6.2). When many knots are tied close together, their tails provide mutual support and can maintain a generally upright position even under pressure.

The knotted technique has been and still is used for many types of objects. However, the immense time requirement of tying the knots individually has made these items less economically viable in the post-industrial age (Spooner 1986:220): they are *very* slow to make. Knotted pile textiles are today limited almost exclusively to carpets, and in fact many "knotted carpets" are actually machine-made with a different, non-knotted piling technique (known as *tufting*) (Absamatova 2017). Many people, in the general public and carpet experts, use the phrases "Oriental carpet" or "Persian carpet" when referencing both the hand- and machine-made versions of these items. Despite this widespread use, knotted carpets are not and never were necessarily Persian, nor do they all come from the vague and outdated "orient". These classifications became popular and took root in the English language when most carpets reached Europe and North America from Iran and Turkey during the Victorian era (Bier 1996:66), but the inexactness and misrepresentation of these phrases lead me to feel that they should not be used in modern carpet studies at all. "Knotted carpet" or simply "carpet" are more accurate and neutral terms, and are the ones used here.

Carpets, as well as all other true textiles, are made on a rigid frame known as a *loom* (Grömer 2016:92). Like the textiles themselves, looms take a huge variety of forms throughout

history and around the world (Broudy 1993). However, a generally compatible core is present in most looms and associated components. A brief outline of those components is presented here: see a more detailed and carpet-specific survey in the next section.

Most looms have two bars, beams, or other structures around which the warp is secured. These are known as *warp bars* or *warp beams*. By holding the warp bars apart, the warp is pulled taught and weaving is possible (Burnham 1980:171; Fig. 6.3c). The simplest looms have only warp bars, and the requisite distance is maintained by human strength (e.g., in a backstrap loom; Broudy 1993:36). A modification can add rigid supports positioned between or around the warp bars to maintain their distance, sometimes called a *frame* (ibid., pg. 17; Fig. 6.3a). Fixed warp bars generally limit the weaving area to the distance between the bars: to extend the weaving area and create a larger textile, some looms have a mechanism for rotating or unwinding the warp around the warp bars to bring new sections into the weavable area. When the warp bars are windable, they are sometimes called *cloth bars* or *cloth beams* (as in, the bar around which the finished cloth is wound to make space for new warps in the weaving area) (Broudy 1993:38; Burnham 1980:25). This usually positions the cloth bar as the one nearest the weaver, as most looms work by weaving away/up from her position (Broudy 1993).

Notable exceptions to the two-bar standard are the backstrap loom and the warp-weighted loom. In some backstrap looms, the weaver herself acts as one or both bars, wrapping the warp around her lower back and/or feet and sitting with her legs out to create the requisite tension (Broudy 1993:76; Burnham 1980:10). In a warp-weighted loom, the warps are secured to a bar at the top and to heavy weights at the bottom. Gravity acts on the weights to hold the warps

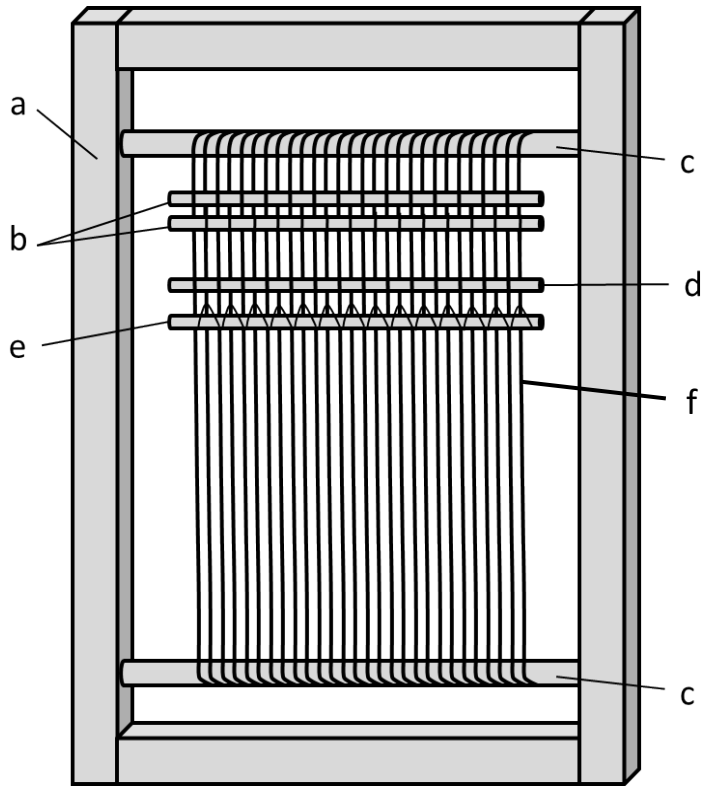

Figure 6.3: Basic Looms

Example of a simple vertical loom, comparable to the carpet looms observed in this study. Figure by author.

A: Frame **B:** Tension Rods
C: Warp/Cloth Bars **D:** Shed Rod
E: (String) Heddle **F:** Warp

in tension, and the cloth is worked from the cloth bar at the top downwards towards the weights (Burnham 1980:177; Ulanowska 2019). As carpets are not usually woven on either of these types, they are not particularly relevant to this study. In all types of looms, individual strands of warp are known as *ends* (Burnham 1980:52), while individual strands of weft are known as *picks* (ibid., pg. 99). 'Warp' and 'weft' should be understood as collective terms.

The remaining common components of a simple loom are not necessarily connected to the loom but can be suspended in the warp. It is therefore important that the warp is held in tension to create the friction and stability needed for the additional components and for weaving. *Tension rods* or *tension beams* are a catch-all term that I use for many types of rods that weave through the warp to take up additional slack, to introduce crossing points needed for the weaving

or shedding mechanisms, or to change the distance between warps wound around the front vs. the back of the warp bars (Broudy 1993:67; Fig. 6.3b). This distance is a *native* or *natural shed* (Burnham 1980:121).

A *shed* is the space between groups of warps through which the weft passes (ibid.; Fig. 6.4). In the simplest type of weave, known as a *plain weave* or *tabby*, the weft passes in front of and behind alternating warps in regular sequence (ibid., pg. 139; Textile Museum 2025). Therefore, the plain weave/tabby shed is open when every other warp is pulled forward and the rest are pushed back, creating a passable space between the two groups for the weft. A native or natural shed is one that is produced unintentionally by the loom's structure or the method of winding the warp (Burnham 1980:121). Some weavers use this native shed as one of the weaving sheds, or they may work to eliminate/minimize the native shed and use others in the weaving process. Or, they may ignore the native shed altogether!

To manage the opening and closing of intentional (non-native) weaving sheds, several components can be added. A *shed rod* or *shed stick* is the simplest: it is woven through the warp threads along the same route that the weft should take in this shed (Burnham 1980:121; Fig. 6.3d). When the shed rod is slid towards the weaving zone, the diameter of the rod pushes the forward and back warps apart, creating space for the weft to pass. When pushed away from the weaving zone, the angle of the opening is reduced by parallax (Fig. 6.5). A loom can only have one shed rod at a time: additional rods will prevent the others from functioning. Shed rods are distinct from tension rods only in that shed rods are actively used to open/close a shed, while tension

rods are generally stationary and have no action in the weaving process (compare many world examples in Broudy 1993).

A more complicated method of managing sheds is with a *heddle*. Rather than simply being suspended in the warp like shed rods, heddles are integrated or attached to the warps in some way (Burnham 1980:70; Fig. 6.3e). When the heddle is shifted in a particular way (usually up off the warp), it forces the shed open by dragging some of the warps away from the rest. Multiple heddles can be installed simultaneously to open many different sheds, and heddles can also be used in conjunction with a (single) shed rod. The draw-loom, used for elaborate Chinese brocades and European damasks, is a particularly alarming example, with thousands of heddles in some iterations (Broudy 1993:126).

To create a basic textile, one shed is opened and a pick of weft is passed through it. The shed is closed, another shed is opened, and another pick of weft is added. This pattern repeats to create the textile, where subsequent weft picks secure the warps together and prevent holes or fraying. Carpet production expands on this basic structure and the functioning of a basic loom.

Chaîne Opératoire

The modern carpets included in this study use several similar systems for weaving. They have minor differences in structure, materials, and tools, but the overarching methods are the same. The variations represented here are by no means exhaustive of all the variations that exist in the world today, or that existed in the past. The types represented here were not chosen specifically or intentionally, but rather are an emergent property of the weavers who could be

identified and agreed to participate. Additional information about them and their selection can be found in Chapter 7.

This study focused only on the weaving process and did not consider fiber acquisition or refinement, dying, tool production, constructing of or setting up the loom, the warping-on process, removal from the loom, or post-loom cleaning or refinement processes. While these aspects are certainly important parts of carpet-weaving's larger technological system, they were not the focus of this work, and variations in those techniques are not measured here. Similarly, this study is purely technical: it did not consider the decorative aspects of the carpet design or color choice. Any information on designs and colors given here is purely for interest, and depth of aesthetic analysis should not be expected. However, design, color, and motif symbolism is the most popular aspect of carpet studies, and a huge variety of academic and amateur work is available on it: see Abas 2001; Albenda 1978; Bier 1997, 2001, 2010; Briggs 1940; Cammann 1975; Crowe 1991; Dalley 1991; Edwards 1953; Eiland Jr. 1976, 1979; Erdmann 1970; Geijer 1963; Laing 1995; Moshkova 1996; Robinson 1893; and Tsareva 1984, 2016, among hundreds of others.

As mentioned in the previous section, most looms worldwide and throughout history diversify on a common core of mechanisms and tools. Knotted carpet production is at the simpler end of the possible complexity: in the grand scheme of textiles available today and in the carpet's heyday, carpet weaving is a relatively simple task (Bier 2000:130), if slow.[18] Standard carpet looms do not require the excessively complicated shedding mechanisms seen in brocades and samits

[18] I tend to agree with Bier's estimation of carpet-weaving as relatively simple compared to other textile technologies. Brian Spooner (1986:204) takes the opposing view and states that carpets are "arguably the most sophisticated fabric ever invented".

that proliferated in the same historic periods, they do not require ultra-fine components to effectively manage hair-spun silks or cottons, and they are generally not expected to produce bolts of cloth tens of meters long. A carpet loom can be constructed with only basic loom components and could be assembled easily by anyone with basic weaving experience. In fact, most looms could be easily re-purposed for the weaving of carpets. The inverse is not true: it would take considerable time and tinkering to efficiently produce a brocade on a carpet loom.

It is the time requirement of carpet-weaving rather than the technical mechanisms that make it laborious. Tying a knot, even for a skilled professional who has excellent muscle memory for the gesture, takes around a second: from videos, I calculated the weavers in this study to work at rates of 15-50 knots per minute. A carpet with 1,000,000 knots would therefore take more than 300 hours (38 working days) for the quickest of these weavers just to tie the knots, without considering time for preparing the materials, setting up the loom, weaving the edge reinforcements, adding the wefts, or cutting the carpet off the loom, and assuming she can work at her full speed throughout. The slowest weaver here would need over 1,000 hours (125 working days)! While the carpets included in the modern sample of this project are generally on the small side and mostly have fewer than 1,000,000 knots, even the smallest and coarsest has nearly 30,000. It is easy to see why the time requirement is more of a barrier to production than complexity of the technology.

It is worth noting that additional experience with carpet-weaving does seem to speed knot-tying, suggesting that if there is a biomechanical limit, it is not quickly reached (Figure 6.6): weavers in this study with 30-50 years of experience show improved speeds compared to more

novice colleagues. This contrasts with the consistency of the knots, which this study shows reaches a maximum level quite quickly and then plateaus, not improving with additional years' experience (see full discussion and evidence in Chapter 8, pg. 495). Extra experience makes a weaver tie knots faster, but not with more consistent results.

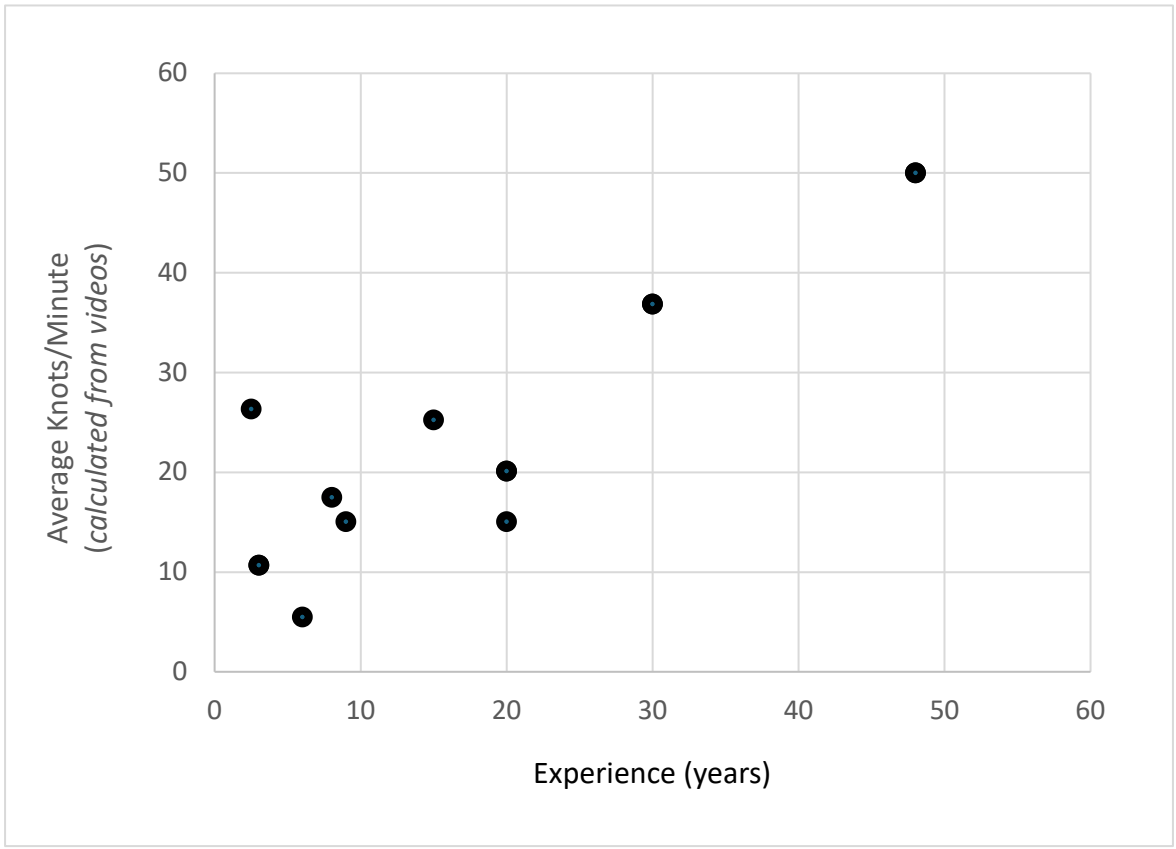

Figure 6.6: Years of Experience vs. Knot-Tying Speed

Weavers work faster with additional years of experience, indicating that the biomechanical limit for knot-tying is very high. Figure by author.

A simple *chaîne opératoire* for knotted carpet weaving is given below, synthesized from my personal interactions with carpet weavers in several parts of the world, including Central Asia,

northwestern Africa, the Arabian Peninsula, and Europe. It captures the basic steps observed in this study and elsewhere in carpet literature, in the common order. Brief summaries of this process are also available in most comprehensive works of the last century, including Edwards 1953; Eiland, Jr. 1976, 1979; Erdmann 1970; and Moshkova 1996. This technological sequence is expanded upon in the following sections, with specific reference to the carpets included and variations observed in this study. Although the basic preparatory and finishing steps are included in this outline for completeness, the analysis presented in this dissertation focuses on steps 4-12.

1. Fibers are collected and spun into yarn.
2. Yarn is dyed.
3. The warp is added to the loom.
4. Tension rods are added to take up any remaining slack in the warp, and to reposition warps for shedding and weaving.
5. Shed sticks and heddles are installed to open the required sheds.
6. A woven selvedge is added.
7. A row of knots is tied.
    a. A knot is tied between consecutive warps by hand, following a determined color pattern.
    b. The knot is cut from the skein using a knife or scissors.
    c. After several consecutive knots are tied, the section is compressed with a beater.
8. Once all the knots in a row are tied, the loose ends are trimmed to a uniform length.
9. The binding yarns are woven up to sit flush with the knots.
10. A weft shot is added across the width of the weaving, on top of the knots in the open shed.
    a. The weft shot is interlaced/overlapped with the binding at each side.
    b. The shot is compressed with a beater.
11. Steps 7-10 are repeated until the entire field of the carpet has been woven/knotted.
12. A selvedge is woven to match the one produced in step 6.
13. The carpet is cut from the loom.
14. The loose warps are secured with fringe, braids, or other finishes and trimmed.
15. Loose yarn tails in the weaving are secured and trimmed.
16. The pile is cut to an even level.
17. The carpet is washed.
18. Steps 16-17 may repeat an indefinite number of times to improve or alter final appearance.

Characteristic Database & Typological System

The basic carpet *chaîne opératoire* is varied upon by different weavers in different ways. While this type of technological data would normally be presented as a holistic text, this project required precise categorization of structures and techniques, for two reasons. First, one of the dissertation's underlying goals was to better describe carpet technical variation, as a step towards improving and diversifying existing classification schemes used to attribute and relate carpets. Second, in order to complete the small-scale technical analysis presented in the next chapters, it was necessary for holistic data to be precisely defined and classified. This allowed for statistical analyses to be performed on the data, and for conclusions to be drawn about specific characteristics without lumping them in with others. The more specific the classification is, the more specific and nuanced corresponding conclusions can be.

It was therefore necessary to create a classification system that captured the variation in succinct and distinct variables: I cannot say that knot size/shape changes based on production characteristics if I do not define what those characteristics are. Each variable describes a different small-scale component of the carpets' structure, loom, tools, or materials, or of the weaver's personal sequences, idiosyncrasies, and social-cultural pressures. These variables, their meaning, their conceptual function within the carpet, and the steps involved in their application are given below. A full database of all recorded weaving characteristics of the project carpets (modern and historic) is given in Appendix C.

Although the unit of measurement in this analysis was the individual knots, an underlying assumption of my questions and hypotheses was that the measurable differences in the knots

are due, at least in part, to displacements in the warp and/or weft, and how the knot interacted with other tools such as beaters and knives. When the warping system, opening of sheds, and other warp/weft factors are introduced, they can cause the knots to tilt slightly off the x-y weaving plane, or to squish/expand into irregular spaces. These pressures from the carpet's other structural components as well as the tools and weaver-introduced variations cause changes in the knot size/shape, which is what I aimed to measure and explain here.

The characteristics documented for the project carpets are given in the text in **Bold**, to remind the reader that I am referring specifically to an individual variable in this dissertation's classification scheme, and not to a more general conception of the process/tool in the wider carpet or textile world. Also note that in the full characteristic database (Appendix C), 'none' and zero (0) are both distinct answers from a blank cell (shown with a dash). 'None' is used for categorical variables when the characteristic was checked but is not present, applicable, or relevant. Zero (0) is used for numeric variables where the count is null. Cells are left blank (-) when the characteristic could not be checked, and its value might exist but is unknown.

All classifications are given from the weaver's perspective (Fig. 6.7). This means that shapes and directions are based on how the weaver would have seen them during the weaving & knotting process. The top of the carpet is the side woven last at the top of the loom from the weaver's seat, while the bottom of the carpet is the side woven first at the bottom of the loom. The left and right sides of the carpet are given from this same perspective. The weaver works from the front, plush side of the carpet: she does not see the back while working. Although the photographs used in this analysis are taken from the back (see Chapter 7 for more details), the

classifications for the carpet structures are all given from the weaver's perspective, not the camera's. Because the carpets were flipped along the Y-axis for photography, the Y-axis directions (top/bottom) remain the same in both the camera and weaver's perspective. However, X-axis directions (left/right) are inverted. The weaver's perspective is, however, preserved in drawn diagrams. The x-axis inversion in photographs has been accounted for in statistical analyses and plots, and results are given from the weaver's perspective. Only the analysis photographs and unprocessed data measurements are inverted.

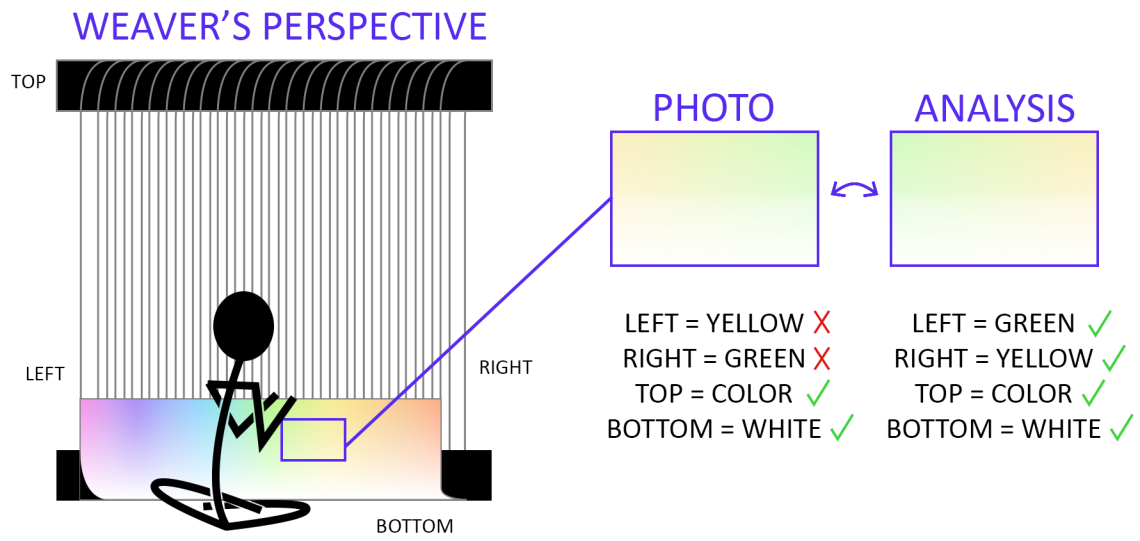

Figure 6.7: Documenting the Weaver's Perspective

Weaver's Perspective: The weaver sits in front of the loom, weaving upwards. Purple attributes are at her left, red attributes are at her right, colorful attributes towards the top of the loom, and white attributes toward the bottom.

Photo: The research photographs are taken from the back of the carpet, inverting left & right but not up & down. The photo shows yellow at the left, when it was actually on the weaver's right.

Analysis: The inversion is accounted for in analysis and structural documentation, giving yellow at right and green at left, just as in the weaver's perspective.
Figure by author.

Diagrams of each carpet's woven structure can be found in Appendix B. These can be used to visualize how the production characteristics look in-situ. Locations referenced in the following sections can be found mapped in Appendix A.

The technical descriptions and diagrams shown in the next sections are based on direct observation of and discussion with the weavers and other peripheral informants included in this study. Details about them and their backgrounds can be found in Chapter 7 and Appendix C**.** The summaries presented are synthesized from in-person conversations, written communications, photographs and videos taken by the weavers, other informants, or myself, and my own direct observation of processes and tools. The terms used in the text are the common English words used by modern weavers. However, terms provided by the weavers in their native languages are included in the Glossary (Appendix F).

The vast majority of my practical carpet-weaving knowledge (including terms, tool and component functions, material concerns, pattern-drawing, time and labor requirements, etc.) comes from direct observation of and conversation with weavers and other textile professionals, primarily in Central Asia but also Europe, North America, North Africa, and the Middle East, and my personal art practice. I received some formal training in general world weaving processes at the University of Wisconsin (2017-19), and in carpet-weaving specifically at the King's Foundation School for the Traditional Arts in London (2016). Unless otherwise noted, all background information is synthesized from my in-person experience with weavers and looms, and any classificatory logic is my own.

Loom Orientation

Carpet looms can occur in both horizontal and vertical orientations (Collingwood 1968:43; Moshkova 1996: footnote 104; Fig. 6.8). In the vertical position, the weaver sits in front of the warps and works from the ground upwards. When designed for larger carpets, these looms can have a winding system that allows the weaver to "scroll" the position of the warps, so that the weaving zone remains comfortably in front of her instead of moving continuously higher. Vertical looms without a winding mechanism require the weaver to move her own body upwards as the weaving progresses, moving from the floor to a low chair, to a higher chair, to a raised platform, etc. (Eiland Jr. 1976:24; Fig. 6.9). All of the looms studied for this dissertation have a winding mechanism, and so the weavers remain generally stationary throughout the weaving process.

Horizontal looms require the weaver to sit either to the side of the warps (see Fig. 6.8), which tends to limit the final size of the carpet to approximately the weaver's arm span, or the weaver may choose to sit on the warps to access the knotting zone more comfortably (Broudy 1993:41; Fig. 6.10). These looms, often staked outdoors, are sometimes called *ground looms*. However, the inconvenience of access plus the discomfort of hunching over a horizontal workspace means that today, horizontal looms are primarily used for flat-weaves and very small carpets, as in Figure 6.8. There is a notable exception: staff at the National Carpet Museum in Ashgabat, Turkmenistan reported that the oversized exhibition carpets displayed there, which were woven to break the world record for largest hand-woven carpets, had been woven by many weavers sitting on the carpet on a horizontal loom (Fig. 6.11). It is reasonable to assume that in



Figure 6.9: Non-Winding Vertical Loom

Weavers working on a non-winding vertical carpet loom. Notice the ladders at left and right that allow them to move their seating platform as their work progresses upward. Photograph taken by Antoin Sevruguin, Sultanabad (modern Arak), Iran, c. 1880. Inv. No., Victoria & Albert Museum: E.339:34-2010. Image © Victoria and Albert Museum, London.

this case, the massive carpets of 200-300 square meters could not realistically have been suspended on a vertical loom regardless of whether it was more comfortable for the weavers.

Despite their ubiquity in most cultures around the world since at least the late Neolithic, direct evidence for looms is exceedingly rare (Broudy 1993:14). Usually made of wood, recovery of even a fragmentary loom is unlikely in an archaeological context. Instead, study of looms is generally in one of two categories: based on depictions or based on experimental studies of textile structure. Depictions of looms appear in a number of ancient contexts, with the earliest currently known being the Badari (central Egypt) loom incised on the bottom of a shallow bowl,

c. 3500 BCE (Collingwood 1968:43; Fig. 6.12). Depictions of horizontal looms, including a miniature model left as a grave good in a c. 2000 BCE Egyptian tomb, are scattered around the ancient world, primarily in Egypt, the Mediterranean, and Mesopotamia (Broudy 1993:40).



Figure 6.12: Badari Loom

The earliest known depiction of a loom, from Tomb 24/3802 at el-Badari, Egypt. Naqada II period (3650-3300 BCE). Inv. No., Petrie Museum of Egyptian Archaeology: LDUCE-UC9547. Photo by author, Aug 2025.

Popular tradition states that carpets were invented for and woven on horizontal looms staked to the ground (Bier 2010:31; Collingwood 1968:42; Edwards 1953:22; Eiland Jr. 1976:23; Spooner 1986:205). However, the evidence for this is not clear. A general modern tendency to link carpets to nomads (Böhmer & Thompson 1991:30; Eiland Jr. 1976:3; Thompson 1993:65; Tsareva 1984:21) may be responsible for the assumption that these objects were made horizontally: a vertical loom is generally a stationary piece of furniture, while horizontal or ground

looms can be un-staked, rolled-up, and moved mid-weaving (Khlopin 1982:117). It would therefore be logical to assume that a craft carried out by nomadic weavers is one produced on a horizontal loom. And certainly photos, drawings, and descriptions from the modern era (18-21st centuries CE) do suggest that rural and nomadic weavers in central Eurasia sometimes make carpets and other knotted-pile items on horizontal looms (Tsareva 1984:8-12).

While it is technically possible to make carpets on horizontal looms, it is not convenient to disassemble and move a carpet loom in the middle of the weaving process, which can take months or even years (Khlopin 1982:117). It is important not to conflate the possibility of weaving on a horizontal loom with a historical mandate for weaving on a horizontal loom. As mentioned above, direct evidence for looms in the archaeological record is rare, and I know of no direct link between *any* type of loom and pre-Renaissance carpet fragments. It is therefore not unreasonable to consider the possibility that knotted carpets were developed by sedentary people on vertical looms (ibid.), even if there is some scattered evidence of horizontal loom-use among nomadic peoples too. The vertical loom is generally considered the more comfortable and efficient of the two for weaving carpets, and more specialized artisans are almost exclusively linked to both sedentary communities and vertical looms from the late Middle Ages to the present (Collingwood 1968:43; Eiland Jr. 1976:23).

Vertical looms do not appear firmly in the archaeological record until the 15th century BCE, in a mural at the 18th Dynasty tomb of Neferhotep at Thebes (Broudy 1993:46; Collingwood 1968:43; Fig. 6.13). As this is roughly contemporaneous with the earliest knotted-pile fragments, it is possible that the technique originated on a vertical loom. It is particularly likely that larger-

scale objects like carpets would have been preferentially made on vertical looms, as their unwieldy size and significant weight would make the rolling-up of a ground loom very cumbersome (Zhang 2015:38).

Horizontal looms are rarely used for hand-knotted carpets of any size today. None of the carpets in this study were made on a horizontal loom, and the only horizontal looms seen in the field were in exhibits & demonstrations in museum settings: in the National Museum of the Republic of Kazakhstan (Astana), the Otrar Museum (Shauldir, Kazakhstan), and the National Carpet Museum (Ashgabat, Turkmenistan). Only one weaver reported having ever worked herself on a horizontal loom (Survey 15), but did so only in her youth (30+ years ago).

The loom type used for the project carpets is recorded as **Loom Orientation** in the full technical database, available in Appendix C.

Warping & Tension

Although this study does not include the warping-on process (the physical addition of warp threads to the loom), it does include the route along which the warp threads are wound through the loom/around the warp bars, most obviously visible in cross-section. These systems reference only the interaction with the warp bars: additional interactions with shedding mechanisms are covered by other variables described below. Five systems were defined for this project: belt, figure-8, conveyor plane, and fixed plane A/B. (Fig. 6.14). These overlap to some extent with the popular system developed by Edwards (1953:22), which he terms Tabriz (belt), roller-beam (conveyor plane), and village (fixed plane), and similar categories developed by

Beattie (1963). However, both systems lack the figure-8 route, which was observed during the fieldwork for this study. They also do not distinguish between the A/B varieties of a fixed plane.

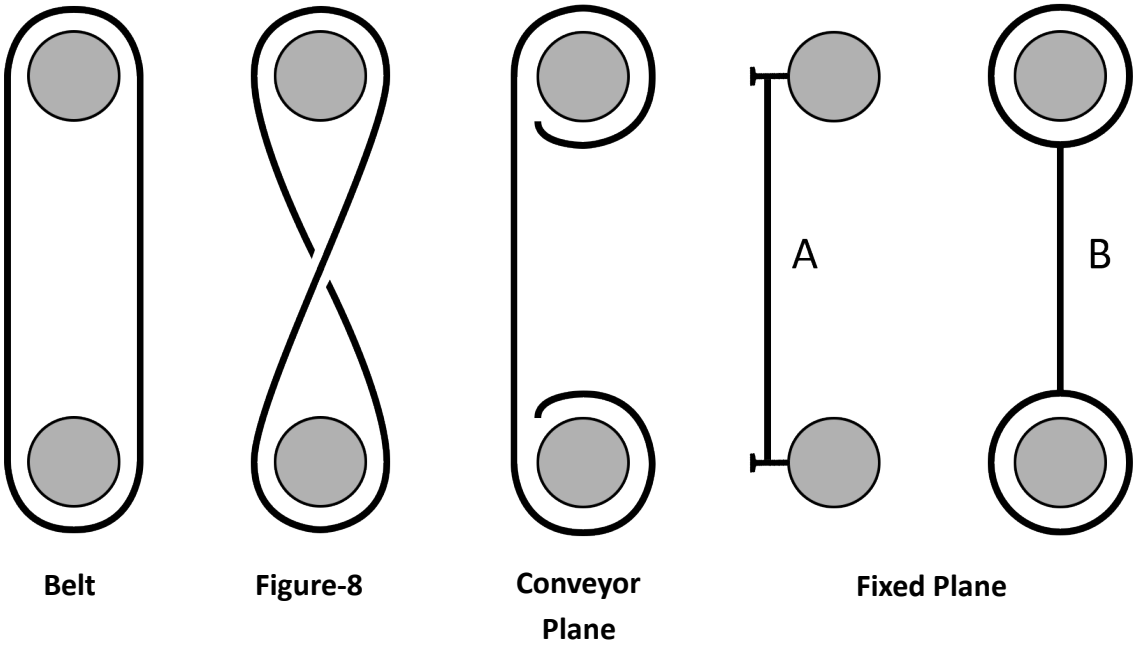

Figure 6.14: Warping Systems

The path of the warp (black) when the loom is viewed from the side/in cross-section. The warp/cloth bars are represented by grey circles. Figure by author.

Belt warps, in my system, make a complete circuit around the two bars with no cross-overs. The warps move from the front of the cloth bar, up to the front of the warp bar, over the top of the warp bar, down the back of the loom to the back of the cloth bar, under the cloth bar, and rejoin the starting point at the front (see Fig. 6.14). In a belt-warp system, there are several options for how to weave the carpet. First, the weaver could work on just one side of the warp, the side that is on the front of the loom. The carpet is woven only between the warp and cloth

bars on the front, and the excess warp threads that run up the back of the loom are cut off after weaving is complete. Second, the weaver can weave only from one position, but has the ability to wind/scroll the warp around to bring unwoven sections into view at the front of the loom. This allows the weaver to double the possible length of the carpet, or to weave several carpets on a single warp (which can be cut apart after weaving is complete). Finally, the weaver could use a tension rod (see the section below) to bring the front and back sides of the warp together on a single plane, doubling the number of warps in the field and therefore doubling the density of the weaving. The weaver can only weave between the warp and cloth bars in this case, but it is less wasteful of warp thread when a dense carpet is required.

Figure-8 systems add a cross-over in the main section of the loom, where a warp passes from the front to the back or from the back to the front of the loom on each journey between the cloth and warp bars (see Fig. 6.14). A fixed-plane system sees the warp stay entirely on one side of the loom, with all the warps following the same route and no ability to wind or rotate the warp as weaving progresses. The A-type may use nails, springs, or staples to secure the warp ends (see Fig. 6.14). In both of these systems, the warp is not windable and the weaving area is only as big as the distance between the warp bars. Finally, a conveyor-plane system works similarly to a belt, where the warp is able to wind around the loom to open up new weaving space and create a larger textile. However, this type buries the out-of-use warp by winding it directly along the two warp bars, and the ends of each warp thread do not necessary connect. This and comparable systems are used by most floor looms, and those designed for weaving long bolts of cloth.

The warp route is recorded in the **Warping System** variable. Although other types were observed in workshops and museum exhibitions, all the ethnographic carpets in this study were made on a belt warp. Weavers at the National Carpet Museum in Ashgabat, however, said that some people do use figure-8 warps on smaller looms, particularly horizontal ones (Survey 16). This seems to be true, as the horizontal loom shown in Figure 6.8 uses a figure-8 warp.

The **Warping System** describes the route taken by the warp threads in the vertical: the **Warp Bar Spacing** describes if the structure of the loom enforces specific positioning of the warp threads horizontally. Some looms, both for carpets and other textiles around the world, use nails, springs, combs, staples, tape, velcro, and other methods to secure the warps in a specific position along the horizontal width of the cloth/warp bars (Fig. 6.15). Historic records also indicate that some weavers used an enforced spacing system for carpets, including a particularly creative solution by 19-20th century Turkmen weavers who smeared clay on the beams, which dried into an immobile plaster and locked the warps in place (Moshkova 1996:58).

This spacing enforcement helps to ensure that warps are distributed evenly, they do not shift sideways during weaving, and that the resulting textile has an even composition and density. Whether or not the looms in this study had any such mechanism is recorded in the **Warp Bar Spacing**. This field is a simply binary, yes Y (yes enforced spacing) or N (no enforced spacing). The cloth and warp bars are recorded individually, as **Top** and **Bottom**. All of the ethnographic carpets included in this study were made on a non-spacing loom, although I did observe spacing looms scattered around workshops.

In some weaving systems, additional components are added to account for emergent problems with the warp system: here, I refer to these components as tension rods. These rods are usually cylindrical dowels of metal, wood, or sometimes heavyweight yarn, rope, or cord with a diameter of a few millimeters to a few centimeters. They are (usually) considerably smaller in diameter than the cloth and warp bars. Wood and metal tension rods are not connected to the loom itself, but rather are suspended in the warp by passing alternately in front of and behind consecutive warp threads. A yarn or rope tension "rod" is sometimes tied to the loom frame at the right and left sides to secure it in place. These rods have several functions: 1) to take up slack in the warp, 2) to create a crossing point in an uncrossed warp, 3) to move the cross-point in a crossed warp, and 4) to reduce the width of a native shed.

The simplest use of tension rods is simply to manage tension in the warps. Many traditional carpet looms do not have a mechanism for tightening or loosening the warp once it is wound on: the tension is set by how tight it is pulled during the warping-on process, and it cannot be significantly reset later. This means that incorrectly-wound warps may be too loose for weaving, or that the warps may stretch out and become slack over time. As efficient and consistent weaving relies on a tight warp, problems with tension is a major concern. Some slack in the warp can be taken up by adding tension rods, which increase the distance that the warp must travel between the cloth and warp bars (Fig. 6.16). This increased distance takes up more thread, increasing overall tension. Rods for this purpose may be added before or during weaving, can be positioned above or below the weaving zone, and on the front or back of the loom.

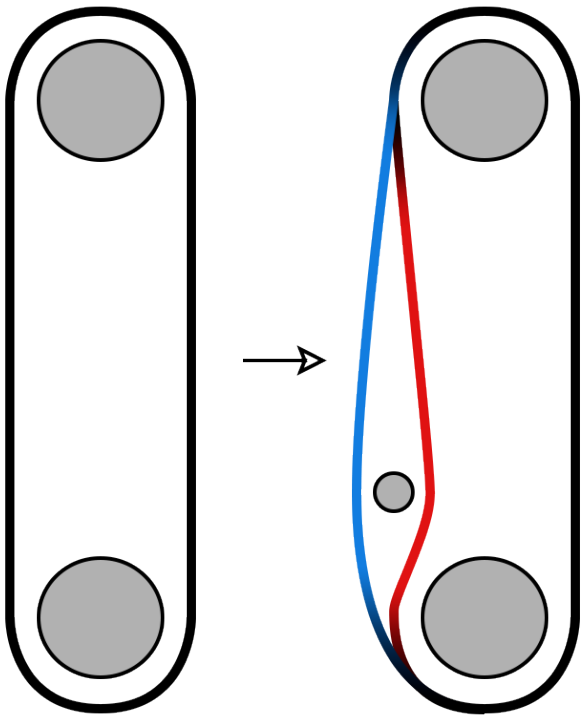

Figure 6.16: Tension Rods for Taking Up Slack

A tension rod (small grey circle) is woven between consecutive warps to increase the distance travelled and take up slack. Although a belt warp is given as an example here, tension rods can be placed anywhere along the warp's open area, in any warping system. Loom viewed from the side/in cross-section; warp bars shown in grey. Figure by author.

Another use of tension rods is to create a crossing point in an uncrossed warp; that is, to bring together sections of the warp which need to coincide for weaving, but which do not. This occurs primarily in belt-warped looms (see above and Fig. 6.16) when both the front and back sides of the warp are needed to achieve the required density. By weaving a rod between both the front and back warp, the two sets are brought together at the center and a single weaving zone is created (Fig. 6.17).

When a figure-8 warp is used, the warp already has a crossing point (see Fig. 6.14). Without any additional interference though, this crossing point will sit halfway between the two warp bars. As weaving can only be effectively completed above the crossing point, leaving it at its natural position severely limits the possible weaving size and wastes considerable warp thread. A tension rod can be added on top of the cross-point to push it downwards and expand the weaving

area. It is usually the weight of the rod and friction with the warp thread that holds it in place at the bottom of the loom (Fig. 6.18), although they can also be tied to the warp bars or loom frame if needed.

Finally, a tension rod can be used to reduce the size of the native shed. By using rods with smaller and smaller diameters, the size of the shed is reduced: in other words, the forward and back warps get closer together as they pass in front of/behind the tension rod, and the space between them decreases (see Fig. 6.18). While many carpets do have a permanent forward-back positioning of their warps in their final state due to the native shed (see Knots: **Knot-Warp Pattern** below), it is often preferable to minimize this where possible as it makes a sturdier and less permeable textile.

The number of rods used at the top and bottom of the weaving zones is recorded in the database under the **Tension Rods** variable, given as an integer and with a count for both the **Top** and **Bottom** of the loom. The carpets studied used between 0 and 2, although some looms/weavers in other parts of the world and for other textile types use many more. Because a single rod is often employed for multiple purposes, their exact function in a particular carpet is obfuscated and is not specified here. Once in place, tension rods are not generally moved during weaving: this distinguishes them from shed rods (see the Shedding Mechanism section below), which are similarly positioned but which move during weaving specifically to open/close a shed. Creation of a shed by a tension rod is an emergent property in pursuit of other goals: creation of a shed by a shed rod is intentional and the main function of the component.

Shedding Mechanism

Knotted carpets tend to have less complex shedding systems than other textiles. While most textiles require at least two sheds and can have tens or even hundreds, carpets often have only one, and rarely more than two. Unusually, the weaving in a carpet (the weft shot) can be done in the same shed in every pick (row). This is because while other textile structures need alternate sheds to lock the weft threads in place, knotted textiles have the knots themselves to provide some of that security. The knots act as one shed even though they do not require any separation of warps, and a true shed acts as the second to secure the textile. This means that only one shed is required.

The shedding mechanisms are added before weaving starts. While there are many mechanisms for shedding used around the world, only two are widely used in hand-knotted carpets today: shed rods and heddles (see Broudy 1993 for survey of examples). A shed rod, like a tension rod, is usually a rigid stick of small diameter (1-5cm), usually made of wood or metal. Unlike a tension rod, a shed rod is never made of cord/rope. The rod is suspended by friction in the warp by passing alternate warps in front of and behind it. A well-tensioned warp is tight enough to hold the shed rod in place, but loose enough that the weaver can move the rod up and down when needed. When brought downwards toward the weaving zone, the diameter of the rod pushes the forward and back threads apart and opens the shed. When pushed upwards away from the weaving zone, the shed closes (Fig. 6.19; also see Fig. 6.5). A loom can only have one functioning shed rod at a time: adding a second would stop the first from working, even if it is for

a different shed. The number of shed rods used in each carpet is recorded as an integer in the **Shed Rod** variable.

Another way to mechanize the shed is to use a heddle. Instead of passing *around* a shed rod, the warps pass *through* or are individually secured to a heddle. While many rigid and flexible heddle types exist around the world, the only type observed anywhere in this ethnography were string heddles. In a string heddle, a bar or beam sits outside the warp (usually in front of it and above the weaver's head). Threads are tied between this beam and individual warp threads. When the beam is pulled away from the plane of the warp, the threads pull alternate warps upward, opening the shed. The movement of the beam can be achieved by physically moving it farther from the warps, or (more often here) by rotating it so that the threads wind around it and slack is taken up (Fig. 6.20). Carpet heddles can be single or double. A single heddle can open only one shed, while double heddles can open two different sheds (but only one at a time). Unlike shed rods, it is possible to add essentially any number of heddles to open any number of sheds, either in singles or doubles. Adding more does not affect the functioning of the existing heddles or shed rods. Textiles with complicated woven patterns, such as brocades, rely on tens or even hundreds of heddles opening as many distinct sheds in sequence. The number of single- and double-shed heddles used in each carpet is recorded as an integer in **Single-Shed Heddles** and **Double-Shed Heddles** in the database.

Shed rods and heddles can both be a loom's only shedding mechanism, or they can occur together. When both appear, they will open two different sheds. No looms were observed in this study with more than two sheds, although twills are known in the carpet record which would

require 3+. Shed rods, single-heddles, and double-heddles appear approximately equally in the sample. Interestingly, several of the weavers (Surveys 1, 2, 4) were observed weaving picks by hand; that is, without using the mechanized system for opening the shed. They instead picked out the alternate warps individually to pass the weft underneath. The reason for this seems to be simply convenience, speed, or personal idiosyncrasy. These looms did have the apparatuses in place to open the shed mechanically, which must have taken considerable effort and time to set up.



Figure 6.20: (String) Heddle

A double string heddle viewed from the left side of the loom. Alternate wool warps (beige) are secured to the top and bottom of the heddle with cotton string (white). When the heddle is rotated clockwise, the top threads pull one shed open. When the heddle is rotated counterclockwise (as now), the bottom threads pull the other shed open.
Survey 16: Ashgabat, Turkmenistan.
Photo by author, May 2023.

Materials

The materials used in the sample carpets are silk, wool, cotton, synthetics, and various blends. Blends are represented with a dash in the database (e.g., wool-synthetic). Each carpet's materials are represented by three variables in the reference table, with one each for the **Warp Material**, **Weft Material**, and **Pile Material**.

Wool is, today and historically, by far the most common material used in Eurasian knotted carpets (Bier 1996:66). This is due to a number of factors, most notably the suitability of the arid Eurasian steppes for raising of sheep and the limited water in those same areas that restricts the wide-scale and intensive cultivation of cotton and flax. Flax, silk, and cotton were all available as domesticated crops at the time of the earliest carpet fragments (early-2nd mill. BCE), so it is not impossible that they were all used. Evidence for cultivated cotton in Eurasia dates from at least the 5th millennium BCE at Mehrgarh in the Indus Valley (Moulherat et al. 2002:1400). Silk is similarly cultivated from c. 2750 BCE in China (Good 1995:962) and appears outside China in the proposed carpet homeland at Sapalli-Tepe in southern Uzbekistan by the early 2nd millennium BCE (Kuzmina 1998:64). Silk textiles were also present in the Pazyryk burials of the south-central Siberian Altai, where the some notable carpet fragments were also recovered (British Museum 1978:25; Høisæter 2017:350; Rubinson 1990:54; Rudenko 1968:5, 1970:206). This tells us that the group certainly had access to both carpet manufacture and silk in their local or extended trade network. Despite the possibility and apparent opportunity to use silk or cotton fibers in the earliest carpets, no examples of such appear before the Medieval period. At that point, physical remains and thorough documentation tell us that both silk and cotton are used in luxury markets,

including the court carpets of the Ottomans, Mamluks, Safavids, and Mughals (Bier 1996:70, 78). Silk carpets start to appear in stately European homes at a similar time (Bidder 1964:26). Despite the popular use of silk in China, firm evidence for its use in Chinese carpets doesn't appear until the mid-Qing Dynasty (c. 1800 CE) when carpets with both silk and cotton components are reported in official documents in Lop, Xinjiang (ibid.). In fact, it may be that to the Chinese, who did not have a substantial wool-processing tradition in the 1st millennium BCE, Central Eurasian wool was the luxury commodity (Høisæter 2017:355). The modern carpets used in this study, on the other hand, include cotton and silk in addition to wool, plus some use of synthetics. Although there is primary physical evidence for very early knotted pile carpets made of linen (flax) in ancient Egypt, the practice did not survive into the common era in any notable quantity.

Wool has some qualities that make it well-suited to carpet manufacture. It is very absorbent, which helps to wick moisture and minimize flooding or dripping in household and clothing applications. The absorption qualities also allow it to take dye well, allowing for a wider range and finer control over colors and motifs. The natural oils in wool also provide dirt and insect-resistant properties, allowing carpets to last longer and stand up better to wear (Bier 1996:67; Cybulska & Maik 2007:186). A downside of wool, particularly in the early domesticate era, is that it has a scaly structure which makes threads catch on each other more than cotton or silk do. Producing even, consistent textiles with wool therefore takes a bit more skill than similar applications of cotton or silk (ibid.).

Selvedges

The selvedges are sections of flat weaving that make up the top and bottom edges of a knotted carpet (Fig. 6.21). They are differentiated from bindings, which are present on the left and right sides (see the Binding section below). The foundational selvedge is found at the bottom of the carpet and is the first set of weaving performed on the loom. Yarn, often a plain color and frequently the same stock as the warp threads, is woven in a flat-weave pattern across the full width of the warps. The selvedge generally has plain edges without any kind of side binding or border, and decoration within the selvedge is usually nonexistent or limited to colorful stripes. Selvedges generally range from 2-10cm in height, but some carpets do not have selvedges at all.

Most often, the selvedge pattern is a simple 1/1 tabby (plain weave), although there is no technical-structural reason that a twill or other woven structure could not be used. However, 1/1 weaves are by far the most common, as they are relatively quick to produce, usually use the same sheds as the knotting so no new heddles or shed rods are required, and they create a durable, sturdy section of weaving. The sheds are opened alternately using heddles and/or shed rods, and the yarn is passed through on shuttles, bobbins, in butterflies or skeins, or as a single loose thread. Consecutive rows of selvedge are packed together tightly using a beater (see the Beater section below).

The function of the selvedge is twofold: first, it provides a stable foundation against which the knots can be compressed. Without the selvedge, the force of packing the knots and weft-shots downward would cause the weaving to slip down the warps, particularly in the first few rows before sufficient friction is built. The selvedge eliminates this problem by building the

friction and stability of position before the knots are added. Any lingering looseness or off-level weaving, particularly in the first few rows of selvedge, can be tightened after weaving is complete. The large variation in the amount of selvedge added is primarily due to this friction-building goal: more rows of selvedge provide a stronger, more immobile base for the knots. This is especially apparent in silk carpets where the fibers are smoother and have less natural friction, and a wider selvedge is required to prevent slipping (see Fig. 6.21c). Very wide selvedges can be partially unwoven from the ends after the carpet is removed from the loom, so the finished product may have a smaller selvedge than the weaving process would suggest.

The second function of the selvedge is to provide a neat, sturdy edge to the finished carpet. Because the knots are inherently rounded and irregular, and because knots left on the edge tend to curl under, a selvedge is used to neaten and flatten the edge. The selvedge also gives the carpet extra durability in use, as any damage caused to the edges or fringe will be distributed away from the knots. A carpet can be re-tensioned and the selvedge re-woven if damaged, and this is commonly observed in antique carpets used in private homes.

All of the ethnographic carpets collected in this study have 1/1 tabby selvedges. They range in pick count from 0 to 60 per selvedge, with the majority having 10-16. The table in Appendix C includes 6 variables relating to the selvedge. These are split into **Top** and **Bottom**, referring respectively to the selvedge present at the top of the woven carpet and at the bottom (from the weaver's perspective). The top and bottom are each represented by **Picks**, **Strankds**, and **Weaves**. **Picks** refer to the number of weft picks present in the selvedge (as above, these average 10-16). **Strands** refers to the number of yarns used in each pick: these strands are treated

as a single unit, but are not plied together. An asterisk (*) in the **Pick** or **Strand** variable indicates an estimate. **Weave** refers to the weaving pattern, represented by a fraction as is common in technical weaving documentation. The two parts of the fraction refer to the number of consecutive warps the weft passes over and under, in repeat. A 1/1 fraction represents an over-one, under-one pattern (also known as a tabby or plain weave). The phrase "match" is used to indicate that the opposite side of the carpet appears to generally match the measured side, but that direct study of both ends was not possible.

Knots / Pile

The knots make up the pile of the carpet. Knots are hand-tied individually to the warps (as opposed to being woven in), and their loose tails stand up in the z-axis to make the carpet's distinctive, plush surface (Burnham 1980:78). Because the knots are tied individually, they can be a different color than their neighbors. This allows the weaver to create a much more intricate design than is generally possible in flat-woven textiles, because the knots work together like pixels on a screen or tiles in a mosaic to form the macroscale image from microscale components.

Many types and variations of knots known around the world: common types include asymmetric, symmetric, wrap, jufti, and Spanish (ibid., pgs. 78-81; Fujii & Sakamoto 1990:49; see Fig. 6.2). Asymmetric and symmetric knots are usually tied around two consecutive warps, jufti knots are usually tied round four consecutive warps, and wrap and Spanish knots are usually tied around a single warp (Eiland Jr. 1973:23). The wrap and Spanish varieties could be considered pseudo-knots, as they lack the complexity and security generally implied by the word "knot".

However, they operate in the same way as the other types. Although these and many other variations of knots exist worldwide, only the symmetric and asymmetric are very common among weavers of the last millennium (Moshkova 1996). These plus wrap knots are the only types that appear widely in either the modern or historic sample in this study.

Knot types are generally regional in the vaguest sense, and so they are often associated with regional names. Symmetric knots are sometimes known as “Turkish” or “Ghiordes” knots (for the town Gördes in western Turkey) (Burnham 1980:78-81). This type is historically associated with the Middle East, Turkey, and the Caucuses. Asymmetric knots are sometimes known as “Persian” or “Senneh” knots (for the historic name of the town of Sanandaj in western Iran) (Burnham 1980:78-81). These knots are historically associated with Iran, Central Asia, South Asia, China, and Egypt (Seager 1964:120). Spanish knots are linked to the Iberian Peninsula, although they also appear in North Africa, including Egypt (Eiland Jr. 1976:23). Although these geographical names are extensively used in scientific, cultural, and art publications, I do not like them, as they give the misleading impression that A) these knot forms are linked exclusively to Turkey and Persia/Iran today, and B) that the knot forms were linked exclusively to these regions in the past. Both are untrue. Therefore, these geographic terms are not used here despite their widespread popularity.

Although it is inaccurate to link specific types of knots to any place or culture in perpetuity or to use them as silver bullets for provenance, it is true that specific communities in specific time periods will vastly prefer one knot type to others, likely due to the engrained nature of fine motor-gestures in craft education and tradition maintenance (see references for regional knot terms

above, and the discussion of communities of practice in Chapter 3). Children and students learn the craft from a parent or teacher who passes along the knot type she is most comfortable with, until entire communities favor one style. 20th century scholars, particularly out of the Soviet Union/Russia, have performed ethnographies matching different Central Asian ethnic and tribal groups to different knot types. A summary of their findings is given in Table 6.1, along with comparative data from this study. These techno-cultural links have been used by merchants and scholars to provenance new and historic carpets throughout the 20th and 21st centuries.

As far as my experience suggests, symmetric and asymmetric knots are comparable in time requirement, stability, and final appearance. I do not know of any formal study that tests these qualities empirically. They would be impossible to tell apart from 10+ centimeters away, and even a professional would need to study the structure closely to determine which were used. Differentiating them often requires the removal of knots, unless a section is already damaged and can be viewed in cross-section. In this sense, we can consider symmetric and asymmetric to be two versions of similar quality. One weaver interviewed for this project argued that asymmetric knots are faster to tie than symmetric knots (Survey 1), but this belief does not seem to be wide-spread as no other weavers gave this reply when asked why they use one knot type over another. There have also been suggestions that symmetric knots are stronger and asymmetric knots more delicate (Survey 1; Böhmer & Thompson 1991:31), but there is no formal study to confirm this either. It is worth pointing out that some Turkmen weavers, including all of those represented in this study, use asymmetric knots for the bulk of the weaving but use symmetric knots on the vertical borders. This may be done to strengthen the edges (Eiland Jr. 1976:21; Moshkova

Group	Sub-Group	Knot Type (published)	Knot Type (this study)	Notes
Arab	Kashkadarya	Both [3]	-	-
Chinese	-	Asymmetric [4, 5]	-	-
Karakalpak	-	Asymmetric [3]	R-Asymmetric [A] Symmetric (pro workshop) [B]	[A] Khorezm cottage industry [B] Professional workshop
Kazakh	-	Asymmetric [3]	Both	-
Kyrgyz	Ilichik	Asymmetric [3]	-	-
Turkish	-	Symmetric [5]	-	-
Turkmen	Choudor	Asymmetric [3]	-	-
Turkmen	Ersari	Asymmetric [3]	-	-
Turkmen	Igdyr	Both [3]	-	-
Turkmen	Salor	L-Asymmetric [1, 3]	-	-
Turkmen	Saryk	Symmetric [1]	-	-
Turkmen	Shiikh	Asymmetric [3]	-	-
Turkmen	Tekke	Asymmetric [1, 3]	R-Asymmetric	Use Symmetric knots at vertical edges to strengthen [2]
Turkmen	Yomud	Symmetric [1] Both [3]	-	Use Symmetric knots at vertical edges to strengthen [3]
Uzbek	-	Asymmetric [3]	R-Asymmetric [A] Symmetric (pro workshop) [B]	[A] Khorezm cottage industry [B] Professional workshop
Uzbek	Nurata Basin	Asymmetric [3]	Symmetric	-

Table 6.1: Eurasian Knot Types, 20-21st centuries CE

The types of knots commonly used by different Central Asian ethnic/tribal groups. The direction of opening is given for asymmetric knots. Table by author.

(1) Tsareva 1984 (2) Tsareva 2016 (3) Moshkova 1996 (4) Bier 1996 (5) Eiland Jr. 1979

1996:60; Tsareva 2016:57), although it may have more to do with correcting the asymmetric knot's natural sideways lilt and unevenly distributed bulk, to ensure a neat, straight, and symmetric edge at both sides of the carpet. Unfortunately, due to international communications issues into Turkmenistan, it was not possible to get an explanation of these knots directly from the weavers.

Jufti knots are symmetric or asymmetric knots that have been stretched across four warps instead of two (Eiland Jr. 1973:23). These are generally viewed as a lower-quality time-saving measure, as they are easier to pull out when snagged and create a less dense piece by half, but are twice as fast to produce (ibid.). They have historic roots in Khorasan, but are becoming more popular to meet demand for hand-knotted carpets elsewhere (ibid.). No true four-warp jufti knots were observed in this study, although some symmetric knots on the edges of the modern Turkmen sample did include three-warp knots (TK-MA-2, 4, 5, 8, 9; see the structural diagrams in Appendix B). As the three-warp variety is not consistent across the whole Turkmen sample, I suspect they are a way for the weaver to accommodate an extra/miscounted warp, rather than an intentional and planned choice. As a true jufti knot uses four warps and a traditional symmetric knot uses two, these three-warp edge-knots in the Turkmen sample are not fully described by either category, but could be described as a variation of either.

The last type of common knot is the wrap knot. While perhaps a little faster to tie, wrap knots create a less dense (and therefore less wear-resistant, waterproof, windproof, insect-proof, and dirt-proof) textile (Buckley 2025). They are also easier to pull out if snagged. These knots are the simplest and possibly most ancient form of knotted pile: they appear in fragments from some

of the oldest surviving textiles, including objects from Taklamakan oases sites in west China (1st cent. BCE) (Zhang 2019:40), the Parthian Al-Tar site in Iraq (2-4th cent. CE) (Fujii & Sakamoto 1990:49), and the Al-Sabah collection pieces included in this study, collected from the Khorasan region in eastern Iran and dated as early as the 1st century CE (see summaries in Spuhler 2014).

The knot types are represented in the database under the **Knot Type** category as SY (symmetric), AS (asymmetric), or WR (wrap). True jufti knots do not appear in this sample.

Asymmetric knots, as the name suggests, are non-symmetric. Their two tails are positioned on one side, while the bulk of the knot's body is at the other (Burnham 1980:79-81). This is known as the knot's direction or the opening direction (Fig. 6.22). Left-opening knots have their tails to the left and the knot body to the right, and right-opening knots have their tails to the right and the knot body at the left (ibid.). Like the knot types themselves, there is evidence that the opening direction may have some general geographic patterns, and weavers within the same community of practice usually make knots that open the same way (Tsareva 2016:15). Overall, the left-opening variety is more common in historic collections; it has been suggested that only the Turkmen routinely make knots that open to the right (Eiland Jr. 1976:21), but the data from this study do not support that. The direction of asymmetric knots is given as **Knot Direction**, either L (left) or R (right).

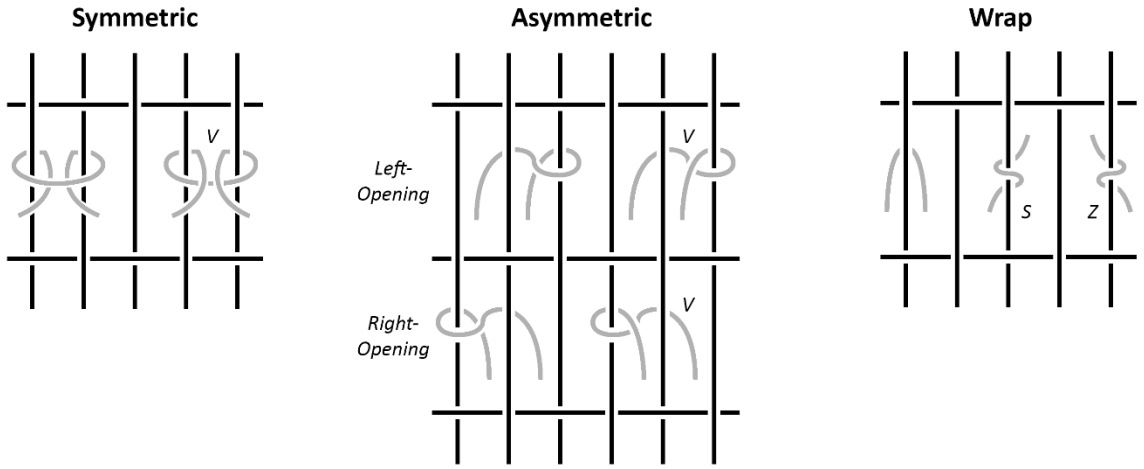

Figure 6.22: Types of Knots, Prefixes, and Directions

Symmetric knots have no direction, but variants (V) are possible.
Asymmetric knots must have a direction of opening (L or R), and variants (V) are possible.
Wrap knots can have no direction (single-wrap), or a twist direction (S or Z), and variants are not possible. Figure by author.

I did not find any consistent classification scheme for wrap knots, and so had to invent my own from scratch. I give wrap knots **Knot Directions** as well, representing the three main forms that wrap knots take in this sample (Fig. 6.22). The simplest wrap knot simply loops behind the warp in a U-shape: it is not really a knot or even a wrap. These knots are given no **Knot Direction**. These knots are structurally identical to a cut pile (Burnham 1980:32; see Fig. 6.2) – the two types can be distinguished by variation in color, ply, or fiber within a single pick. A cut pile will generally require all the "knots" in a single row to match (or if they do not match, to have a weft float across the back), while individually-tied wrap knots need not match, and do not require a weft float. As the very earliest pile textiles are woven (not knotted) pile, it may be a reasonable jump in

technology and logic to move from woven pile to simple, individually-tied wrap knots before moving to more complex symmetric and asymmetric knots.

When the yarn is wrapped 720° or more around the warp, it becomes a true wrap. These knots are described by the direction of the wrap as is used in many studies of yarn twist and ply: s-direction and z-direction wraps. When viewed side-on, an *s* wrap takes the form of a typographic S, with the central diagonal running northwest-southeast. When viewed from the end in cross-section and wrapping towards the viewer, the yarn appears to wrap in a clockwise direction. Wraps in the z-direction are the opposite: when viewed side-on, a *z* wrap takes the form of a typographic Z, with the central diagonal running northeast-southwest. In cross-section and wrapping towards the viewer, the wrap seems to run counterclockwise. These two varieties are indicated in the **Knot Direction** as S or Z. Symmetric knots do not use a **Knot Direction**, as they are directionless/symmetric.

I add another variable to account for variant forms found in both asymmetric and symmetric knots. These are the same knot, just inverted vertically. The non-variant form is the more common type, and what is found in most technical discussions of knot shapes and observed in this ethnography. The variant types are less common but do appear in some of the historic carpets studied here. The difference between the standard forms and the variant forms considers whether the tails of the knot are "trapped" under the body of the knot. In standard forms the tails are trapped, and in variants the tails rest on top of the body and could be considered loose. Because these variants depend on the perspective of viewing (a standard form becomes a variant when flipped 180°), they are classified from the weaver's perspective as discussed already. **Knot**

Variants are given as Y (yes a variant) or N (not a variant) in the database (Fig. 6.22). Wrap knots do not have a **Knot Variant** form, as they appear the same when flipped 180°.

In the database, the predominant knot forms are given. These represent the majority of the knots and can be considered a good approximation of the carpet. However, there is nothing to stop a particular weaver from distributing different knot forms throughout their work either in pattern or at random. As already discussed, some of the modern Turkmen carpets have different knot types along their vertical edges. Some of the historic fragments have similar inconsistency. As a single carpet may have thousands or even millions of knots, it is outside the scope of this study (or likely any other) to check each knot individually and create a fully-comprehensive description. A selection of knots was checked at random across the body of each carpet, and the knot type(s) represented most frequently there is used to describe the entire carpet.

To make a fluffier, fuller knot and to account for variation in yarn diameter (particularly for hand-spun yarns or after dying), many weavers use more than one strand of yarn to tie their knots. As in the selvedge, these strands are not plied together but are just drawn side-by-side. The standard number of strands used in the knots is recorded as **Strands Per Knot**. Half-plies are used to indicate variability in the yarn stock, usually between different colors (i.e., some colors consistently use 2 strands while other colors consistently use 3). This type of variation was only ever documented between two consecutive integers (e.g., 2-strand red, white, and black and 3-strand blue, yellow, and green → 2.5 strand in the database).

In addition to the shape of the knot itself, it is also important to record its position in relation to the surrounding warps and wefts. Five additional variables capture these data: **Knot-**

Warp Pattern, **Knot-Weft Pattern**, **Knot Spacing**, **Knot-Row Offset**, and **Knotting Shed Position**. This information provides more details on the weaving process, the types of shedding mechanisms required, and records community and personal idiosyncrasies. As this study works primarily with knot shape and size as the analytical units, these aspects of warp/weft structure are also relevant for how they would affect the knot.

The **Knot-Warp Pattern** refers to the physical position in the z-axis of a knot's two base warps, relative to the average X-Y plane of the finished carpet. The structure of the weaving, the shedding system, and the type of loom used can force alternate warps to be slightly raised/depressed in their final position; this variable describes how pairs of consecutive warps are positioned relative to each other. When alternate warps are raised/depressed, this is known as *double warpi*ng (Bier 1996:69; Eiland Jr. 1976:23). Double-warps can be used to increase the weaving density, as the warps can sit closer together in the x-axis when slightly offset in the z-axis. This is particularly useful for woolen warps, as the scaly fibers will tend to catch and start to felt if repeatedly weft-beaten. By off-setting the warps slightly, they can sit closer together without becoming matted (Pfifster & Bellinger 1945:2). This has the side effect of increasing the number of knots in the carpet but decreasing their individual size, leading to increased resolution in the image. Knots tied around raised/depressed warps sit at an angle and jut out slightly into the Z-axis, rather than directly along the X-Y plane of the carpet's surface. Three options for the warp position were defined here as I, II, and III. Pattern I has two warps that sit on the same plane: whether that plane is depressed or raised is not a meaningful distinction. Pattern II has the left warp raised/the right warp depressed. Pattern III has the right warp raised/the left warp

depressed (Fig. 6.23). Asymmetric and symmetric knots can occur in any of these three patterns, but wrap knots can occur only in pattern I (because there is no second warp to compare to, it is not meaningful to say if the warp is raised/depressed). Because this variable is concerned only with the warp's effect on the shape and position of the knot, it is not important to specify whether a separation in warps is caused by one being raised vs. one being depressed relative to the average plane of the carpet: it is enough to know that they are offset relative to each other, regardless of whether they are centered slightly above or slightly behind the weaving plane.

This variable references the positions of the warps & knots in the completed carpet and may not reflect the position of the warps or the opening of sheds during weaving (see **Knotting Shed Position** below). All of the sampled carpets use a single **Knot-Warp Pattern** throughout their entire structure.

The **Knot-Weft Pattern** describes the way in which the weft picks immediately above and below the knot interact with the knot's warps. The relative position of the weft inherently pushes the warp out of true vertical, which in turn may affect the final shape of the knot. Sixteen weft patterns were categorized, named A-R (Fig. 6.23). Note that for typographic clarity, there is no pattern I or pattern O. These sixteen patterns describe the possible combinations or four weft patterns, which can be read left-to right regarding how they pass over/under the warps: under-over (blue wefts), over-under (red), under-under (purple), and over-over (orange). As with the **Knot-Warp Pattern**, asymmetric and symmetric knots can occur in any of the sixteen **Knot-Weft Patterns**. Wrap knots, however, can only occur in patterns A-D because they only interact with one warp and therefore have fewer possible combinations. Carpets that routinely use multiple

patterns (often in a repeating sequence) have all their major patterns indicated by a semi-colon in the database.

Approximately half of the sampled carpets use a consistent **Knot-Weft Pattern** throughout their entire structure. The other half uses two different patterns, usually alternating relgularly, which are shown in the database with a semi-colon. Occurrence of the dual-pattern variable is due to the weave pattern of the weft shot, which is discussed below.

Although conceptually related to the warping system, shedding system, and weft weaving patterns, the **Knot-Warp Pattern** and **Knot-Weft Pattern** variables are specifically interested in how the position and interaction of the threads immediately around a knot might affect the knot's size, shape, position, or angle in the finished piece. Consideration of the warp & weft positions in their own right is given later in the classification system.

In most carpets, knots are tied on every pair of warps without gaps or overlaps. This helps to create a durable and impermeable surface without adding unnecessary bulk, and creates a level plane for onward weaving without potholes or hillocks. However, it is possible to skip warps with any knot type, or to overlap multi-warp knots (Fig. 6.24). The variable **Knot Spacing** is used to capture this positional pattern and describes the number of empty warps between one knot and the next consecutive knot in the horizontal row. When knots sit consecutively without gaps or overlap, the **Knot Spacing** is listed as zero. When there are empty warps between consecutive knots, the number of empty warps is given as a positive integer. When knots share warps and overlap with each other, the number of shared warps is given as a negative integer. In this set of carpets, only gaps and overlaps of ±1 warp were recorded, and the vast majority of knots sit side-

by-side without gaps or overlap (spacing of 0). Because wrap knots use only one warp each, it is not possible for them to overlap in this system: two wrap knots sitting on the same warp would be considered a single knot, just with more circuits around the warp. As in the **Knot-Weft Pattern**, most carpets use a consistent **Knot Spacing** throughout: the few carpets with consistent variation have the different patterns separated by a semi-colon in the database. These dual-spacing patterns were seen to occur only when wrap knots were involved, possibly as a method for refining the pattern (i.e, using a combination of whole and half-sized knots to make smoother shapes).

In the same way that the **Knot Spacing** describes the shifts in alignment between knots in the same row, the **Knot-Row Offset** describes shifts in knots on the same column. In other words, it describes how one row of knots is offset horizontally from the rows that precede and follow it. In the simplest (and most common) **Knot-Row Offset**, the warps are always paired off in the same way in every row. The knots appear as regular, straight columns. This is described as a **Knot-Row Offset** of 0, where there is no horizontal shift between consecutive rows of knots (Fig. 6.25). When consecutive rows are shifted relative to each other, different warps are paired off in row A vs. row B. The resulting pattern is a herringbone. This herringbone-style **Knot-Row Offset** is described as 1, where there is a 1-warp horizontal shift of pairings between rows. Because a horizontal shift to the left or to the right would look structurally identical and is not a meaningful distinction, the direction of shift cannot be given. Similarly, as a shift of 2 (or any multiple of 2) would return the knots to the regular grid pattern of 0, the **Knot-Row Offset** cannot be higher than 1. All even-numbered offsets are already captured by 0, and all odd-numbered offsets are

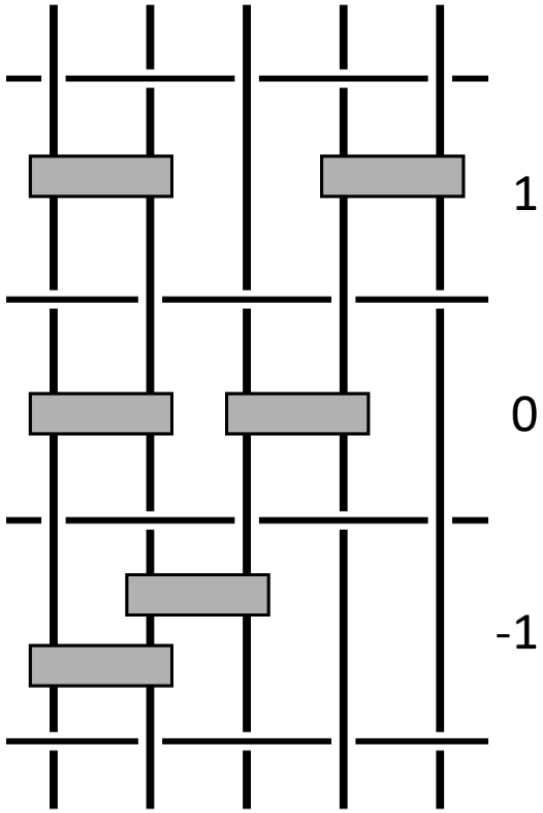

Figure 6.24: Knot Spacing

The number of empty warps between consecutive horizontal knots. Each grey rectangle represents one asymmetric or symmetric knot. Figure by author.

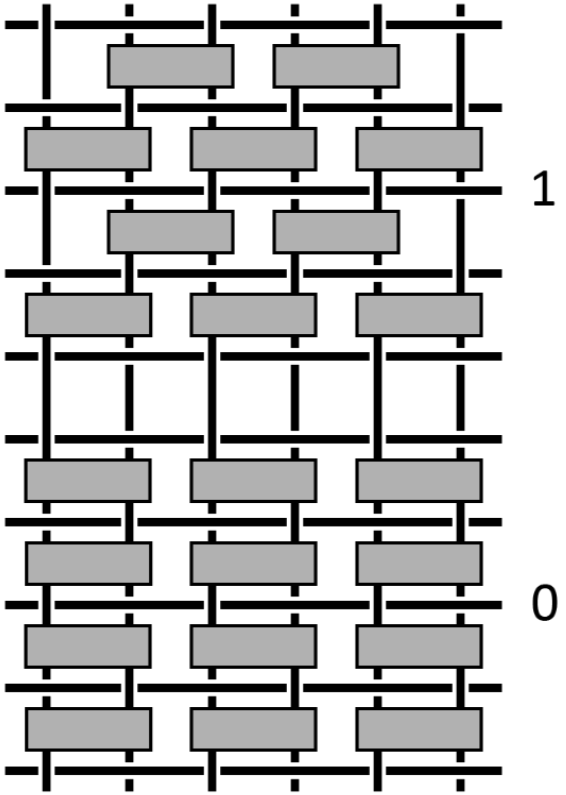

Figure 6.25. Knot-Row Offset

Whether consecutive vertical knots sit on the same pair of warps (0) or are offset in a herringbone pattern (1). Each grey rectangle represents one asymmetric or symmetric knot. Figure by author.

captured by 1. Most carpets use a **Knot-Row Offset** of 0 throughout, where the same warps are always paired off in knots.

The last characteristic of the knot shapes & positions is **Knotting Shed Position**. This variable describes the mechanical position of the warps when the knot was tied. In other words, it tells whether or not a shed was mechanically held open by a shed rod or heddle when the knot was tied. An open shed will increase the distance between warps, including those used in individual knots. This increased distance during knotting would tend to result in a larger knot being tied with longer yarn. When the shed is later closed, the warps return to a single plane and sit closer together, which slightly loosens the knot. A slightly loose knot may appear differently to one that was tied tightly. The **Knotting Shed Position** is given in three categories: closed, partial, and open (Fig. 6.5). When closed, there is no shed being held open by the loom. However, this is not to say that the warps are sitting on a flat plane: other structural factors, such as a native shed, can cause the warps to sit slightly offset even when the loom is not mechanically opening a shed. However, the warp-separations that remain even when the sheds are closed usually remain into the finished carpet, and therefore would not be expected to cause any loosening of the knots. This permanent physical offset of the warps is covered in the **Knot-Warp Pattern** variable, described above.

If the **Knotting Shed Position** is given as open, this means that the weaver made an active choice to mechanically open a shed before tying the knot (or at the very least, they didn't make an active choice to close the shed before tying the knot). In an open position, the loom is holding consecutive warps apart, away from their natural position (see Fig. 6.5). This shedding could be

done with a heddle or shed rod, as discussed already in the Shedding section. Finally, there is a partial option. This option acknowledges that in certain loom mechanics, particularly those which use shed rods instead of (string) heddles, it is not possible to close the shed completely. Instead, it always exists on a scale from slightly open to completely open. In these systems, a completely/intentionally open shed would be categorized as open, while partial is used to note that the weaver "closed" the shed to the extent possible in this system, and any remaining separation between warps is unavoidable and unintentional (see Fig. 6.5).

It is possible to create a double-sided textile by working simultaneously from the front and back of the loom and tying knots in each direction (Fig. 6.26) – I have witnessed this process on several occasions in Turkmenistan. This creates pile on both sides of the textile and completely obscures the underlying warp and weft. As with the primary knots on the front, the knots on the back can be any shape and any color, and they do not need to match those on the front. The two sides can have different offsets and shedding positions, they can sit in the same pick or be separated by a weft shot. Today, double-sided knotting seem to be a display of skill more than a practical feature, but many of the world's oldest carpet fragments (including some in this study: MU-AS-1, 3, 5, 7, 9-10, 14-18) have double-sided knotting. When double-sided knotting is used historically, one side is the decorative side with fine-spun yarn, dyed colors, and intentional design, while the other has coarsely-spun (or even unspun) wool in its natural coloring. This may be a way to increase water-resistance, and to create a soft, warm layer of insulation when worn against the skin (Collingwood 1968:246; Zhang 2019:44). When observed in historic carpets in this study, the "back" knots were much less dense than the "front" knots, occurring after every

few rows of front knots rather than alternating 1:1. For simplicity, only the front/decorative knots are studied in this analysis. A future study could be performed that focuses on double-sided carpets.

The density of knots in a carpet, like the shape of the knots themselves, is used as a widespread indication of origin and quality (Eiland Jr. 1979:14). Higher-density carpets are generally understood to be higher-quality, due both to the vastly increased labor requirement and to the improved design resolution. It is worth pointing out that increased time commitment is not necessarily synonymous with increased skill in the weaver, or quality in the finished textile (Böhmer & Thompson 1991:31). However, the density is a wide-spread method for quickly characterizing carpet quality. In general, village or "tribal" (nomadic) carpets are expected to have a lower knot density, while city, workshop, or other specialized carpets are expected to have a higher density (Bier 1996:74). An average-quality modern Turkmen carpet produced for export will have 250,000 knots per square meter, while a fine, luxury carpet may reach 450,000 k/m^2, and low-quality carpets may have only 100,000 k/m^2 (Bier 1996:72; Eiland Jr. 1976:1979; Hodjamukhamedov & Dovadov 1982:22; Tsareva 1984:12). The ethnographic carpets in this study range from 41,500 k/m^2 to 442,000 k/m^2, with the lowest-density carpets produced by a cottage-industry weaver in multiple fibers, and the highest-density carpets by professional workshop weavers in silk.

Separate from the shape and structural relationship of the knots, the order in which the knots were added to the carpet is also recorded. This is within each row, as only one row is accessible at a time (working from the bottom of the carpet upwards). When in a knotting phase,

there is no required order in which to add the knots: any knot in the row can be added first, and the weaver can progress from there in any order. As most carpets have hundreds if not thousands of knots in each row, it is not realistic to document the exact sequence of every knot in every row. Instead, a generalized order is given in the **Knotting Order** variable. Some weavers self-reported working consistently from one edge to the other, tying each knot in sequence (like writing a line of text, where each letter is written in the order it will be read). This probably minimizes the chances of errors because the weaver does not need to count out empty warps, but it may slow them down if they need to regularly change colors between knots. Carpets woven with this sequence are categorized as D (directional) with the direction of movement given as L-R (left to right) or R-L (right to left) (Fig. 6.27).

Other weavers use a color-based sequence, which minimizes the time they spend switching colors between knots. The weaver picks a color and ties all the required knots in that color before switching to another. The knots in a particular color may be consecutive or not, and therefore may sometimes need to be counted out across empty warps. This system would be akin to writing all the L's in a sentence, then writing all the C's, etc., until the entire sentence has been written out. Carpets knotted one color at a time (per row) are listed as 'color' (see Fig. 6.27).

Finally, some weavers use a design-based sequence where they complete one entire motif unit before moving to another. They might create the main medallion knots first, followed by the minor motifs, followed by borders, and finally fill in the solid background. An analogue to a written sentence would be to write all the nouns out first, then the verbs, then adjectives and adverbs, then articles and other filler words. This pattern may be a mix of the other two, where sometimes

colors are maintained between consecutive knots and sometimes colors have to be swapped between consecutive knots, and where some knots would have to be counted out across empty warps, while others could be built consecutively. This method is categorized as 'pattern' (see Fig. 6.27).

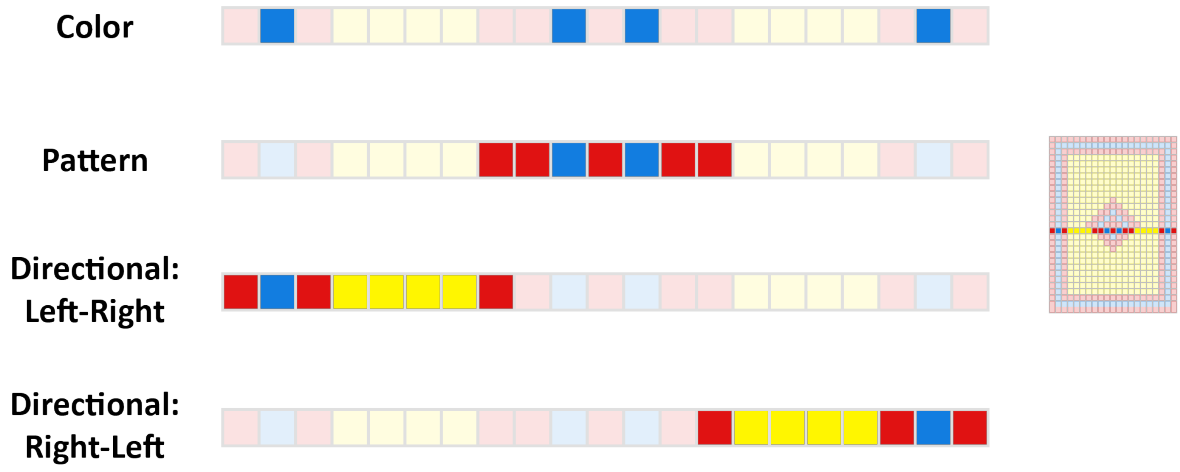

Figure 6.27: Knotting Order

The order in which the weaver tied knots in a particular carpet row. Figure by author.

Color: Weaver adds all the knots of one color before moving to another color [blue here].

Pattern: Weaver completes a whole design motif before moving to another [central medallion here].

Directional: Weaver knots consecutively from one side to the other.

As even a small, low-quality carpet can have thousands of knots and larger, higher-quality carpets easily get into the millions, the decorative patterns can be extremely complex. Especially for repeating and geometric motifs where the weaver usually wants consistency across the carpet, careful attention to the design plan is generally required. Some weavers, particularly those

with more experience, have memorized various patterns and are able to execute them accurately without reference to a diagram or instruction (Bier 1996:74; Tsareva 1984:10). Other weavers do not know the designs by heart and need to check each knot's color against a diagram before tying it. Of course, many weavers fall somewhere in between, where they can execute some sections of a design from memory but require instruction for other areas. When a reference is required, weavers use a *cartoon*: a diagram drawn on graph paper, where each square represents one knot (Absamatova 2017; Fig. 6.28). The weaver moves through the diagram one row at a time, tying knots in the colors and positions indicated (ibid.). Cartoons are often drawn "in-house", although there are professional designers producing commercial cartoons for purchase (ibid.).

Hand-drafting a design requires a strong grasp of carpet weaving and special reference to the techniques and skills of the weavers who will use the design. This is because carpet knots are rarely perfect squares: they may be portrait or landscape rectangles, which would result in vertically or horizontally stretched designs respectively. Either, or preferably both, the cartoon-drafter and the weaver need to be aware of the techniques and average shapes of the knots to account for the transition from paper to carpet and ensure a carpet with the desired visual effect (Böhmer & Thompson 1991:31; Fig. 6.29). Symmetric knots are particularly susceptible to this type of distortion (ibid.), and therefore there is a general belief that the use of asymmetric knots is an indication of increased design and weaving skill, as they create more precise shapes and smooth curves (Bier 1996:75; Moshkova 1996:232). The use of a double warp also contributes to this distortion effect, as the depressed warps take up less horizontal space and therefore shrink the design in that direction (Böhmer & Thompson 1991:32). These methods for increased design

precision, and the designer-weaver relationship required to produce accurate designs, may be an indication that these characteristics are more likely to occur in sedentary and/or specialist spaces, versus in pastoral communities where movement and inconsistent personal interactions are more likely (ibid.).

Alternatives to drawn cartoons are *ta'lim*, where the individual knot colors are written out in sequence to be read off in order (Böhmer & Thompson 1991:31-32). These sequences can be read by the weaver as she works, or they can be read out to a group by a designated reader (ibid.; Tuck 2006:540). Repeated calling-out of familiar patterns have been shown to transition over time into music, where the consistent sequences form metrical units with verses and repeated choruses. Historic evidence for the singing of weaving patterns appears in the Rig Veda and the Odyssey (Tuck 2006:539-545), although it can't be said that these refer explicitly to knotted textiles. This practice persists into the modern period: the Afghan war rugs (kilim) that gained international fame in the 1980s following the USSR's invasion of Afghanistan were sometimes sung out (ibid.). Weavers in other modern cultures have been documented singing their weaving as well, including in India and among the Diné of North America (Bulow 1972:58, quoted in Tuck 2006:545).

Larger-scale professional workshops mostly no longer use knotted-from-memory designs, nor do they usually rely on a designer to hand-draw cartoons on graph paper as was the standard for many centuries. Instead, these workshops generally use digitally-generated designs produced by trained professional designers that ensure accuracy and symmetry, which are printed in segments for the weavers (Absamatova 2017). These could be designed in-house or be purchased

from a design studio, and can be used to make one-off carpets or for mass-manufacturing. A notable exception to the use of digitally-generated cartoons in professional spaces are the silk carpet workshops in Samarkand and Khiva. Founded with UN funding and a mandate for heritage retention, they emphasize natural materials and traditional methods. Their cartoons are still drawn by hand in-house (see Fig. 6.28b, c), as are the cartoons of the rest of the weavers included here.

In this study, the use of cartoons was recorded in the **Cartoon Use** variable. Three levels of use were categorized: none, sporadic, and continuous. When a weaver did not use a cartoon at all/had the design entirely memorized, the carpet is recorded as 'none' (no cartoon use). When a weaver reported needing continuous and consistent reference to the cartoon to reproduce the design, the carpet is categorized as 'continuous'. When a weaver fell somewhere in between, where she needed the cartoon for some sections but not others, or where she used the cartoon to double-check work that she thought was memorized but that she wasn't confident in, the carpet is categorized as 'sporadic'. These levels are based on the weaver's self-reporting, and were not checked directly by the author because an effective check would have required observation of the entire weaving process across several months.

Although the method used here acknowledges the use of cartoons and variable knotting-orders to reproduce a design accurately, the patterns themselves are not studied. Social-cultural connotations, symbolisms, color preferences, or motif histories are outside the scope of this work. Similarly, the weaver's accuracy in copying a cartoon was not measured here. The weavers did report various attitudes to mistakes though, ranging from one weaver claiming not to have

made one in several years (Survey 2), to other weavers reporting that they would only bother to correct a mistake if it was significant to the design and obvious from a distance (Survey 14).

Weft

The weft, like the warp, is part of the carpet's underlying structural grid. Because knots are (usually) tied on the same pairs of warps in each row, a weft is required (Burnham 1980:72). Without a weft, the stacks of knots would not be connected to each other except at the selvedges and would fall apart like the coils in a slinky. The weft binds the rows together horizontally, acting as a basic structural component of the finished piece. In the course of the ethnographic work, the weft structure and method were found to vary more than any other part of the carpet weaving process. Various explanations for different types of weft shot were given, including to make the carpet sturdier, thicker, or stronger. Here, I use the phrase *weft shot* is used to reference the set of all weft lines that occur between consecutive rows of knots. The individual lines are called *picks* (Burnham 1980:99).

The simplest aspect of the weft shot is the number of picks. Although only one pick is required between rows of knots, many weavers add additional rows. The choice of pick count was usually explained as a strength consideration, with additional wefts adding strength and stability to the carpet by making it denser. It is also likely that the addition of a specific number of weft picks helps to correct aspect ratio differences between square cartoons and non-square knots (see the Knot section above, and Fig. 6.29). By adding more or fewer weft picks, the weaver can stretch and compress the pattern vertically, correcting (or amplifying) distortion in that direction.

This relationship is likely unconscious for many, as only one weaver mentioned it (Survey 8) when asked to explain their choice of pick count.

While there is no structural limit to how many picks can be used between knot rows, there is a visual correlation between the number of picks, the length of the pile, and the final appearance. A certain number of picks can be hidden by the fluff of the pile (Collingwood 1968:236). Eventually, additional picks spread rows of knots too far apart and will create a ridged texture like corduroy. Spread even further, the weft shot becomes clearly visible and takes over as the primary visible surface of the object. To include many weft picks and keep them hidden, the pile would need to be longer, creating a shaggier surface (i.e., a kaunakes or zhylkishi). While this may be an artistic choice in some pieces, the general goal in modern carpet-making is to avoid these gaps as they expose the underlying structure to the elements and accelerate deterioration (ibid.). A corresponding concern is the resistance of the pile to collapse; that is, its ability to stand upright rather than to fall sideways. An upright pile, where objects, debris, and water are kept away from the base structure, requires tightly-packed knots that provide mutual support. The addition of excess weft picks will spread the knots too far apart, and they will not stay upright (ibid.).

Therefore, in most knotted carpets where a rigid pile and an invisible weft are primary goals, the weft picks are most obvious when viewing the carpet from the reverse (where the pile is not visible). Even when viewed from the back, carpets that use fewer weft picks can appear to have no weft at all, as it is only a very thin line that gets buried in the knots (Fig. 6.30). The visibility of the weft from the back is also affected by the material, color, and gauge of the weft yarns

relative to those of the warp and knots. This aspect is captured by two variables in the database: **Weft Rows** and **Weft Shot Pick Count**. **Weft Rows** is a simple binary describing whether the wefts create physical space between rows of knots when viewed from the back of the carpet. Y (yes) indicates that the extra weft picks visibly separate the knots, while N (no) indicates that the wefts do not separate rows of knots, and that rows of knots appear to touch their vertical neighbors despite the weft between them. This variable is not especially relevant to conceptual or technical descriptions of the carpet structure, and instead is used in the manipulation of measurement data described in Chapter 7. The more socially-technologically relevant variable is the **Weft Shot Pick Count**, which approximates the number of picks between consecutive rows of knots. Most of these counts are given as a single whole number, as the weaver adds the same number of picks each time. When there is a consistent alternating pattern (e.g., every other weft shot has 3 picks or 5 picks), the two counts are given separated by a colon (3:5). When the count varies but does not appear to follow a consistent pattern, an estimated average is given instead, indicated by an asterisk (*).

The weave pattern of the weft was also documented. Like other aspects of the carpet, there are many weave patterns that would not have a notable effect on the finished structure, particularly when multiple picks are used in each weft shot. And yet, most carpets (modern and historic) use a tabby weave. This may be because the weft is hidden in the carpet, not even necessarily visible on the back, so there is little incentive to complicate the process by using a decorative weave. The process for setting up the loom and shedding mechanisms for a plain 1/1 tabby is the easiest option, requires the least attention to detail during set-up, errors are easiest





Figure 6.30: Weft Picks
Left: When a carpet has few weft picks between rows of knots, or the wefts are very tightly packed, the wefts are not visible at all on the back of the weaving. Yellow and brown knots here, weft (white) not visible. Carpet KZ-OT-1.

Right: When there are more weft picks or they have not been tightly packed, they are visible on the back. It is easy to count the 6-7 picks of tan weft between rows of colorful knots. Carpet MU-VA-4.

to spot, and needs the least attention to detail during weaving. Almost all the sampled carpets used a 1/1 tabby, but a handful used a 2/2 tabby. Only one carpet (MU-AS-6) used a non-tabby. This carpet used a 3/1 twill instead. The weave pattern is captured in two variables: **Weft Shot Weave** (tabby or twill) and the **Weft Weave Size** (X/X, following modern technical weaving notation).

The next structural consideration of the weft is the **Weft Offset Pattern**. This variable describes whether the picks always fill the same sheds before/after different rows of knots. The goal here is not to understand whether the shed before the knots is the same as the shed after the knots, but rather to say that the weft always fills X shed before knots, and Y shed after. This

would indicate the differential pressure exerted by the upper and lower wefts on an individual knot, and whether the same type, direction, and strength of pressure is expected in every knot across the carpet (Fig. 6.31). As this study relies on measurements of the size and shape of individual knots, distortion and tilting introduced by the weft sheds is an important note. Although a more detailed study might differentiate between the different shed combinations and resulting distortions, that was beyond the scope of this study (particularly as many carpets have more than one pattern). Instead, the variable **Weft Offset Pattern** indicates whether the knots in a carpet are tilted the same way as each other (whichever way that may be). The variable has four categories: regular, alternate, pattern, and random (Fig. 6.32). 'Regular' carpets are those where each row of knots has picks in the same shed both before and after it. Every knot in these carpets is expected to display the same tilt-distortions. 'Alternate' carpets have two sheds that alternate in a consistent pattern, so that alternate rows of knots are tilted in opposite directions. 'Pattern' carpets have some other regular, repeating sequence of 2+ sheds (e.g., A-B-C-A-B-C or A-B-B-A-B-B). 'Random' carpets are those with multiple sheds represented before and after the knots, but without an apparent pattern. Although four categories were defined, only 'regular' and 'alternate' offsets occur frequently in the sample; 'random' offset occurs once (MU-VA-4), and 'pattern' offsets do not occur at all. The **Weft Offset Pattern** references only those picks immediately before and after the knots: if there are many picks in a weft shot, the sheds of the interior picks are not represented here (Fig. 6.33).

As in the **Knotting Order** described in the previous section and as shown in Figure 6.26, there is an idiosyncratic element to the weft that cannot be measured from the carpet itself.

Although a weft shot cannot be completed until the preceding row of knots is complete, it is possible to add the weft in sections as groups of knots are completed. This requires a complete sequence of knots from the carpet interior to the edge, so that the weft does not pass over any "empty" warps. However, it is not necessary to go all the way across the carpet at once: part of the weft can be woven in, then the weaver can let the skein/shuttle hang while they finish knotting the remaining knots. When the next set of knots are complete, the weaver can pick up the hanging weft and continue across the carpet. Although it is possible to add the weft in small sections, only one weaver in this study (Bashorat) chose to do so. This method is described as 'broken' in the database variable **Weft Addition Rate**, while adding the weft in a single run after all knots are complete is listed as 'continuous'.

Like the knot type, there is some modern and historic evidence that weaving communities tend to stick to a consistent style in applying the weft (Tsareva 1984:12), and most groups studied here have little or no variation in style between members.

(Side) Binding

The *bindings* create a neat, study edge on the vertical sides of the carpet (Fig. 6.34). They are separate from and produced differently than the selvedges, which finish the horizontal sides of the carpet. The bindings are generally produced by weaving a thicker yarn in a tight pattern through the last few warps at each side. These warps carry the binding and the weft shots, but do not carry knots and are not part of the carpet's design. Although the bindings could be any width/use any number of warps, they are usually limited to between two and ten warps per side.

A standard binding will appear as 1-2 cm wide when complete, and the size is not generally correlated to the overall size of the carpet.

Side bindings could be made of any weave pattern, but are usually tabbies. When a tabby weave is used, it could be a simple 1/1 plain weave, or it may be a tabby varietal known as rib weave (e.g., 2/2, 3/3). In these variations on tabbies, consecutive warps are grouped together and treated as one. An alternate form is a wrapped or overcast binding, where instead of weaving through the edge warps, the binding yarn wraps around them in a tight coil (Fig. 6.35) (Collingwood 1968:240-245). In wrapped bindings, a thick cord is sometimes added as extra fill and to strengthen the carpet's edge. The type of binding structure is given in the **Binding Weave Pattern** variable, as either 'tabby' or 'wrap'. The **Binding Warps** variable gives additional details about the structure. This information is given as a two-part ratio, where the first number represents the total number of warps included in the binding, and the second number represents the number of groups used. For instance, in Figure 6.35, the left binding would be categorized as 4:4 (four warps acting as four distinct units). The center binding in that figure is categorized as 8:4 (eight warps acting as four distinct units). The right binding is 4:1 (four warps acting as one unit). All wrap bindings are represented by X:1, as a wrap binding necessarily indicates the binding yarn wrapping around a single core bundle. When the exact number of warps could not be counted, either side of the ratio can be given as a question mark (?).

The side bindings have additional structural variations relating to how they interact with the weft shots. The side binding may be woven with the weft yarn, where the weft completes a pick, creates the next section of binding, and then weaves the next pick (Fig. 6.36). Alternatively,

the weft and binding may be made of two different yarns, which interact but are distinct. The specific pattern of interaction used can have wider effects on the carpet structure, including the number of picks per weft section, the weft pick weave, and the weft offset pattern (see the Weft section above). The **Binding-Weft Overlap** variable records the binding-to-weft interaction type, with either C (continuous; both weft and binding are woven with the same continuous skein), or S (separate; the weft and binding are separate skeins). This interaction traces the route of the yarn, and does not comment on the gauge, material, or color (which may be the same or different).

Bindings and wefts must overlap by at least one warp: if they do not, there would be a slit or gap in the carpet the full length of the piece, because the bindings and knotted area would be connected only at the top and bottom selvedges. Technically only some weft picks, and not all of them, need to overlap with the binding to prevent this, but the further apart the overlaps are, the larger holes will be created in the carpet. In most cases, the weft overlaps with the binding in every pick.

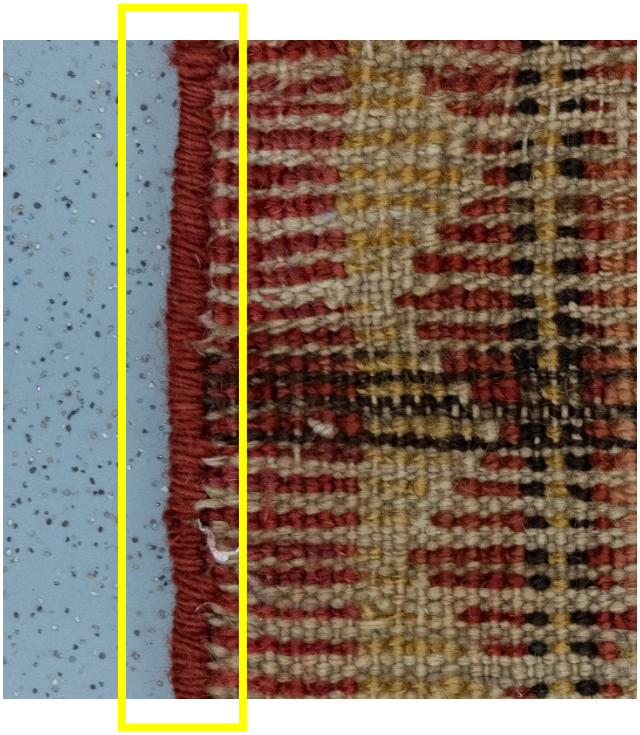

Figure 6.34: Side Binding

The edge of a carpet, with a red side binding (marked in yellow).
Carpet MU-CH-2.
Photo by author, Oct 2021.

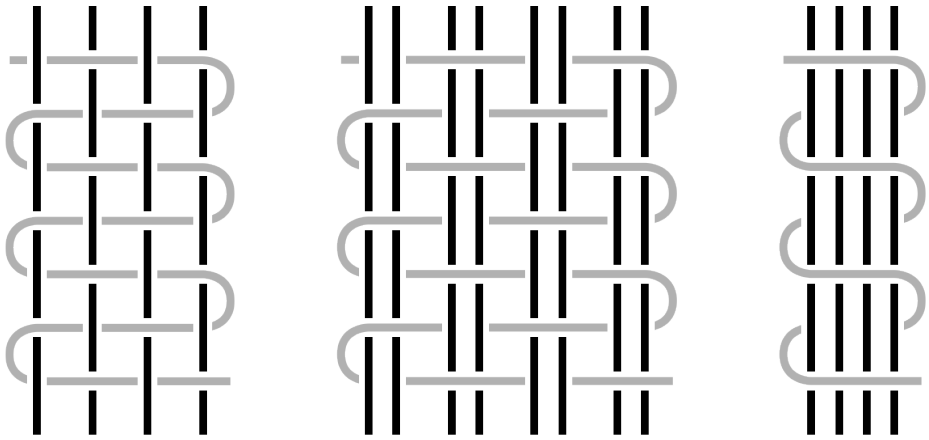

Figure 6.35: Binding Weaves

A comparison of the common binding methods. Figure by author.

Left: A 1/1 plain weave.

Middle: A rib weave, here 2/2.

Right: A non-woven, wrapped binding.

Trimming

When tying a knot by hand, an experienced weaver will hold a specialized blade in her (usually dominant) hand. She will tie the knot at the end of a long length of yarn or even an entire skein, and then will cut the knot from the skein using a quick gesture with the blade. Depending on the shape of the blade and her weaving speed, this gesture usually looks like either an inward rotation of the wrist (clockwise for left-handed weavers, counterclockwise for right-handed weavers), or a quick downward movement of the hand. This cut is merely to separate the new knot from the skein, and is not intended to be the final length or surface of the carpet. A notable exception to this is the *жұлқышы* [zhylkishi, Kazakh] carpets, which appear across Central Asia and known also as kaunakes, rya, and many other regional names. The knots in these carpets are cut from the skein during knotting and are minimally or never re-trimmed. This creates a much longer pile and a shaggier surface. One weaver interviewed (Kulyash) mentioned having worked on zhylkishi carpets in her youth, but reported that they were long out of fashion. In the course of fieldwork, the example held at Kulyash's workshop was the only modern zhylkishi carpet observed in-person, although several of the historic sample fit this category. After cutting, the knot tails in these carpets are generally 2-5cm long, compared to the <0.5cm tails in standard knotted carpets.

Several types of knives were documented in the field (Fig. 6.37). These included both straight and curved varieties, and versions made locally and versions imported from elsewhere. The knives used on each carpet are documented as either 'curved' or 'straight' in the **Knife Type** variable in the database, referring to the shape of the blade only and not the handle or other

components. The direction of motion the weaver used to cut the knot from the skein was also recorded in the **Cutting Direction** variable, as a set of cardinal directions (e.g., a cut that starts at the top of the knot and moves straight down is described as N-S, for north-to-south).

The carpet knife is only used to separate the knot from the skein and is not used to refine the cut. After larger sections of knots have been tied, the weaver returns to trim the knot ends down to a uniform length with scissors (Fig. 6.38). This forms the finished surface of the carpet and brings the pattern into clearer focus. As with knives, the weavers use several types of scissors including standard/in-line scissors and off-set shears. The use of off-set shears allows the weaver to trim the pile without her hand getting in the way and causing a tilt in the cutting plane. The type of scissors used (standard or offset) is recorded in the **Scissor Type** field of the database.

In order to maintain consistency in length, the knots are trimmed at regular intervals: the weavers interviewed here trimmed knots after every 1-2 rows of weaving (Fig. 6.39). They reported that trimming more rows than that becomes difficult (Survey 4), and the results get more jagged and less precise. While they could trim after every row to minimize this problem, they report that that slows the work down too much (Surveys 2, 4). The number of (knot) rows after which the weaver trims the knots is recorded as an integer in the **Trim Frequency** variable.

After the carpet is complete, it is sometimes trimmed again using scissors, shears, or (today) an electric trimmer. This step is not generally necessary though, except for very high-quality carpets. Additional post-weaving trims are not recorded here, as the scope of this study only includes the weaving process and not post-loom finishing practices.

Other Tools

In addition to the carpet knife and scissors, many weavers used other hand-held tools during weaving. Some weavers use a hooked instrument to assist with tying the knots. Specifically, the hook is used to separate and grab individual warps around which the knots are tied. Although a hook could be helpful for a carpet of any quality, they are particularly important for very high-quality carpets where the warps are both very fine-gauge and are packed together very tightly. In these carpets, there may be less than a millimeter of space between consecutive warps, which makes it very difficult to quickly pick out a specific warp with the fingers. A small hook resembling a dental instrument, usually metal, allows the weaver to pull out just the one warp she needs for a knot, and allows her to move much more quickly (Fig. 6.40). In this study, about half of the participant weavers used a hooked tool. In all of the observations where a hook was used, it was integrated into the carpet knife (see Fig. 6.37a-c): this allows the weaver to hold only one object in her hand and cuts down on the time she spends picking up and replacing these two tools for every single knot. This style of integrated hook-knife was developed during the 19th century carpet boom in Tabriz (Edwards 1953:24), but has not been adopted by the entire carpet-knotting world. The first use of a hook in Central Asia is recorded in Andjian, Uzbekistan in 1930, where it was introduced by an Azerbaijani master (Moshkova 1996: footnote 106). Whether or not the weavers used a hooked instrument is recorded in the **Hook** variable, as a binary Y (yes) or N (no).

An important part of weaving, particularly when a solid, impermeable, and un-snaggable textile is required, is to compact consecutive rows of weft (and in this case, pile) together. This eliminates space between yarns and creates a more robust object (Burnham 1980:5). This

compaction is known as *beating*, in the sense that the weaver is beating (compressing) the new weaving down into the old (ibid.). Weavers were observed to compact their work at random intervals with no consistent pattern: after adding sections of knots or whole rows, after single picks of weft or after many. Some rows required extensive beating, while others seem to only need a light touch-up. The weavers beat their work down whenever they think it needs it, and they keep going until it is done to their satisfaction. Although it is possible to beat the weaving by hand simply by pushing on the weft with the fingers, the use of an implement to beat will result in tighter and more consistent textiles (Grömer 2016:117). There are several beater types used in weaving around the world, with the most common being swords, heddles, reeds, and combs (Broudy 1993; Fig. 6.41). Sword beaters are placed in the shed, like tension and shed rods, and are pressed downward so that the "blade" of the (wooden) sword presses the weaving to compact it (ibid., pg. 25) They are the simplest form and are generally simple lengths of wood with a narrowed edge – they are not sharp, despite the name. (Burnham 1980:138). Sword beaters are not connected to the weaving or loom, and can be removed/replaced as needed.

Heddle beaters (or sometimes rigid heddle beaters) are integrated into a rigid heddle, where sturdy pieces of wood or metal are used to divide the warps into different sheds (ibid., pg. 89). These rigid pieces can be slid up and down the warp to open/close the shed, as well as to compact the weaving. Because they are integrated into the warp and shedding system, rigid heddles cannot usually be altered, added, or removed during weaving (ibid.).

A loom beater, often called a reed, is similar to a rigid heddle in that it has rigid vertical slats to divide warps and keep them in order (Broudy 1993:105; Burnham 1980:105). However,

reeds do not separate, open, or close the sheds. The reed can be slid up and down the length of the warp to compact the weaving (Burnham 1980:105). Like a rigid heddle, it is not usually possible to add, remove, or alter a reed while weaving is in progress.

Finally, there are comb beaters. These function similarly to a reed, except that they are not integrated into the warp or loom and can be removed/changed during weaving (Burnham 1980:28). These beaters are variations on normal hair combs, where the teeth can be inserted between warps and packed down to compress wefts (ibid.). These beaters are often weighted, slightly or significantly, so that the level of compaction does not rely entirely on the weaver's downward strength. The only type of beater used by the weavers in this study were comb beaters, recorded in the **Beater Type** variable. They take several forms, but most are variations on the same long-toothed theme (Fig. 6.42). Interestingly, the most unusual beater in the study sample (Fig. 6.42e) has very short teeth, much more similar to the Berber beater from North Africa shown in Figure 6.41d than to the other Asian beaters recorded here. It is also notably similar to the Tarim Basin combs from the early common era (see Fig. 5.17). The weaver Kulyash was careful to point out that this distinct, short-toothed beater was the traditional local Kazakh style, while the longer and finer-toothed versions are imported from elsewhere (Survey 14). Kulyash's knowledge is backed up by historic ethnographic records, which indicate that the chunkier, short-tooth beaters are associated with old-fashioned weaving in villages and tribal settings and archaeological contexts, while the slimmer, long-tooth beaters are seen as more modern and are associated with urban and professional settings (Edwards 1953:23).

A side-effect of beating is that it creates a natural preference for the pile to lilt in a particular direction (downwards, towards the carpet's bottom and towards the weaver's seat) (Collingwood 1968:229; Spooner 1986:205). This natural knap can be felt when touching the pile: running fingers with the knap feels smooth and natural, while running the fingers against the knap feels ruffled. The knap is also visible in some situations, particularly in silk carpets where differential penetration of dye into the fiber core creates a slightly different shade when viewed from above versus in cross-section. This quality of silk carpets to slightly change color depending on the angle of viewing is often presented in sales pitches as a "magic trick" in the carpet bazaars of Central Asia. The knap is not technologically relevant (as it is an emergent, unavoidable, and extremely consistent property), but it is useful for establishing the top/bottom of a carpet for analysis: see more details on how this was used in Chapter 7.

For a look at tool continuity, compare the curved knives recovered from Bronze Age Turkmenistan and Iran (Figs. 5.6) to those used by Turkmen weavers in the 1970's (Fig. 5.7), in 1989 (Fig. 6.43), and in 2021 (Fig. 6.37h). Although the form changes slightly, the core idea of the curved blade in a wooden shank remains remarkably consistent. Some Uzbek weavers working near the modern Turkmen border use similar knives too (Fig. 6.37f, g). Next, compare the "traditional" Kazakh beater from 2021 (Fig. 6.42e) to those recovered from the late Iron Age in the Tarim Basin, west China (Fig. 5.17).

Carpet Dimensions

The carpet dimensions are measured in two ways: the **Total Dimensions** and the **Knotted Dimensions**. **Total Dimensions** represent the entire woven surface, including selvedges and side bindings. **Knotted Dimensions** only represent the area of knotted pile, and exclude selvedges and bindings. For consistency, aspect-ratio checks performed throughout the imaging and data collection process use the **Knotted Dimensions** rather than the **Total Dimensions** when both are available, as the knotted area is the primary focus of this research. In historic fragments where the original extent of the piece is unknown, the measurements are given as **Knotted Dimensions** only. All single-axis measurements are given in meters, and areas are calculated in meters squared. Fringe and other warp-finishing treatments are not included in any dimensions.

The two types of dimensions are subdivided into 5 more specific variables: **Right Warp** (right-hand vertical length, along the warp-line), **Left Warp** (left-hand vertical length), **Top Weft** (top horizontal width, along the weft-line), **Bottom Weft** (bottom horizontal width), and **Area**. Because most carpets are slightly out-of-square, two separate measurements were taken to create an average length and width. These measurements are taken from the edge of the relevant zone. The average carpet in this study is just over 1 square meter in size. Most are portrait rectangles with an average aspect ratio of 1:0.657 (length:width).

Summary values called **Total** and **Knotted Height** / **Width** are also given. These are averages of the two warp (height) and two weft (width) measurements. Because this project focuses on the knots as the unit of variation/measurement, only the **Knotted Height** / **Width /**

Area are used in statistical analysis. In the few cases where these values are not available, the **Total Height** / **Width** / **Area** are used instead.

Estimates for the total number of knots in the carpet and the average knot density are given in **Total Knots** and **Knot Density** respectively. In complete and nearly-complete carpets, these are calculated from the measurements taken of individual knots. Three full-size clusters were selected from each carpet and the average number of knots per cluster was calculated (see more information on clusters and knot sampling in Chapter 7). Where possible, complete clusters with few or no missing knots were selected. Using the proportional area covered by a complete cluster sample box, a total number of knots for the entire carpet is calculated (e.g., KZ-SH-2 has ~69 knots per full cluster, on average; each full cluster represents 0.25% of the carpet area; therefore the carpet has approximately 27,600 total knots). The total estimated number of knots is divided by the carpet's total knotted area to estimate its average density (e.g., KZ-SH-2 has approximately 27,600 total knots and its knotted area measures 0.163m^2; therefore, it has an average knot density of 16.9 knots/cm^2).

For fragmentary carpets (all MU-AS, MU-DY, MU-VA), the **Knot Density** is calculated slightly differently, as damage to the carpet makes clusters and edges irregular. In fragments, a 5x5 cm square was drawn over the best-preserved section, and knots were counted manually. A **Total Knots** value is not calculated for fragments, as their original size is unknown.

Idiosyncratic & Social Variables

Several additional idiosyncratic and social-cultural variables were recorded from the ethnographic weavers. They all include information that would be entirely indeterminate if the carpet was the only source of information: all require direct reference to and knowledge of the weaver and production setting.

First, the **Weaver** is recorded for each carpet. The weavers were given the option to share their full names, just their first or surnames, or to remain anonymous. All names given in this document, including in the main text, appendices, tables, and figure captions, follow the weaver's wishes for credit/anonymity. Names provided by the informant in the Latin alphabet are reproduced as given; those provided in Cyrillic were transliterated by the author, with the original spelling given in some summary tables. To minimize the chances of accidental spelling mistakes in computer code and to ensure privacy in collaboration settings (i.e., with volunteers and in presentations), each weaver was given a familiar female first name as a pseudonym. These were assigned randomly and have no specific relationship or correlation with the weavers or the carpets. The weavers' real names and their assigned pseudonyms are recorded in the **Weaver** and **Pseudonym** variables. In statistical analysis, only the **Pseudonyms** were used (as a measure against spelling mistakes which can create artificial separation in computer code).

The number of weavers who worked on the knots in each carpet is recorded as an integer in the **Number of Weavers** variable. This references only those who worked on the knotted or weft sections: it does not include people who assisted with warping, cartoon-drawing, or selvedge-weaving. A weaver was counted if they contributed 10% or more of the carpet knots, by

the weavers' reckoning. A second variable, **Weaving Position**, is used to clarify the working system of multiple weavers; it therefore only applies to carpets with 2+ weavers. The **Weaving Position** records whether the multiple weavers worked on a consistent, definable section of the carpet (consistent), or if their work is sporadic and mixed at random with the other weavers' (random). For instance, the weavers Maloxat and Nazokat consistently sat on the same side of the loom every day, and so their work has a clear distinction along the central vertical line: their carpets have a consistent **Weaving Position**.

The dominant hand of the weavers is recorded in the variable **Handedness**, as reported by the weavers themselves. All the weavers represented here are right-handed (R). Interestingly, some weavers reported that it was not possible to tie the carpet knots if you are left-handed (Surveys 2, 7): I know this to be untrue from personal experience, and this was confirmed by Mr. Khodji Soat Durdi of the Samarkand Silk Workshop. The founder and a master craftsman, Durdi has over 50 years' experience in knotted carpets. He mentioned that one of the weavers in his workshop was left-handed, and that her work was as good as anyone else's (Survey 3). However, the three countries included in this study all have some cultural biases against left-handedness, so it may be that some weavers are naturally left-handed but were forced to switch to the right in childhood (particularly older weavers).

Many of the weavers included here work in group workshops settings where there is some amount of **Oversight** and quality-control. The amount is as given by the weaver and was not directly checked by the author (as that would have required observing the entire carpet-weaving process of several months). Categories include 'none' (no oversight at all), 'PR' (production-

regular, the work is checked at regular intervals during weaving), 'PS' (production-sporadic, the work is checked at random, inconsistent intervals during weaving), or 'PP' (post-production, the work is checked only after weaving is completed). Approximately half of the weavers interviewed here are not subject to any oversight at all.

The weavers self-reported the amount of time they spend weaving per day on average (**Workload**, given in hours per day), and how long they have been weaving (**Experience**, given in years). Traditionally, weavers would start to learn the craft as children, generally at the age of 6-8 and taught by their mother or another female relative (Tsareva 1984:9). Over their youth, they ultimately memorize their community's popular motifs and are able to reproduce them from memory by adulthood (ibid.). Only some of the weavers here reported learning to weave in childhood, and mostly at school rather than at home.

The type of environment in which the weavers worked is recorded in the **Production Setting** variable. This refers to the social, hierarchical, and economic structure of their organization, and is categorized at three levels. Domestic weavers are those working independently from their own homes, producing items primarily for themselves or their families and friends. Domestic weavers have no oversight and do not have notable economic interest in carpets. They are free to weave any size, style, and design of carpet, and to experiment with new techniques, tools, and materials. They might be considered artists or hobbyists. Workshop weavers are those working as paid professionals in a non-familial, controlled, centralized setting. These weavers are generally subjected to strict quality controls and have limited (if any) control over the styles, structures, sizes, and designs they weave. Weavers in these settings have usually

had some amount of standardized training, and use consistent sets of tools, techniques, and materials. They are paid in direct proportion to their output and hours spent weaving, and are contributing notably to their household income. They have normal working restrictions and rights (for their country) such as statutory leave, sick days, standardized hours, lunch breaks, health & safety requirements, etc.

Weavers working in collectives fall somewhere in between the domestic and the professional workshop. Those in collectives may regularly sell carpets and make a notable income on carpet sales, but weaving would not be considered their full-time job, nor are they subject to internal quality control or oversight. Their outputs are a mix of personal preference and creativity, and marketable or commissioned pieces. These weavers often work from their homes but have a network of partners within the collective with whom they can collaborate on larger orders, trade tools, learn new techniques, or share sales leads. These weavers often enter the collective with some existing weaving knowledge and may receive a bit of standardized training to expand their skills. However, unlike weavers in professional workshops, these weavers are not necessarily expected to adopt the group's techniques or tools, and may choose to continue with those they learned in childhood or elsewhere. Collective weavers can generally control their own schedules to accommodate childcare, illness, vacations, and other life events, and to increase or decrease their working hours as they see fit. Collective weavers may sell directly to the public (as the Khivan collective observed in Uzbekistan), or supply carpet merchants for domestic or international resale (as the collective in Mary, Turkmenistan).

Weavers working in collectives or workshops have an additional unit of information in the database: the **Community**. This references the specific organization to which they belong. Note that **Communities** do not necessarily co-locate, nor do weavers who co-locate necessarily belong to the same communities. The formal names of the organizations are given where they exist (e.g., the Altyn Orda [Алтын Орда, “golden horde”] art studio in Shymkent, Kazakhstan). Organizations without formal names are given another recognizable moniker (such as Collective-Khiva).

Finally, geographic data are given in three variables: **Country**, **City**, and **Village**. **Countries** are self-explanatory. **Cities** refer to the nearest town or city that are large and cohesive enough to appear on Western maps, including Shauldir, Shymkent, Samarkand, Khiva, and Mary. When a carpet was produced in a small village (as reported by the weaver), too small to be mapped, this information is listed in the **Village** variable. Those living in villages still have notable interaction with the associated city, but do not live/work within it. Those without a listed village work within the city/town limits.

Figures: Chapter 6

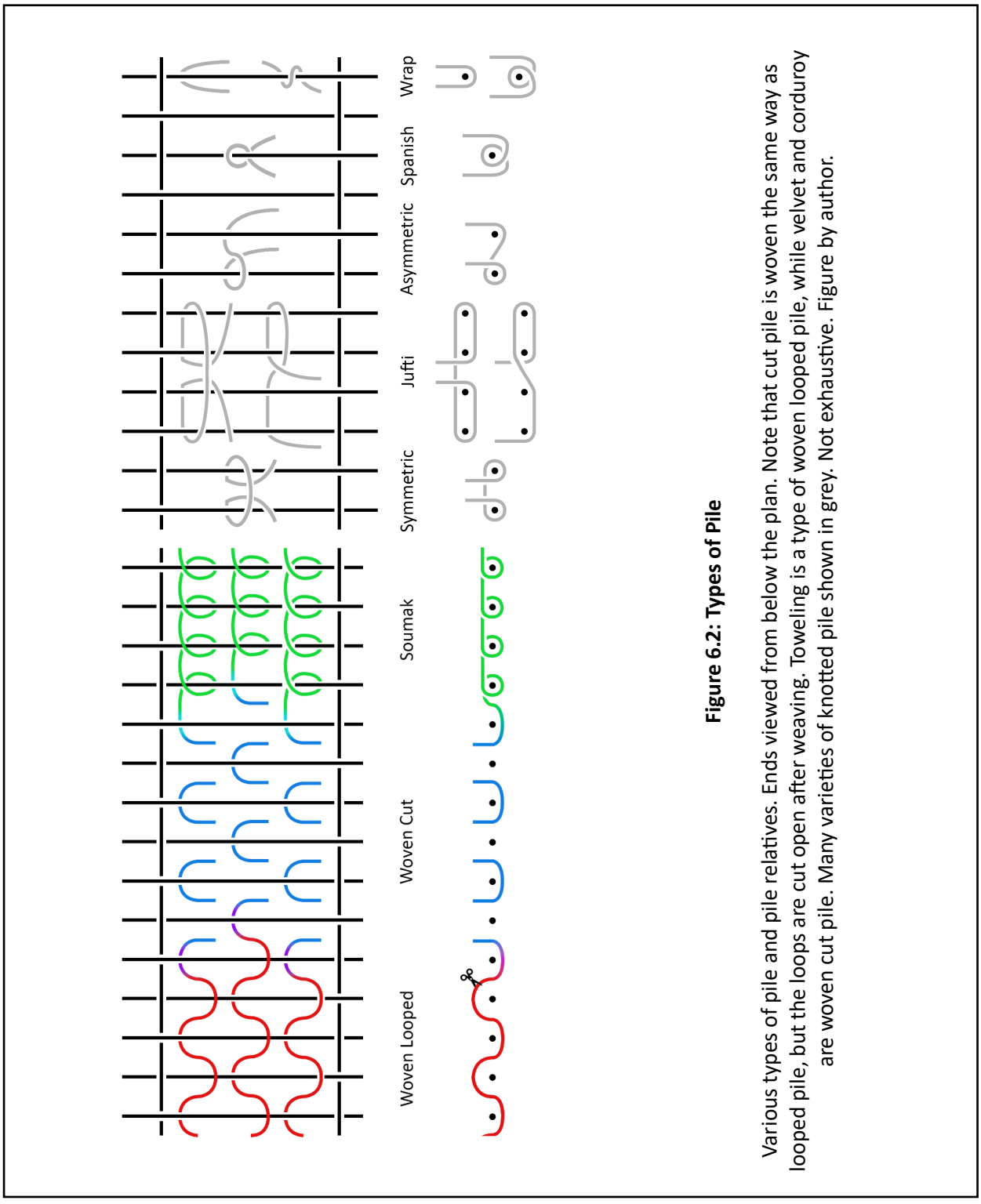

Figure 6.2: Types of Pile

Various types of pile and pile relatives. Ends viewed from below the plan. Note that cut pile is woven the same way as looped pile, but the loops are cut open after weaving. Toweling is a type of woven looped pile, while velvet and corduroy are woven cut pile. Many varieties of knotted pile shown in grey. Not exhaustive. Figure by author.

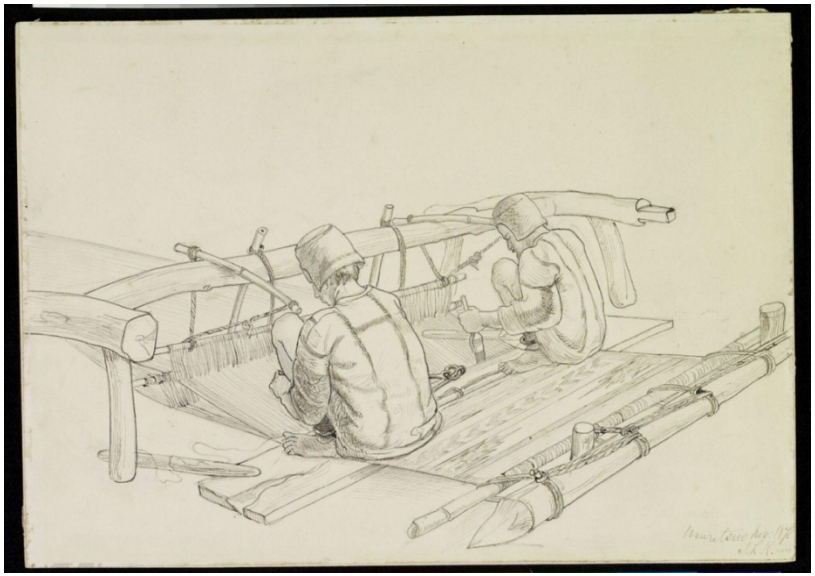

Figure 6.10: Weavers Seated on a Horizontal Loom

Weavers working on a large horizontal or ground loom. They sit directly on the finished section of weaving. Sketch by John Lockwood Kipling from the Amritsar Jail, Punjab, India, 1870. Inv. No., Victoria & Albert Museum: 0929:38. Image © Victoria and Albert Museum, London.

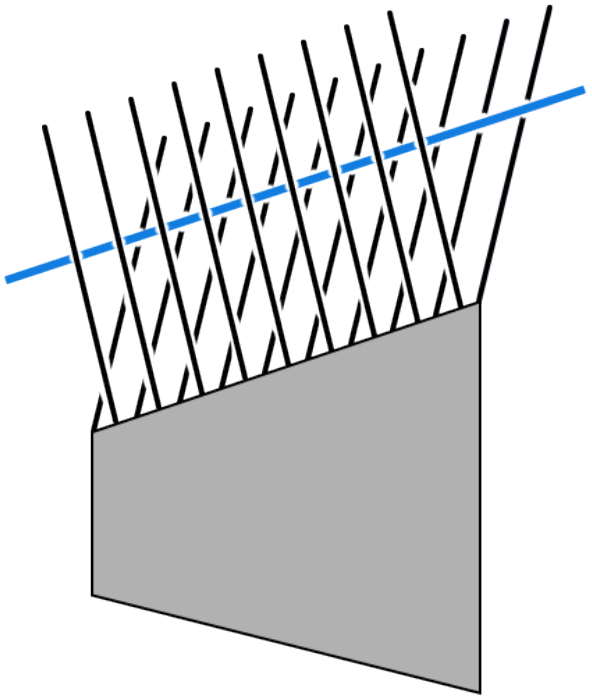

Figure 6.4: Weaving Shed

A weft (blue) runs through the gap created when some warps (black) are pulled forward, and some are pushed back. Many wefts passed through different sheds and packed together creates the textile (grey). Here, alternate warps are forward/back but any combination of warps in any order would be a different shed. Figure by author.

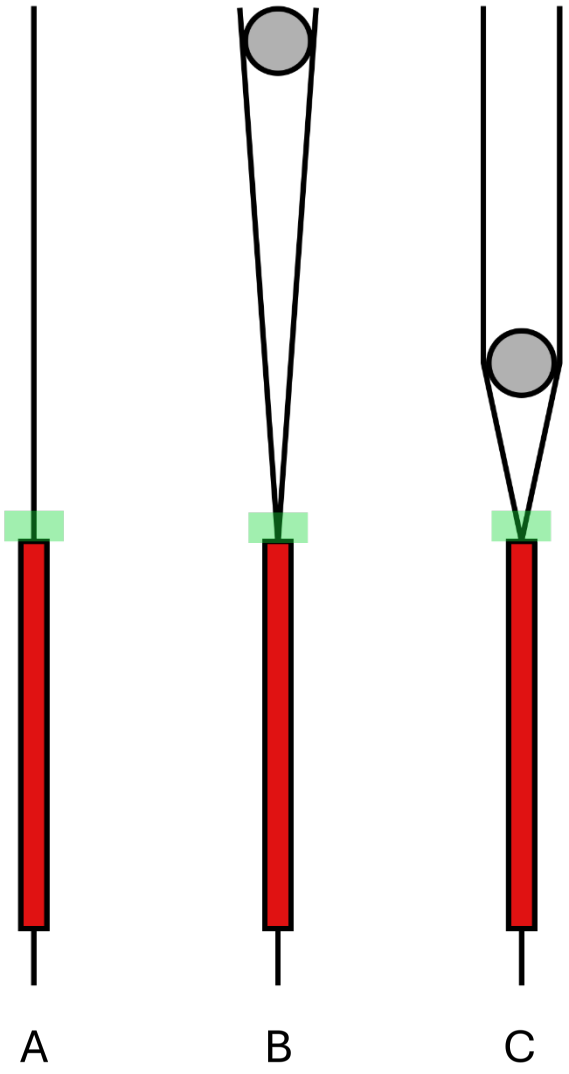

Figure 6.5: Knotting Shed Position

Weaving plane viewed in cross-section; woven area in red, zone for adding new knots in green; shed rod in grey. Figure by author.

A: Closed: shed completely closed at weaving zone, no separation between alternate warps. This category can only occur in systems where a shed can be completely closed (e.g., in systems with only a string heddle).

B: Partial: shed manually closed by pushing shed rod to top of loom, but small unintentional separation between alternate warps remains at weaving zone.

C: Open: shed manually opened by pulling shed rod down towards weaving zone, creating significant and intentional separation between





Figure 6.8: Loom Orientation

Left: A weaver working on a small horizontal loom during the National Carpet Holiday exhibition at the National Carpet Museum, Ashgabat, Turkmenistan. Photo by author, May 2017.

Right: Study participant Kulyash (Teri) working on a vertical loom in her workshop in Shymkent, Kazakhstan. Photo by author, October 2021.



Figure 6.11: Oversized Carpets of the Turkmen National Carpet Museum

Two massive carpets hanging in the central hall of the National Carpet Museum in Ashgabat, Turkmenistan. Photo by author, May 2023.

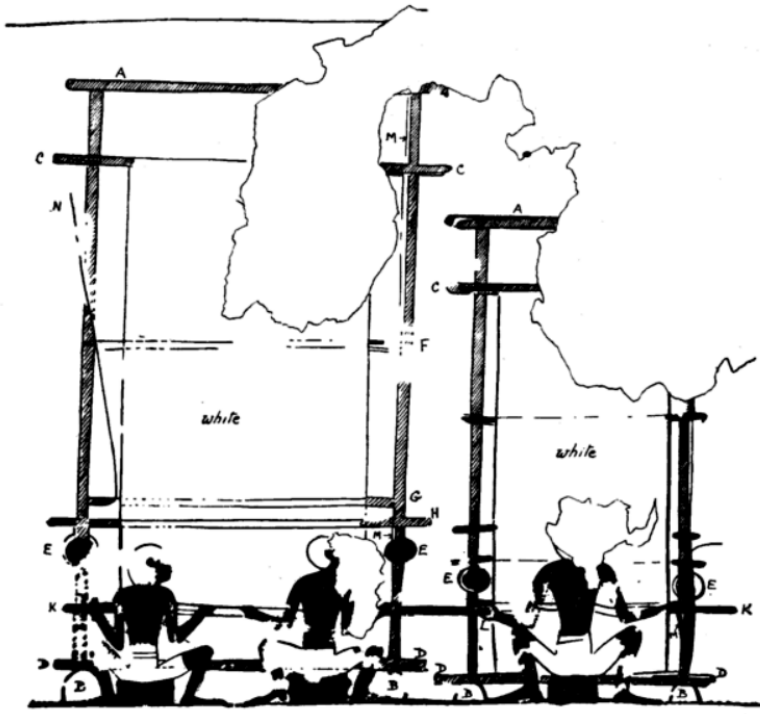

Figure 6.13: Neferhotep Loom

The earliest known depiction of a vertical loom, from the Tomb of Neferhotep (TT49), Thebes, 18th Dynasty (c. 1425 BCE). Drawing from in-situ mural by N. de G. Davies, 1913, from Roth 1913.



Figure 6.15: Warp Bar Spacing

Nails used to enforce even spacing of the warp at one end of a narrow table loom (not for carpets). While this loom positions the warps in groups of four, some systems position each warp end individually. Inv. No., Victoria & Albert Museum: T.172:1-2000. Image taken with permission of the Victoria & Albert Museum, London.

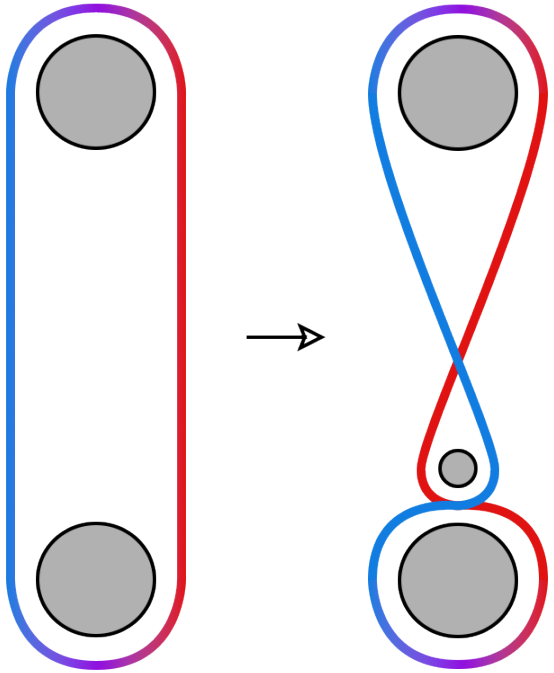

Figure 6.17: Creating a Cross-Point

A simple belt warp (left) limits the weaving zone to either the front (blue) or the back (red). The warp would need to be let out of tension, manually rotated, and re-tensioned to bring new warp into the weaving field. By adding a tension rod near the cloth bar, the weaver can bring both sets of warps together at the center and double the density of the weaving. Loom viewed from the side/in cross-section; warp bars shown in grey. Figure by author.

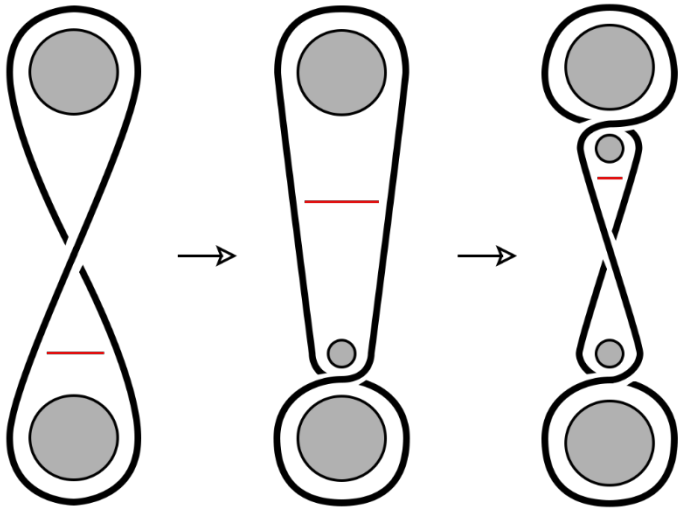

Figure 6.18: Moving a Crossing-Point and Reducing the Native Shed

A simple figure-8 warp (left) sets the weaving area above the crossing point; this limits the possible carpet size, and wastes warp thread. The weight of a tension rod (middle) can force the crossing-point downwards, opening a wider weaving area. Additional rods can be added (right) at the top, bottom, front, or back of the warp to reduce the size of the native shed (red).
Loom viewed from the side/in cross-section; warp bars and tension rods shown in grey. Figure by author.



Figure 6.19: Shed Rod

A shed rod (upper of the two metal rods). Notice how alternate warps pass in front of and behind the shed rod, allowing the weaver to open the shed by pulling the rod down, or close it by pushing the rod up. This loom also has a heddle (lower metal rod).
Survey 1: Samarkand, Uzbekistan. Weaver: Nigora (Mairead)
Photo by author, Sep 2021.



A

C





B

Figure 6.21: Examples of Selvedges

A: The selvedge on a finished carpet, measuring approximately 3cm high and using the same beige wool as the warps (visible here as fringe), plus a single decorative pick of green. Carpet TK-MA-5. Photo by author.

B: A section of foundational selvedge on an active loom, measuring approximately 2cm and using a single row of thick white cotton cord before a teal skein of the synthetic-blend pile yarn, all on the white cotton warp. Survey 11: Ingilis, Khiva, Uzbekistan. Photo by author, Sep 2021.

C: The base selvedge on an active loom, measuring approximately 45cm and using the same white silk as the warps. Note the loose ends at the left side: these selvedge threads are being used as a base for the weaving, but will be removed after weaving is complete by pulling the loose ends. This image is shown right-way up, but the carpet & weaving appears up-side down: as the weaver worked upwards from the shown selvedge, the finished work was pushed onto the back of the loom where it appears inverted. Survey 2: Samarkand, Uzbekistan. Photo by author, Sep 2021.

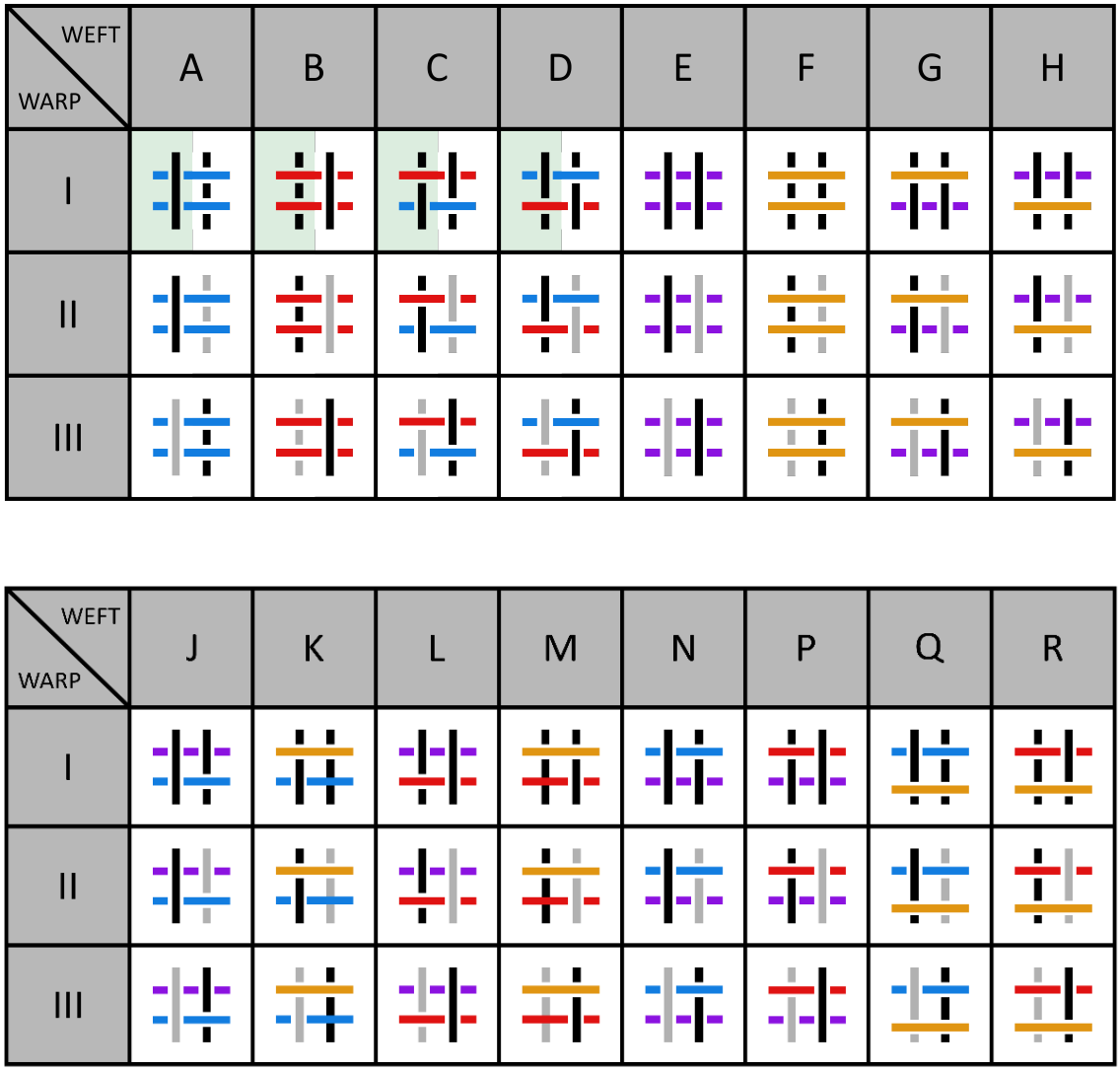

Figure 6.23: Warp & Weft Patterns

Warp Patterns I, II, and III describe whether consecutive warps sit on the same plane, or if one is depressed in the final carpet. Depressed warps shown in grey.

Weft Patterns A-R describe how the rows of weft before and after a knot interact with the warp. When read left-to-right, blue wefts pass Under-Over the warps, red wefts pass Over-Under, purple wefts pass Under-Under, and orange wefts pass Over-Over.
For typographic clarity, there is no pattern I or O.

Because wrap knots use only one warp instead of two, they can only be described by warp pattern I, and by weft patterns A-D (shaded green). Figure by author.

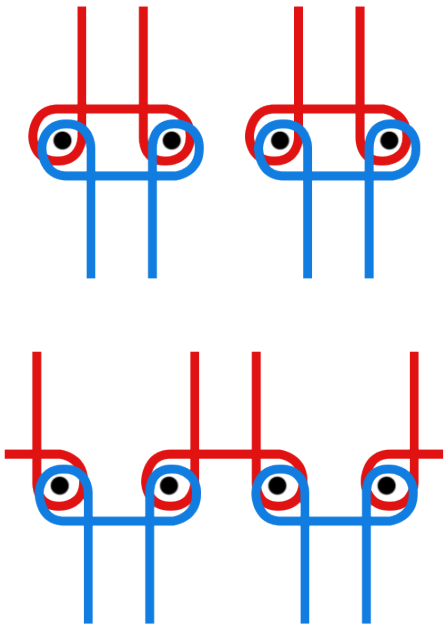

Figure 6.26: Double-Sided Knotting

Double-sided knotting, viewed in cross-section. Warps in black, knots in blue and red. Two offset versions shown, both using symmetric knots. Figure by author.

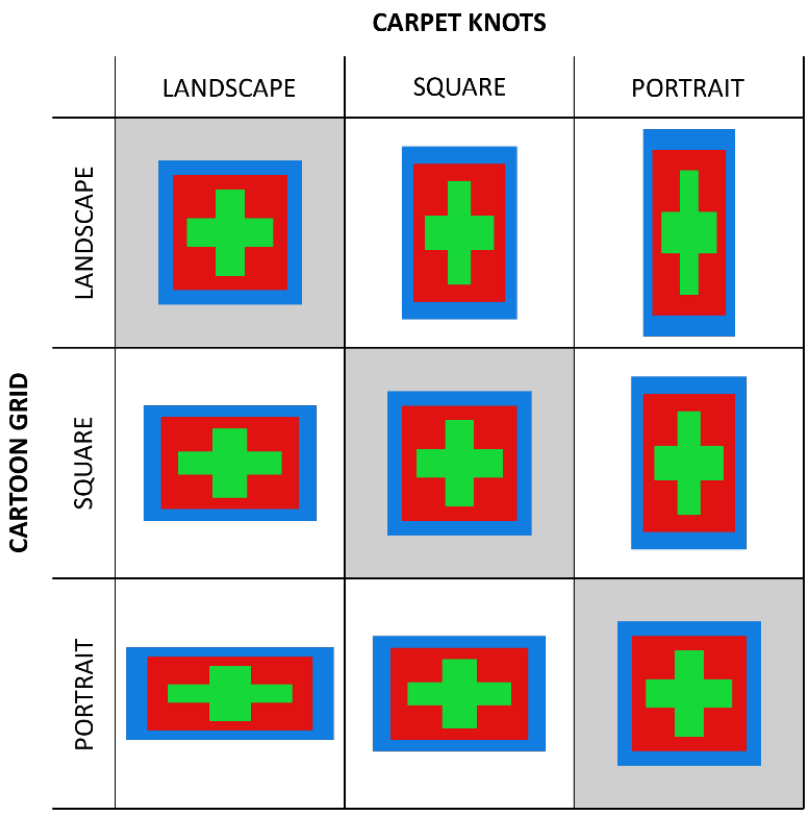

Figure 6.29: Aspect Distortion in Cartoons → Carpets

A comparison of the shape of knots as shown in the cartoon to the shape of the knots as woven in the carpet. The grey shaded boxes are correctly proportioned, while the white boxes are distorted due to a cartoon-carpet mismatch. Figure by author.

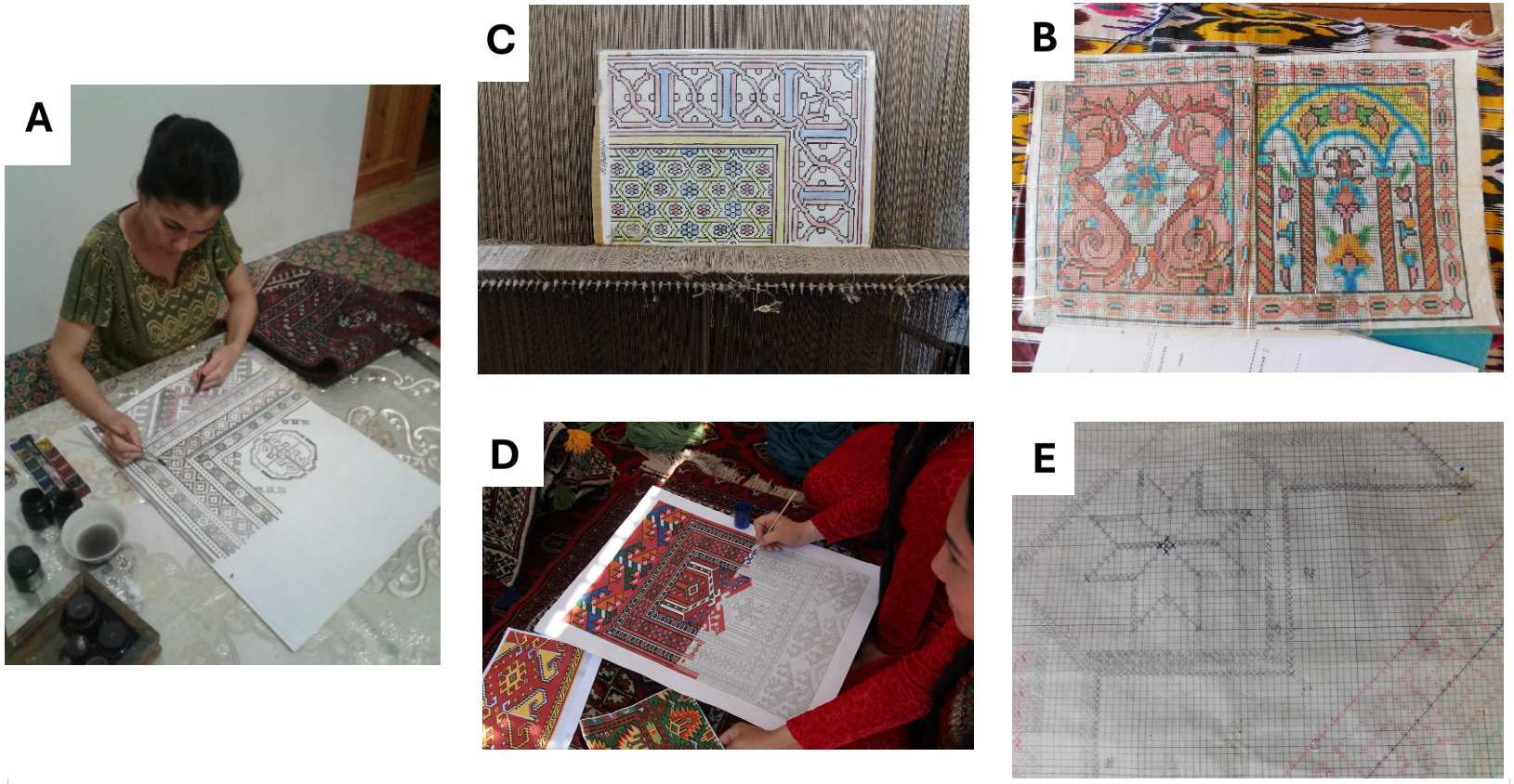

Figure 6.28: Cartoons

A: Drawing cartoon for carpet UZ-KH-5. Survey 12: Gondimiyon, Uzbekistan. Photo courtesy of Dilbar Omonova, 2021.
B: Tiles from pattern 'to'rt fasl' [four seasons], used in carpet UZ-SK-1. Survey 1: Samarkand, Uzbekistan. Sep 2021.
C: Pattern called 'parda gul' [screen/curtain motif], used in carpet UZ-KH-10. Survey 8/9: Khiva, Uzbekistan. Sep 2021.
D: A teenage student colors a cartoon during a carpet-making exhibition. Survey 15: Ashgabat, Turkmenistan. May 2017.
E: A hand-drawn cartoon of 'шатыр гүл' [shatir gul, tent motif, referencing the distinctive shape of the opening used to release smoke from the apex of a traditional yurt], variation used in carpets KZ-SH-1:2. Survey 14: Shymkent, Kazakhstan. Oct 2021.

All photos by author unless otherwise noted.

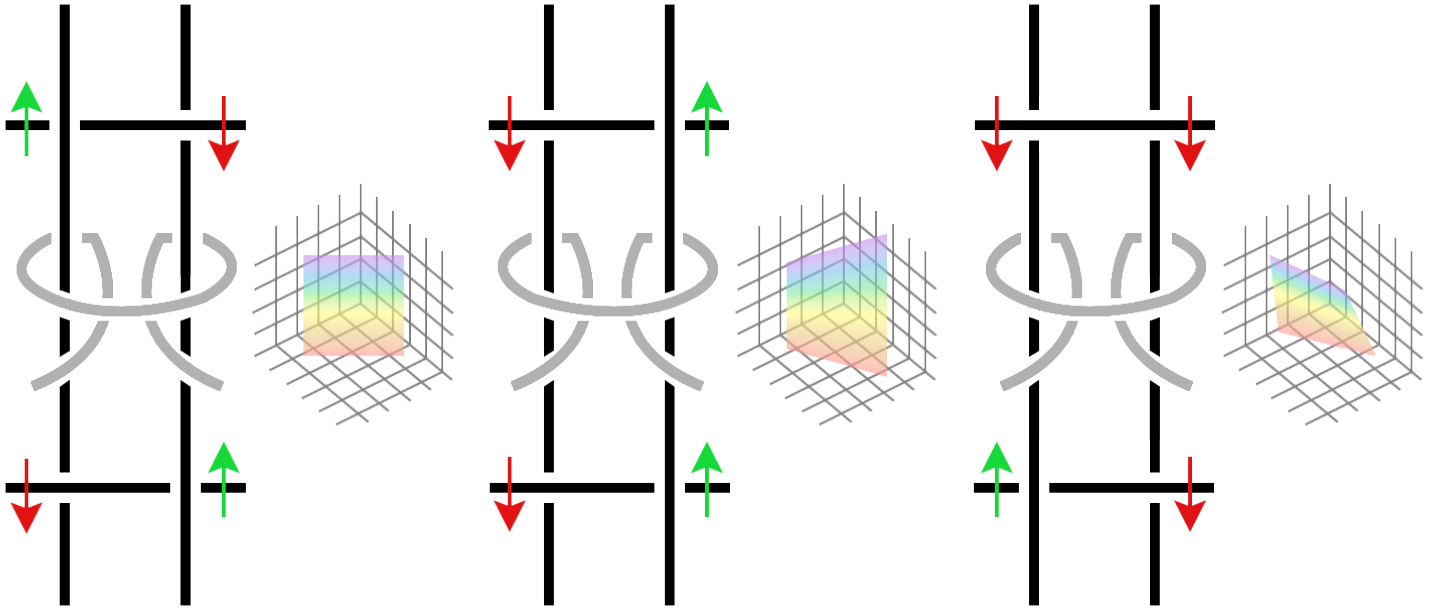

Figure 6.31: Weft Offset Distortion

The ways in which knots are tilted off-plane by the variable pressure of the wefts above and below. Red and green arrow indicate the direction of pressure that the weft is exerting on the warp at each corner of the knot, in turn tilting the plane of the knot. Not all possible combinations are shown. Figure by author.

Left: NW and SE corners are pushed up, NE and SW corners are pushed down, holding the knot on the carpet's plane.

Middle: NE and SE corners are pushed up, NW and SW corners are pushed down, tilting the knot's left side below the carpet plane and the right side above it.

Right: SW corner is pushed up, all other corners are pushed down, tilting the knot's lower-left corner above the carpet plane and all other sides below it.

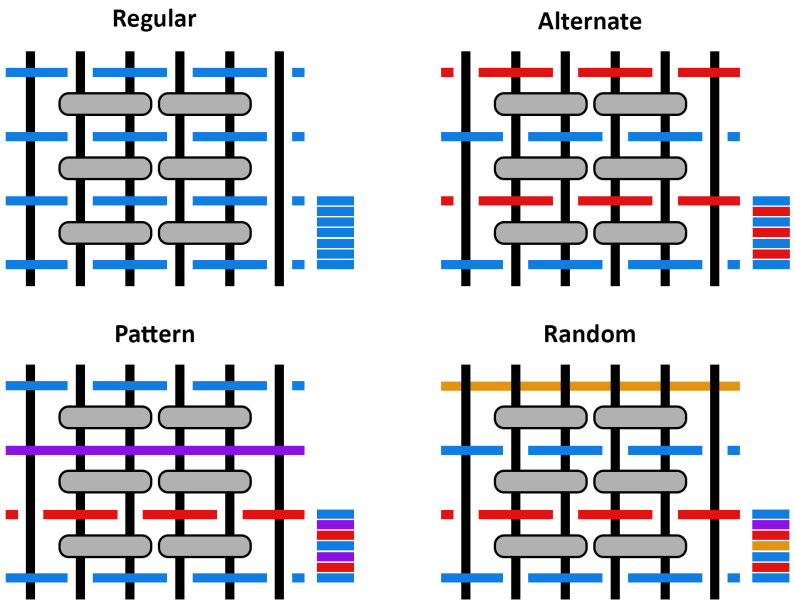

Figure 6.32: Weft Offset Pattern

Whether wefts before/after consecutive rows of knots always fill the same shed(s). Knots shown in grey. Figure by author.

Regular: Wefts always fill the same shed.

Alternate: Wefts consistently alternate sheds in consecutive rows.

Pattern: Wefts follow another regular, repeating pattern (here, a 3-shed repeating sequence).

Random: Weft sheds do not appear to follow any regular, repeating pattern.

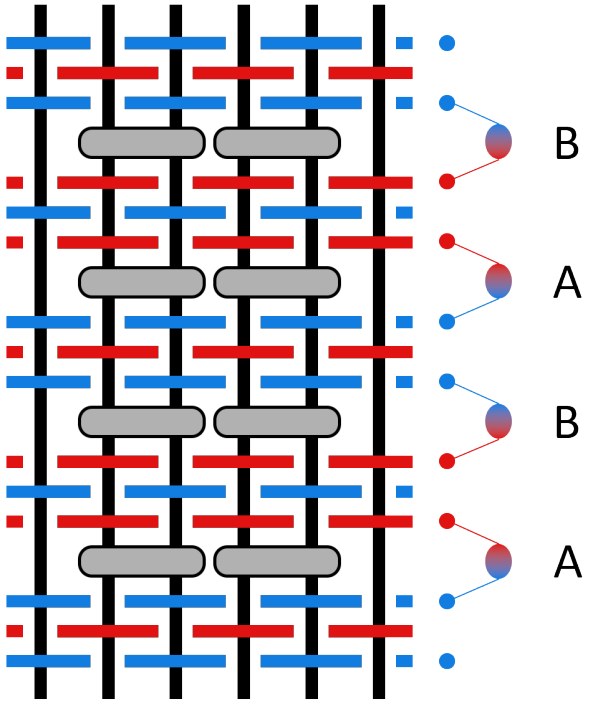

Figure 6.33: Understanding the Weft Offset Pattern

The weft offset pattern considers only the picks immediately before/after the knots. The relevant picks are marked by the colored dots at right. The pattern describes how the combination of the before/after pick changes between rows of knots. Here, the knots at the bottom have an A-pattern (blue weft below, red weft above). The next row of knots up has a B-pattern (red weft below, blue weft above). This diagram has an Alternate pattern. Figure by author.

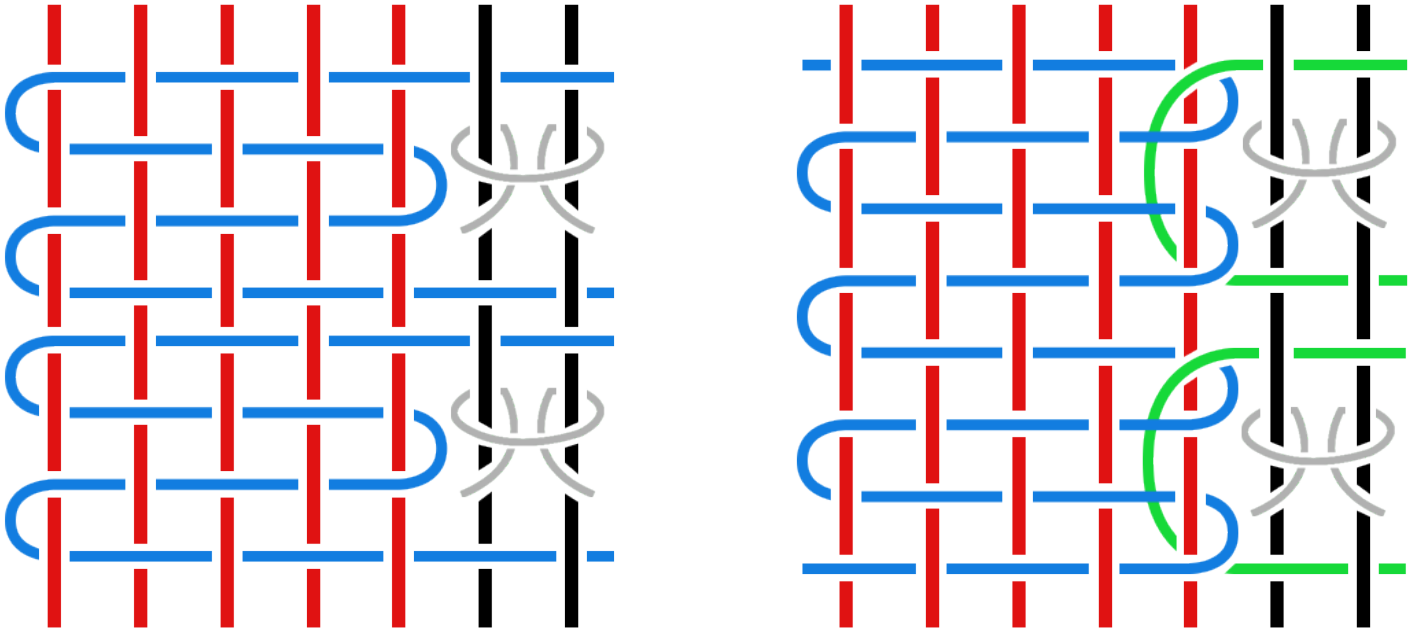

Figure 6.36: Binding-Weft Interaction

Two ways for the weft to interact with the binding, at the left-hand edge of a carpet. The carpet continues with more knots to the right to other side binding. Binding warps are shown in red, knotting warps in black, and knots in grey. Figure by author.

Left: A binding that is woven with the main weft yarn (blue). The weft that passes between rows of knots is the same skein that constructs the bindings.

Right: A binding that is woven with its own yarn (blue), separate from the skein that acts as the weft (green).

Note that the weft and binding must overlap by at least one warp to prevent a gap in the weaving, but can overlap by more or all warps.

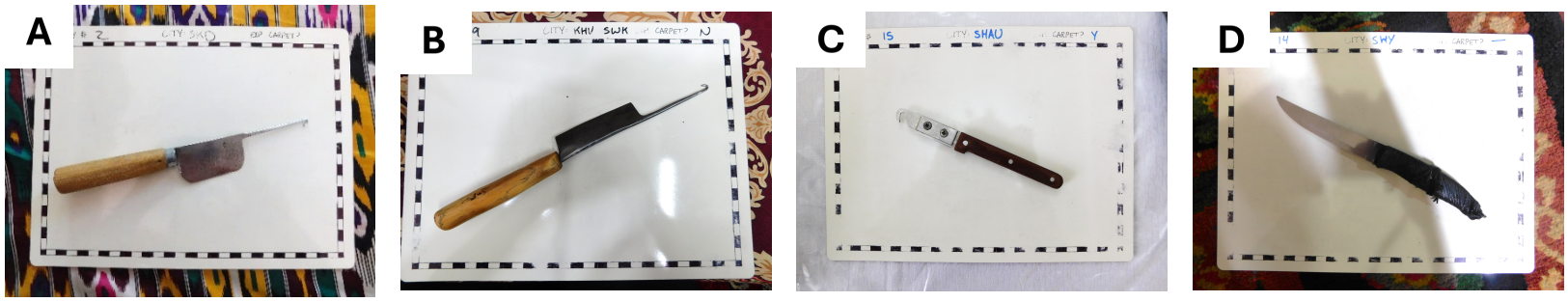



Figure 6.37: Carpet Knives

Selection of distinct knife-types used by the ethnographic weavers in this study. The scale grid on the board is in centimeters. All photos by author.

A: Survey 2: Samarkand, Uzbekistan.
Also represents Surveys 1, 4. Sep 2021.

B: Survey 9: Khiva, Uzbekistan.
Also represents Surveys 7, 8. Sep 2021.

C: Survey 15: Shauldir, Kazakhstan. Oct 2021.

D: Survey 14: Shymkent, Kazakhstan. Oct 2021.

E: Survey 11: Ingilis, Khiva, Uzbekistan. Sep 2021.

F: Survey 12: Gondimiyon, Khiva, Uzbekistan. Sep 2021.

G: Survey 6: Angarik, Khiva, Uzbekistan. Sep 2021.

H: Survey 16: Ashgabat, Turkmenistan. May 2023.

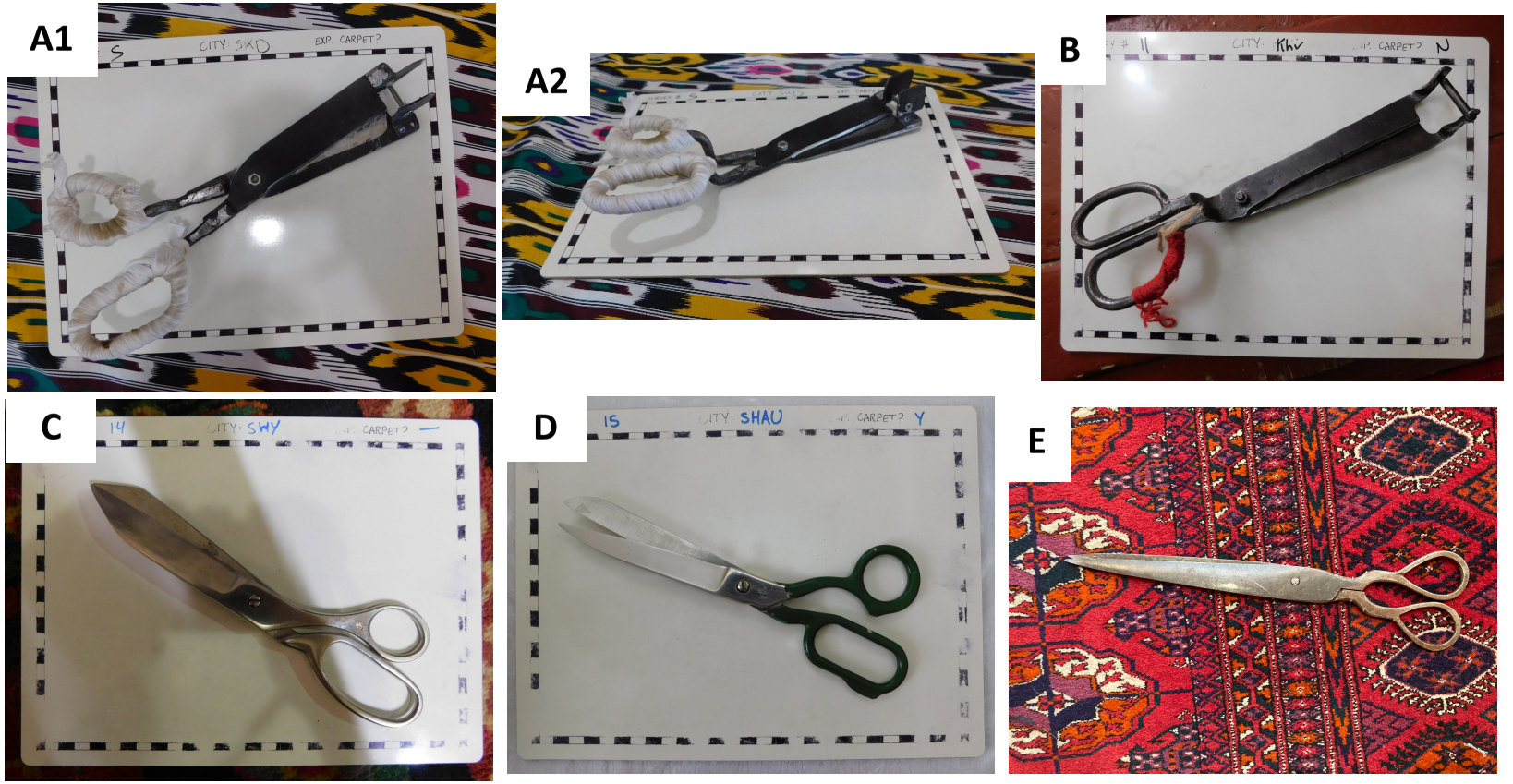

Figure 6.38: Scissors & Shears

Selection of distinct knife-types used by the ethnographic weavers in this study. The scale grid on the board is in centimeters.

A: Survey 4: Samarkand, Uzbekistan. Also represents Surveys 1,2, 7, 8, 9. Photo by author, Sep 2021.
B: Survey 11: Ingilis, Khiva, Uzbekistan. Also represents Surveys 6, 12. Photo by author, Sep 2021.
C: Survey 14: Shymkent, Kazakhstan. Photo by author, Oct 2021.
D: Survey 15: Shauldir, Kazakhstan. Photo by author, Oct 2021.
E: Survey 16: Ashgabat, Turkmenistan. Photo by author, May 2023.



Figure 6.39: Trimming the Knots

A weaver (Nigora/Mairead) trims a row of knots. Notice that the knots are shaggy and uneven ahead of the scissors, but are shorter and uniform where she has trimmed. Survey 1: Samarkand, Uzbekistan. Photo by author, Sep 2021.



Figure 6.40: Using a Hook

Two weavers use a hooked knife to pull individual warps forward on fine, high-quality silk carpets. See photos of the tools in Fig 6.37a, b.

Left: Survey 4: Samarkand, Uzbekistan. Weaver Bashorat (Kathleen). Photo by author, Sep 2021.

Right: Survey 9: Khiva, Uzbekistan. Weaver Nazokat (Jean). Photo by author, Sep 2021.

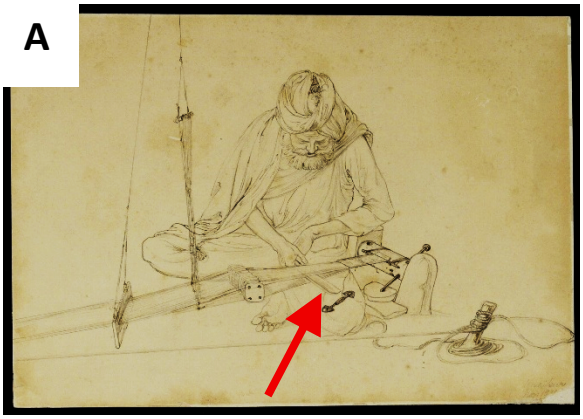









Figure 6.41: Beater Types
Photos by author unless otherwise noted.

A: A man uses a sword beater to compact weaving on a tablet loom. Sketch by John Lockwood Kipling from the Amritsar Jail, Punjab, India, 1870. Inv. No., Victoria & Albert Museum: 0929:15. Image © Victoria and Albert Museum, London.

B: A rigid heddle. Although this loom has a separate beater, this heddle does have the capacity to act as a beater. Loom used by the Zuni peoples of New Mexico. Inv. No., Pitt Rivers Museum: 1884.46.7. Image taken with permission of the Pitt Rivers Museum, Oxford. Aug 2015.

C: A reed beater on an ikat loom, brought forward to compact the weft. The heddle, a separate component, is suspended in the warp behind the reed (white). Ashgabat, Turkmenistan. May 2017.

D: A 19th century comb beater used on knotted carpets by Berber weavers in the Atlas Mountains, Morocco. Private collection.

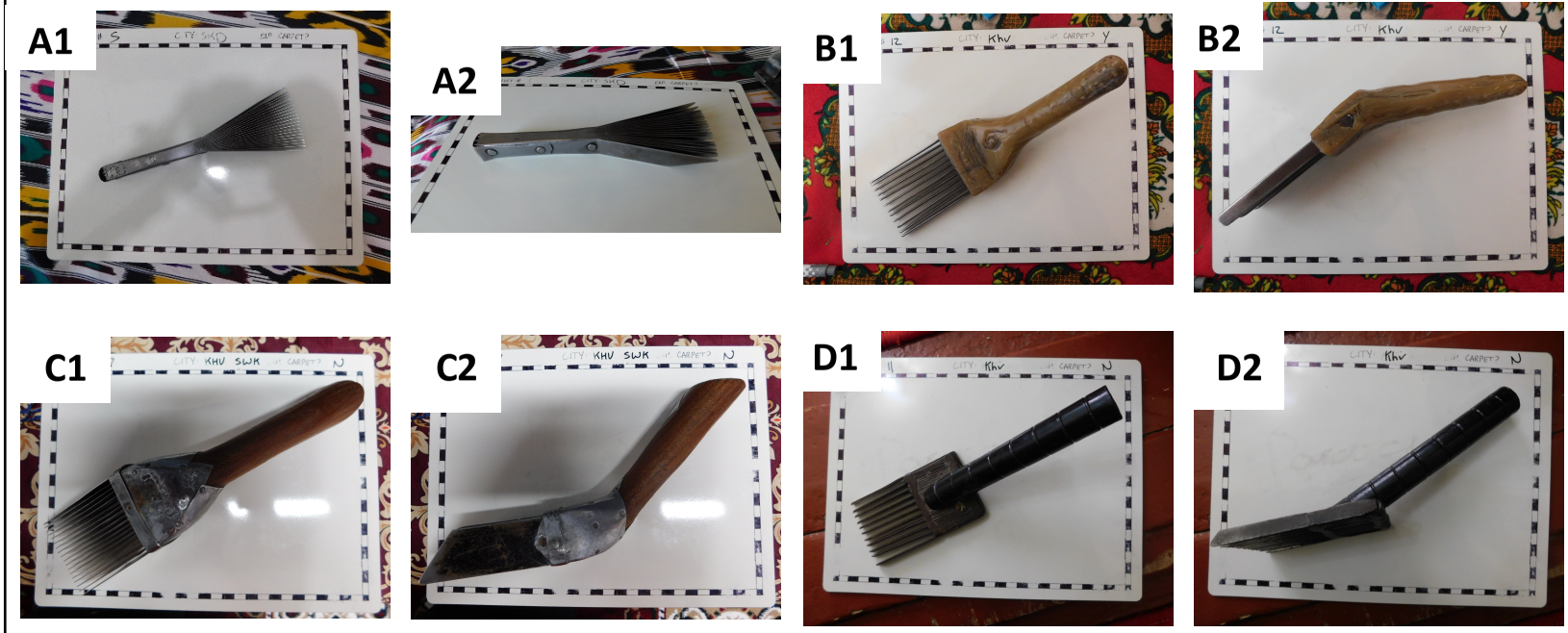



Figure 6.42: Comb Beaters
All photos by author.

A: Survey 4: Samarkand, Uzbekistan. Also represents Surveys 1, 2. Sep 2021.

B: Survey 12: Angarik, Khiva, Uzbekistan. Also represents Survey 6. Sep 2021.

C: Survey 7: Khiva, Uzbekistan. Also represents Surveys 8, 9, 15, 17. Sep 2021.

D: Survey 11: Gondimiyon, Khiva, Uzbekistan. Sep 2021.

E: Survey 14: Shymkent, Kazakhstan. Oct 2021.



Figure 6.43: Turkmen Weaving Tools in the 20th Century

A weaver works on a loom in Ashgabat, Turkmenistan (then the Turkmen SSR), 1989. Note similar curved knife and in-line scissors 35 years before this study: compare to Figs. 6.37 and 6.38. Photograph by Carol Bier, used with permission.

7. Data Collection, Sampling, and Processing

Sampling Scheme

The foundation of this project is a set of carpets and carpet fragments, sourced from various locations and representing both living and ancient craftworks. Acquiring this sample was therefore the first step of the research. Archaeological evidence is not currently capable of determining with any certainty which of several regions was the first to produce knotted textiles, nor whether the technique was spread to other areas by cultural contact/transmission, or by independent innovation, or by some combination of the two. It is therefore not possible to justify a sampling scheme based on antiquity or originality alone, and other factors had to be used to narrow down the sampling region to a realistic size. So, although knotted carpets appear in several disparate parts of Eurasia and North Africa at approximately the same times, this experiment focuses on materials from Central Asia. In modern geopolitics, Central Asia is understood to be the region comprising the five Turkic-Iranic post-Soviet republics of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. More specifically, this study is limited to the arid, non-agricultural zones of those countries where sedentary, pastoral, and nomadic communities interacted in and around trade-hub oasis cities and settlements over the last three millennia. This choice was made for several reasons, the first and most salient of which is that it

was necessary from a purely logistical standpoint to select a target zone, rather than to try to source carpets and visit weavers across the entire continent.

The second reason was that the archaeological evidence for ancient and historic carpets vastly prioritizes deserts and arid grasslands. The oldest knotted carpets and fragments are from Egypt and China's Taklamakan desert. Later finds are in the arid Iranian Plateau, the Middle East, and the steppes of Kazakhstan and southern Siberia. None of the carpet fragments from before c. 1400 CE can be definitively sourced to temperate or humid regions, or to areas without a hot summer. Because this climate and landscape has the longest and by far the most prolific history of carpet manufacture, it was selected as the regional focus to minimize mismatches in textile function/goal, pressures of weather or waterproofing, and major discrepancies in environmental resources. Of course, there are no weavers left living today working under exactly the same conditions as their ancient counterparts, but by limiting the study to a consistent and ancient biome, I hope to minimize comparative problems as much as possible.

A significant portion of the historic carpets that still survive in cultural collections, particularly in Europe, were transported along the Silk Roads at the end of that network's period of dominance in the Renaissance. Although a lack of detailed provenance data on these carpets generally precludes us from making high-probability assertions about their precise sources, it is reasonable to expect that many were picked up in the Central Asian oasis cities, near where they were made. Khotan, situated in western China in a desert basin bounded by high mountains, is noted by several Medieval chroniclers for its robust carpet industry (Bidder 1964:18-19; Gyul 2016:6; Tsareva 2009:75; Zhang 2019:36-37). Across the Tian Shan along the edge of the arid

lowlands, the Sogdians are also noted for their high-volume trade in textiles (Gyul 2016:6-7). These cities acted as hubs for local and international trade and commerce, which brought in members of the outlying community to purchase resources, sell their own goods, and interact with local artisans. People living in and around those same historic cities were prioritized here, as opposed to people living in more remote locations where long-term mercantile relationships with Europe and East Asia are less firmly defined, or in more modern cities where there is no historic-cultural carpet mandate.

Related to the pressures of the environment and climate, historic evidence suggests that carpets are almost exclusively produced in areas with a significant sheep and wool industry. The structure of knotted textiles requires several times more yarn than flat-woven textiles do, meaning that even the base materials would be difficult and/or expensive for a community to procure without regular access to large-quantity fiber production. Although linen knots are known in antiquity and silk and cotton from the Renaissance, these pieces likely make up <1% of all the carpets ever made. The environmental resources (especially water) and labor investment needed to generate mass quantities of linen, silk, or cotton in ancient times would have made those fibers prohibitively expensive for large-scale carpet production. The centers of ancient, historic, and modern carpet production (Central Asia, the Tarim Basin, Iran, Turkey, and the Caucuses) are therefore all sheep economies. While certainly the importance of sheep and the average weaver's day-to-day interactions with them has dwindled notably in the modern age, the cultural background of pastoral and shepherd communities is still present in arid Central Asia. Global production is now dominated by post-colonial Australia and New Zealand, but historic

carpet zones in China, Turkey, Morocco, Iran, India, Kazakhstan, Turkmenistan, and Uzbekistan are all still among the top twenty global wool producers (IWTO 2022: table 1.2).

Although the lore of the last century has been that carpets are a nomadic product, there is actually little archaeological evidence that this was the case in ancient times. Even the modern (20th century) weavers whose whereabouts are known were predominantly based in cities and villages, with only a very small number being truly transhumant. This is mainly because carpets take months to make. Even a skilled master devoting all their working hours to a weaving will need a few months to produce one carpet of a couple meters square, and larger pieces or ones worked ad-hoc around other chores could take over a year. Working around my coursework and athletics training, it took me a full academic year to weave a doormat-sized carpet in my undergraduate dorm room!

Carpet looms are also not really something that can be rolled up and transported. While not impossible, it is certainly inconvenient, time consuming, and difficult, and probably not a task that nomadic weavers were eager to take on very often. However, it must be acknowledged that some nomadic-pastoralists have been documented in the last two centuries making carpets and other items with the knotted technique, and therefore we cannot say it is or ever was an exclusively sedentary craft either. But as the overwhelming evidence is that most ancient and historic carpets were made in villages and cities, the same types of places were targeted in this study. Focusing on sedentary weaving has the added benefit of logistical ease, as it was easier to identify participants and travel to their homes and workshops when they were stationary themselves.

Finally, personal interest in Central Asian history and culture, along with years of experience in Turkic, Persian, Arabic, and Russian textile terminology made Central Asia the preferred zone. Cultural comfort, language skills, and personal networks and connections in the region allowed me to locate and interview more weavers than I would likely have been able to find in a less familiar place, particularly when the complications of the COVID-19 pandemic were factored in.

Based on the above targets, this study uses western Central Asia as its core region. This area is bounded by the edge of the Iranian Plateau in the south, the Aral Sea in Kazakhstan in the north, the Caspian Sea in the west, and the foothills of the Tian Shan and Pamir ranges in the east. This area is known as the Central Asian Southern Desert, encompassing two smaller regional deserts: the Kyzylkum in Uzbekistan and southern Kazakhstan, and the Karakum in Turkmenistan. This area is arid, with low annual precipitation, extreme seasonal temperatures, sharp difference between daytime highs and overnight lows, low population densities, and limited large-scale agriculture (barring cotton, a Russian imperial addition). The ancient and historic oases studied here include Otrar (modern Shauldir) and Shymkent in Kazakhstan; Samarkand, Bukhara, and Khiva in Uzbekistan; and Merv (modern Mary) in Turkmenistan.

The data in this study are divided into two categories: the ethnographic sample and the historic sample. The ethnographic sample is made up of 30 carpets woven in 2020-2021 CE in the target zone (see the dedicated section below for details, and a summary of the included pieces in Table 7.1). These carpets act as a control sample, where I was able to document the weaving techniques, social structures, and individual idiosyncrasies employed in their production. By

basing the analysis on carpets with a firm technical, social, and idiosyncratic description, any conclusions drawn about ancient or historic carpets will be more robust. I commissioned a group of participant weavers to produce these carpets specifically for this study, with the goal of ensuring thorough documentation of that specific item's production. A handful of additional carpets were not commissioned but instead studied with the weavers' permission in the field. These carpets are items made for other clients but use the same techniques and in the same settings as the commissioned carpets. They are therefore an effective way to expand the ethnographic sample without overextending the budget.

The historic sample is made up of 52 whole carpets, orphaned fragments, and fragment groups held in various museums and private collections (see the dedicated section below for details, and a summary of the included pieces in Table 7.2). These carpets were described and measured with the same methodology as the modern carpets (where possible), and the conclusions drawn from the ethnographic sample were used to estimate new details about the historic sample.

It is necessary to acknowledge that knotted textiles are a living craft system, and that it would never be possible to exactly replicate the materials, skills, environments, personal identities, or socio-cultural pressures that characterized ancient or historic weavers. The modern weavers, while possibly related to their historic counterparts, are not identical to them, nor are they necessarily part of the same cultural or craft lineage. Minimizing rather than eliminating confounding factors is the target here. While it would have been possible to perform a narrower study on a larger number of similar weavers, covering a larger area helps to strengthen

conclusions about production, as well as to eliminate small-scale, individual, or random variations that might be exaggerated by centuries of cultural and technological change. This study should be viewed as a small-scale test for the methodology and theory, rather than one producing absolute results about the individual carpets included.

The Ethnographic Sample

Generating the ethnographic sample for this study faced considerable limitations due to the geo-political state of the target area in 2020-2023. At the most basic level, there are simply not that many people left who make knotted carpets by hand. The weaving process is very slow and it is not economically viable for most people to weave low- to medium-quality carpets full-time out of cheap, readily accessible materials (like wool, cotton, or synthetics). Machine-made carpets are more popular as a cheap alternative accessible to most average people in the area and worldwide, while luxury silk carpets are hand-woven for the domestic and international upper classes: the market for new low- and medium-quality hand-woven carpets is small, both locally and globally. This is partially due to the carpets' longevity: while many modern Western homes have hand-knotted Asian carpets, they were produced 50-150 years ago and do not require replacement yet.

Even when economic support for weavers is available, it does not necessarily work in this project's favor. Government certification and export controls in Turkmenistan, as well as a recent re-emphasis on centralized workshops, has notably strengthened the carpet economy there. Unfortunately, the structure of this revitalization heavily prioritizes professional weavers working

in standardized workshops with standardized materials and techniques, derived primarily from a single ethnic group (Teke). This has tended to reduce technical and idiosyncratic diversity amongst Turkmen weavers.

A similar situation is occurring in Uzbekistan, where UNESCO and NGO funding in the last 20-30 years has re-focused carpet production on silk statement pieces. The immense time requirement, strict quality controls, and the added cost of the base materials similarly limits the economic spread and consequent diversity of weaving in Uzbekistan. One informant in an Uzbek silk workshop suggested that the weaving techniques used today are not traditionally Uzbek at all, and rather were imported from Afghan-Turkmen weavers in the mid-20th century to replace inefficient and less refined Uzbek techniques (Survey 3). Although this study has no inherent preference for traditions associated with one central Eurasian ethnic group over another, this acknowledgement of traditions being revised or replaced wholesale quite recently within the weaving community does suggest that there may be an active cull of variation in effect, which could skew the results of this and similar research. It is particularly jarring to compare the number and type of structural variations present in ancient fragments compared to the significantly reduced number present in this ethnographic sample (compare Fig. 5.4 to the ethnographic schematics in Appendix B), or to ethnographies produced only a century ago (see Moshkova 1996).

Kazakhstan alone of the sampled countries does not have any national or international carpet revitalization strategies in place, and so the majority of weavers are still domestic or the proprietors of small independent studios. This is not due to a lack of interest or support for

heritage textiles in Kazakhstan, but rather is a result of the cold steppe and high-altitude plain's comparatively stronger history in felt. It is felt that receives national and international attention in Kazakhstan, as most of the country sits within this colder, wetter climate. A similar priority for felt is seen in Kyrgyzstan and to a lesser extent Tajikistan, both of which are high-altitude cultures. Kazakh carpet-weavers are focused primarily along the southern border with Uzbekistan, where the colder steppe and Central Asian North Desert transition to the dryer, hotter South Desert. This lack of carpet attention produces its own set of challenges in Kazakhstan, as these disparate weavers are usually not part of traceable networks or registries, and there are not major resale organizations or bazaar presences. This makes Kazakh carpet-weavers very difficult to identify without on-the-ground enquiry.

The research plan was originally to visit various cities and locate independent weavers through on-the-ground enquiry in bazaars, art studios, craft collectives, through family ties, and other community networks. This was based on the issues presented above, and also on the assumption that a majority of living hand-weavers are elderly: instruction in the technique, which likely used to be common training for most if not all children, is losing momentum.[19] It is therefore reasonable to suspect that a majority of the people who know how to weave are older, and possibly less visible or active in public and economic networks. Unfortunately, the COVID-19 pandemic made travel to the region in the required timeframe (2020-2021) impossible. Identification of possible informants had to be done remotely through existing contacts and

[19] All of the weavers over 40 in this study reported learning at least some weaving at public school, while younger weavers and translators mostly did not.

formal organizations, which skewed the sample towards professional and semi-professional weavers and away from domestic, casual, or hobbyist artisans.

The weavers that were identified remotely via personal contact networks were invited to participate in the study. Participation included an interview about their weaving techniques, materials, and tools, and a discussion of their personal weaving histories. Some of the weavers were commissioned to produce carpets for the study: to ration funding, purchases were limited to wool, cotton, and synthetic carpets. As silk carpets are several times more expensive per square meter and tend to be larger in size, weavers working exclusively in silk are not represented in the commissioned sample. However, it was possible to document some silk carpets in the field without purchasing them, with permission of the weaver and relevant workshop managers. Silk weavers are therefore represented in the ethnographic sample, if not the commissioned one.

Eighteen weavers contributed twenty-one commissioned carpets and nine unpurchased field carpets to the ethnographic sample. The weavers reside in and around the historic oasis cities of Shymkent (x2) and Otrar [modern Shauldir] (x1) in Kazakhstan; Merv [modern Mary] (x5) in Turkmenistan; and Khiva (x8) and Samarkand (x3) in Uzbekistan. They work for professional workshops, independent art studios and collectives, and privately. They include both professionals and domestic hobbyists. All the weavers are women over the age of eighteen, and all are of a modern Central Asian ethnicity. Socio-economic class, religion, marital status, and other demographics were not considered or documented.

After a weaver was identified, I gained the necessary permissions to interview, record, photograph, and/or name the weaver from the weaver themselves and any relevant supervisors

or managers. All names and images included in this document are with permission of the subject: weavers uncomfortable sharing their information are referenced as “Anonymous”. Interviews were performed through local translators and documented through voice recordings, videos, photos, and written notes.

Interviews included questions about the weaver’s personal and craft history, including their age, where they learned to weave, how long they have been weaving, what their favorite designs are, whether they are right- or left-handed, how many hours they spend weaving per day, who their normal customers are, etc. The interviews also included documentation of weaving techniques and tools, through discussion with the weaver and observation of the weaving process. Several peripheral informants were also interviewed, including workshop managers, retired weavers, student weavers, and dyers. Although these people are not the primary sources of information, their comments did provide a holistic companion to the weavers’ data. A summary of the weaver’s demographic & personal characteristics is given in Table 7.3.

Turkmenistan and Uzbekistan both use the Latin alphabet. Therefore, the names of people living in those countries have not been transliterated or otherwise changed. Spellings of personal names are exactly as the informant gave them. Kazakhstan uses a variant of the Cyrillic alphabet: I transliterated the names into the Latin alphabet myself, as I have had formal education in Kazakh language. The original Cyrillic spellings of personal names are given in Table 7.3. Although most of the weavers were happy to share their names for publication, all were assigned an English-language pseudonym for data analysis. This was done for two reasons. First, spelling mistakes can cause errors and artificial separation of data in the computer analyses used here, so it seemed

prudent to use names that the research team was more comfortable with and could confidently and repeatedly spell correctly, especially when dealing with several million individual data points. Secondly, some volunteers assisted with data collection and analysis who have no familiarity with Central Asia, and so using English-language names was easier for them and provided a bit of extra anonymity and privacy to the weavers. These pseudonyms were assigned randomly and have no meaning or pattern beyond identifying the weavers. Although not blinded, randomly assigning new names to the weavers also reduced the changes that I would accidentally bias results or interpretations.

Larger cities and villages are spelled in the standard way used in modern American and British maps and encyclopedias, while smaller villages and neighborhoods that do not generally appear in English-language documents are either given exactly as spelled by the informants (in Turkmenistan and Uzbekistan) or were transliterated from Cyrillic (Kazakhstan).

Three weavers in Kazakhstan agreed to participate in this study. The first lives in Shauldir, a small town about 12km southeast of the ruins of historic oasis city Otrar. The village hosts the Otrar Museum as well as the research camp used by archaeological teams working in the ancient city and surrounding sites. The weaver, Sholpan Zhycinbek [Шолпан Жүсінбек], was suggested by contacts in the Otrar Museum. Sholpan is a married woman with grown-up children. Professionally, she works as a music teacher at a local school. She is a domestic hobbyist weaver, making items for herself, her family, and her friends in her home. She rarely sells her work, although she has exhibited it in a few art shows. I commissioned two carpets from Sholpan, and one additional carpet was photographed for study in her home. These carpets were collected

and the interview conducted in-person by the author in October 2021, shortly after the COVID-19 travel ban was relaxed for professional visitors by government invitation.

Two more Kazakh weavers reside in Shymkent, another historic city on the southern border with Uzbekistan. Madina Ahmetova [Мадина Ахметова] and Kulyash Aidarbekova [Куляш Айдарбекова] both work for Altyn Orda (Алтын Орда , “golden horde”), a family-run art gallery that produces traditional handcrafts and modern art in a wide range of media. The studio employs multiple generations of the extended Beicbekov (Бейсбеков) family working in a large, shared workshop space. The gallery and studio spaces are in a residential neighborhood near the center of the city. Madina is a member of the studio family, and the mother of a young family herself. She acts primarily as a workshop manager rather than an artisan, but she does participate in production occasionally and was able to produce one carpet for this study. Kulyash is an older relative who learned to weave from family and at school in her early teens, and she was commissioned to make one carpet for this study as well. The interviews and carpets from Altyn Orda were retrieved in-person by the author in October 2021.

Ten weavers were interviewed in Uzbekistan. The first group of three are professionals working at a UNESCO-founded silk carpet workshop in Samarkand. With their sister workshops in Bukhara and Khiva, this organization works with natural dyes and exclusively in silk. They were founded to promote interest and maintain skills in this ancient craft via UNESCO and other NGO funding, although they run independently now. Their modern workshop sits in the heart of the city within walking distance of many famous Medieval sites. The Samarkand silk weavers include Maftuna Narzulloeva, Bashorat, and Nigora. These weavers were trained on-site by master

weavers to follow a particular set of techniques and standards, and their work is subject to considerably more oversight and quality-control than any of the weavers already discussed. This workshop tends to specialize in arabesque and curvilinear designs traditionally associated with Iran and Persia, as these are more fashionable in countries outside Central Asia where most of their carpets are sold. Although the silk carpets produced here start at several thousand dollars and none could be purchased for this study, it was possible to photograph one carpet from each weaver in the workshop's showroom. The Samarkand silk weavers were interviewed and their carpets photographed in-person by the author in September 2021, shortly after the COVID-19 travel ban was relaxed for professional & business visas.

Another group of three professionals work in the corresponding silk workshop in the Itchan Kala (inner or old city) of Khiva in western Uzbekistan. Once the capital city of the Khwarezmian Empire (c. 1075-1230 CE) and later the Khanate of Khiva (c. 1510-1920 CE), the weavers here have a notably different set of aesthetics than their counterparts in Samarkand. Here, they draw designs from engravings, tiles, and calligraphy present in the historic city as well as from historic illustrations. Many of their patterns are drawn on-site and are unique to this workshop. Halima Matyaqubova, Maloxat Qurbonova, and Nazokat Aminova were interviewed for the study, working out of a cell in a 19th century open-air madrassa. The courtyard of the madrassa hosts a set of large cauldrons where the workshop manager Madrim Matkarimov experiments with natural dyes.[20] Like the weavers in Samarkand, Halima, Maloxat, and Nazokat

[20] Matkarimov's extended family were the foundation of the carpet workshop when it was first opened, performing many operations out of their family home, now a small B&B.

received formal training in carpet-weaving and are held to a high standard. Maloxat and Nazokat were the only pair of weavers in the study observed working together on a single carpet. Like the Samarkand silks, purchasing a carpet from this workshop was not feasible, but it was possible to photograph two carpets woven by Halima, one each from Maloxat and Nazokat independently, and one joint-effort from Maloxat and Nazokat. These interviews were conducted and the carpets photographed in-person by the author in September 2021.

The last four Uzbek weavers are part of a semi-professional collective operating in sub-urban and rural villages around Khiva called Angarik, Gondimiyon, and Ingilis. These villages are all within a 30-minute drive of the Khivan city center, but have their own resources and can operate without direct interaction with the city. These weavers share resources, tips, and customers, but don't necessarily work together or have a shared weaving history. They learned their craft through various skill schools, professional weaving workshops, or from family, in their youth and as adults. They work out of their individual homes on a made-to-order model: although they make some money from their carpets, none are supporting their households or dedicate all their working hours to weaving. Most have children or grandchildren in the home, and all are still responsible for day-to-day housework and errands. Due to the natural inconsistency of the made-to-order model, they sometimes weave full-time and sometimes not at all. This group includes Durdiposhsha Omonova, Dilbar Omonova, Mehribon Haitova, and "Stephanie". They range in age from their early 30s to their late 60s, and the group includes one family duo (Dilbar is Durdiposhsha's daughter-in-law). Each weaver wove two carpets for the project on commission. These carpets were collected and the interviews conducted in-person by the author in September

2021. Additional photographs and details were shared via messaging app, facilitated by a local contact.

Finally, five weavers working in a similar semi-professional collective in Turkmenistan were commissioned to make nine carpets. These weavers work in villages around Mary, about 35km west of the ruins of ancient oasis city Merv in eastern Turkmenistan. Due to the COVID-19 pandemic, the difficulty in accessing Turkmenistan generally, and the lack of international telecommunications within the country, interviewing these weavers directly was impossible. The information used in the analysis for these weavers was mostly synthesized from other sources. Due to Turkmenistan's recent emphasis on carpets as a national heritage product and their rigid quality and certification standards, the carpets produced there are far more consistent (aesthetically, physically, and technologically) than those surveyed in Kazakhstan or Uzbekistan. While the carpets produced elsewhere clearly differ between groups, workshops, and locations, there is no clear difference in structure or design between the carpets commissioned by this project and those from other Turkmen sources. Therefore, it is reasonable to estimate the missing ethnographic and technological information based on other weavers. The Turkmen weavers all elected to remain anonymous, and are given the following pseudonyms: Anna (x3 carpets), Barbara (x2), Christina (x2), Dorothy (x1), and Eleanora (x1). The limited contact possible with the Turkmen group was done through messaging app via a local contact. The Turkmen carpets were collected in two phases. Three were carried home by a colleague completing archaeological research in Merv in April 2023. The remaining six were transported to Ashgabat by courier and

then carried home by the author following a visit to Ashgabat in May 2023. Unfortunately, I was never able to meet or speak directly to the Turkmen weavers.

When the extent of the COVID-19 pandemic became clear and I realized I would likely not be able to identify large numbers of weavers in the original target region, I considered extending into the similarly arid parts of the northern Iranian plateau and Pamir mountains. I therefore entered discussions with contacts in Afghanistan to extend the sample around Herat and Mazar-i-Sharif. Unfortunately, due to the withdrawal of the US military from the country in August 2021 and the subsequently increased unrest and reduction in women's rights (a direct concern for me as the primary researcher), this idea was scrapped. A similar train of thought nixed the idea of drawing samples from Iran after Masha Amini was killed in police custody in 2022 for refusing to wear a head covering, sparking local unrest and drawing global attention.

When commissioning carpets, only a few constraints were placed by me. A specific size target (in m^2) was selected based on a combination of local cost, transport and storage practicalities, and a preference for making a comparable sample with all pieces of similar size. Most of the commissioned carpets are around 0.6 square meters in size: the smallest is 0.178 m^2 and the largest is 0.993 m^2. They differ in aspect ratio, but many would be considered runners, and most are suited to hallways, doorways, or under small tables.

Although a customer would normally specify the desired pattern and colors when commissioning a carpet, I chose not to do so. Instead, I asked the weavers to weave any pattern they liked and encouraged them to make me their favorite designs. Because the patterns, aesthetics, colors, and symbolism are not studied here, it did not matter what the designs were.

But it also did not make sense to commission carpets of a solid color, as the routine of reading cartoons, swapping colors, matching gauges, and making mistakes in the color order is an important part of carpet technology and I did not want to artificially eliminate it from the sample. The weavers interpreted my request in various ways, with some producing their most popular and well-memorized designs, some weaving a personal favorite that no one ever orders, some taking inspiration from local traditional and iconic patterns of their city, and some mixing common motifs not normally used together. My personal favorite is carpet TK-MA-4, which is a dark green carpet featuring the five guls associated with Turkmenistan's largest tribal groups and mimicking the national flag (see Fig. 5.28).

No specific constraints or requests were placed on material, structure, or technique: the weavers were asked to use their most popular materials and their normal, comfortable techniques, and to price accordingly. This resulted in a range of materials, including cotton, wool, and synthetics, at a range of knotted densities from 4 to 27 k/cm^2, with prices from $50 to $235 USD per carpet. All the carpets have traditional side bindings, selvedges, and loose fringe, and all were made with tools and techniques that would be considered standard for the region/group. None of the structures, techniques, or materials could be considered novel or experimental. Some purchasing metadata appears in Table 7.1.

When commissioned carpets were collected, a tag was immediately sewn into them. This tag gives the carpet ID, location and date of collection, associated survey(s), and other notes. By permanently labelling the carpets in the field, I ensured that no carpets got mixed up or mis-assigned to weavers, workshops, or locations. The tags were sewn into the woven selvedge of the

carpets; as these areas were not included in the analysis, damage or distortion from the needle or tag do not affect the results. The tags could be cut out in future if needed but cannot be removed accidentally. This was particularly important as all the carpets had to be transported internationally in cargo, and I had to move one group the length of Uzbekistan in various ground transports.

The carpets retained their tags throughout analysis. Carpet IDs are used to differentiate the carpets and are coded in a three-part system. The first segment represents the country of origin (KZ = Kazakhstan, TK = Turkmenistan, and UZ = Uzbekistan). The second part represents the city (SH = Shymkent, OT = Shauldir, SK = Samarkand, KH = Khiva, and MA = Mary). Note that 'OT' is used for Shauldir to avoid confusion with Shymkent; the 'OT' is taken from the nearby ancient city Otrar. The final section of the ID code is a number, which counts upwards from one and resets to one in each city. Carpets were given the next sequential number in the order they were collected. Although carpets from the same source usually have sequential numbers, that is not necessarily the case, nor do the numbers have any meaning or grant any preference in the analysis.

Carpets that were studied in the field but not collected/commissioned were not physically tagged but were still assigned an ID number following the same pattern as the commissioned carpets. As these pieces were not woven for this project, I had little or no control over them: I documented whatever was available. The field carpets therefore vary significantly in size, from less than 0.5 m^2 to more than 3. They also feature silk, and the weavers had little (if any) control over the design. However, these carpets are still made in a way that is standard and comfortable

for the weaver, and represent the normal technology for that group. None of the weavers in this study were learning, experimenting, or "branching out" in their techniques or materials.

In total, twenty-one modern ethnographic carpets were commissioned and purchased by this project, and an additional nine were studied in the field. Following analysis, the purchased carpets were offered as a donation to the Helen Louise Allen Textile Collection (HLATC) at the University of Wisconsin-Madison. Carpets not accepted by the HLATC were gifted to informants and consultants who assisted with the research, or were retained by the author. A summary of the ethnographic carpets' logistical and metadata can be found in Table 7.1.

The Historic Sample

The historic sample is made up of 52 historic and archaeological carpets, single fragments, and fragment groups held in various museums and collections. When looking for relevant objects in collections, a primary target was established. The top-priority objects were those woven before 1500 CE (as the Silk Roads are generally accepted to have collapsed as a dominant network in the mid-15th century), and those woven in the Central Asian target zone described already. The low survival rate of textiles in archaeological settings, however, meant that it was unlikely that these narrow limitations would yield a significant sample, especially in conjunction with museum access restrictions. Peripheral carpets meeting some but not all targets were therefore also accepted, with production dates through 1900 and a geographic range anywhere in Asia. Any carpets or fragments that fell within these peripheral targets and for whom access was approved

by the owning institution is included; the samples were not narrowed or selected intentionally beyond these guidelines. All accessible carpets were studied.

Like the ethnographic sample, accessing these materials was significantly limited by the COVID-19 pandemic and radiating factors. As all data collection was planned for 2020-2021, the pandemic had an enormous impact on this study. Many museums closed completely during the height of the health crisis, and many more permanently cut staff. This meant that even when relevant pieces were identified in a collection, it was often not possible to arrange a research visit or to commission the detailed photographs required for this study, due simply to limited staff. This was particularly relevant to carpets, which are often quite large and heavy and require a larger staff presence to pull from storage. Multiple museums were initially open to the idea of providing photographs, until they realized that large carpets were required. This was particularly the case for smaller museums.

Several pre-planned renovations, events, and exhibitions ensured that other collections remained inaccessible even after pandemic restrictions were lifted. The Pergamon Museum in Berlin, Germany, widely known for one of the largest and most important carpet collections in the world, closed completely for renovations in late 2023 with a re-opening date in 2027. In preparation for the works, staff took the opportunity of the pandemic closures to pack most of the carpet collection into long-term storage, leaving no chance for a research visit between the lifting of COVID-19 travel restrictions in late 2021 and the planned works. The Museum of Islamic Art in Doha, Qatar was similarly inaccessible during the pandemic and then closed for renovation works in advance of the 2022 FIFA World Cup. The Hermitage Museum in St. Petersburg, Russia,

initially open to the idea of a visit to view ancient Altai fragments once pandemic restrictions lifted, was deemed an inappropriate source following the Russian invasion of Ukraine in February 2022. Had the project been able to proceed on its original research timeline and undertaken these museum visits in 2020 or 2021, more objects and particularly more relevant objects would probably have been accessible.

A large and critical collection of carpet fragments, including some of the oldest in the world, are held in museums in western China, primarily the Xinjiang Regional Museum in Urumqi. A request to view these pieces was submitted but it was flatly denied, citing an inability to sponsor an American research visa to the area. Photos were requested in place of an in-person visit, but this was denied as well. These refusals were despite a personal connection to the museum's director. The inability to access the Chinese and Russian collections was a particular blow to the project, as many unique and important pieces are held in those countries. Hopefully it will be possible to add those items and refine the results in future.

52 carpets and carpet fragments were ultimately accessible for study. A summary of these pieces, including their institutional catalogue numbers, can be found in Table 7.2. The historic pieces were given identification codes following the same three-part system devised for the ethnographic sample. Instead of a country code, all the historic IDs start with MU for 'museum', followed by a two-letter code based on the museum or collection's name. As with the ethnographic sample, carpets are then numbered 1 through *n* in order of access, and the numbers have no function or meaning in the analysis except to identify the carpets. Because many of the historic carpets are fragmented, a letter code is sometimes added to the end of the

ID when multiple discrete fragments are believed to come from the same original carpet. These usually start at '*a*' and proceed alphabetically, but were assigned by the owning institution and not by me (e.g. if the museum catalogue calls them e-h, then I use the same e-h designations). The fragment lettering therefore does not follow a consistent pattern based on size, preservation, or any other factor, as each museum uses its own system. Where it was possible to determine how the fragments were originally positioned relative to each other, they may be treated as a single entity in the research. When it is not possible to orient them, they are treated separately.

The first set of 7 historic carpets are held by the Indianapolis Museum of Art (IMA) at Newfields in Indianapolis, Indiana. All 7 were woven in eastern Iran, and they date between 1825-1900 CE. The IMA pieces are all complete and in relatively good condition. These carpets were viewed by in-person at the IMA stores in Indianapolis in July 2018. They were initially photographed for another study, but were added to this project despite their late date in light of the COVID-19 access limitations elsewhere. These carpets are identified with the codes MU-IN-1:7.

Four pieces were studied at the Victoria & Albert Museum (V&A) in London, United Kingdom. All four pieces are fragments: although the V&A holds many complete carpets that would have been relevant to this work, all were too large to pull for research or are on permanent display. Two of the fragments viewed at the V&A (MU-VA-3, 4) are the oldest in the historic sample, dating to 150 BCE-60 CE and recovered from excavations by the famed British archaeologist and explorer Aurel Stein in Loulan, Xinjiang Uyghur Autonomous Region, China, in

the early 20th century. These two pieces are small fragments about the size of a sheet of A4 paper but are in remarkably good condition. The two other pieces from the V&A collection are bigger and have clearly been cut from very large carpets. One is from Ottoman Turkey, dating to the 17th century, and the other from Tabriz, Iran under the Safavids, dating to the early 16th century. Both pieces are somewhat threadbare but not degraded beyond use. These pieces were viewed in-person at the V&A stores in Kensington, London in January 2020. These carpets are identified with the codes MU-VA-1:4.

An important set of older pieces was made available by the Al Sabah Collection, managed by the Dar al-Athar al-Islamiyyah as a long-term loan to the Kuwait National Collection. Twenty-three pieces representing seventeen original carpets were photographed. These date from the 2nd–17th centuries CE, with fourteen of seventeen woven in the 1st millennium CE. Most come from eastern Persia (modern Iran or Afghanistan), possibly the historic Khorasan region although the newest (17th century) is sourced specifically to Herat, Afghanistan.[21] These fragments are in variable conditions but are mostly quite degraded and fragmented. These pieces were viewed in-person at the Dar al-Athar al-Islamiyyah stores in Kuwait City, Kuwait in May 2023. These carpets are identified with the codes MU-AS-1:14, 16:18. The missing carpet (MU-AS-15) was viewed, but the high density of its double-sided knotting meant that I could not consistently photograph the underlying warp-weft structure without excessive and potentially damaging pressure on the pile. It was therefore removed from the sample and not formally analyzed.

[21] Note that historic Khorasan is not entirely co-located with the modern Iranian province of the same name. Historic Khorasan is considered to include most if not all of Afghanistan, as well as eastern Iran.

Two more carpets in seven pieces are held by the de Young Museum, a member of the Fine Arts Museums of San Francisco collective. One carpet was produced in or near Ushak, Turkey in the 16th century under the Ottomans, and the other in Central Asia or west China in the 5th-6th centuries. Although fragmented, these pieces are in relatively good condition. These seven pieces were the only ones not viewed in-person, and instead were photographed in line with study specifications by museum staff. Photographs were taken in the summer and shared in August 2023. Items from the de Young collection are identified with the code MU-DY-1:2. Four more carpets (MU-DY-3:6) were photographed by the De Young team, but poor photo resolution made them unusable for analysis and the staff were not able to devote time to re-taking them. These carpets are therefore excluded from the analyzed sample.

As it became apparent that COVID-19 museum access limitations were unlikely to resolve in time for this project, I chose to expand the historic sample via private collections. The British luxury auction houses Sotheby's and Christie's both agreed to allow access to carpets held on consignment for auction. Due to the ownership agreements in place for consignment, the carpets could be studied with only the permission of the auction house as they were in a limbo state between private owners. This was fortunate, as objects in private collections are often difficult to access or entirely unknown. Letters of thanks were passed to both the previous and new owners of the carpets by the auction house on my behalf, inviting the owners to get in touch with me if they wanted to learn more about the project or be acknowledged as the carpet's owners: none ever reached out. Without those connections, Christie's and Sotheby's privacy policies mean that the current location and state of these carpets is unknown.

Seven complete carpets on consignment to Christie's auction house were approved for study. They were consigned to be included in the *Art of the Islamic and Indian Worlds, including Oriental Rugs and Carpets* auction (#21017) held in London on October 27, 2022. Provenance data (provided by the previous owners and/or established through Christie's in-house research teams) date these carpets to the 17th-19th centuries CE, originating in China, Turkey, and undefined 'Turkestan'. These carpets were in acceptable condition, with some distortion, holes, water damage, and staining, indicating centuries of use in family homes. They were all viewed in-person at the Christie's storeroom in Park Royal, London in October 2022. Items from Christie's are identified with the codes MU-CH-1:7.

Finally, four carpets were studied while on consignment to Sotheby's auction house. They were consigned to be included in the *Art of the Islamic World & India, including Fine Rugs and Carpets* auction (#L22223), held in London on October 22, 2022. As with the Christie's items, provenance data were provided by the previous owner or supplied by the in-house research team. These four carpets date from the 17th-19th centuries CE. Two were made in or around Ushak, Turkey, one in or around Isfahan, Iran, and the last in the vague 'east Turkestan'. Like those from Christie's, these objects have clearly been used as floor coverings in homes for many years and have some amount of damage and distortion. The Sotheby's consignments were viewed in-person at the company's storeroom in Greenford, London in October 2022, and are identified as MU-SO-1:4.

In total, 62 individual pieces representing 41 original historic carpets (as grouped and defined by the owning institutions) are included in the historic analysis. Because some fragments

could not be oriented relative to each other and because relative position is a critical component of this analysis, some fragmentary pieces are treated individually rather than as original wholes. There are therefore 52 historic carpet units represented in the analysis, with most being disparate original carpets (either whole or fragmentary), and a small handful representing the same original carpet in un-oriented fragments. These 52 groups are joined by the 30 ethnographic carpets to create a full sample of 82 carpets, fragments, and fragment groups (see Tables 7.1 and 7.2 for summary metadata).

Data Collection

The ethnographic and historic samples were described by two paired groups: production characteristics and knot variation. The first set describes the technologies, tools, and materials used in carpet production, the social-cultural setting, idiosyncratic characteristics of the individual weavers, and the physical structure of the carpet. The production characteristics represent social-technical qualities of the carpets and weavers. These data are derived from ethnographic observation and direct contact with the weavers, and from structural analysis of the completed carpets.

These variables were documented in the hope that they could be used to explain the second set of data: variation in knot size and shape within the carpets. The knot variation data were derived completely independently from the weavers, and was generated by the research team from direct measurement of the carpets.

Production Characteristics

The social-technical characteristics were documented for each individual carpet in both the ethnographic and historic samples. A set of technological, social-cultural, material, and idiosyncratic variables were defined specifically for this study, to capture the types of small-scale variation that I hypothesize might have an effect on knot size/shape. Although these types of data would normally be presented in a narrative ethnographic format or through diagrams, it had to be simplified into discrete categories for the statistical analyses to function. It was therefore necessary to break down features that would normally be described in a holistic way into very precise and narrowly-defined subdivisions. The systems for describing each variable were developed primarily be me; beyond a few simple categorization schemes related to loom type and knot shape, I am not aware of any established system for defining carpet structures with similar detail. I also found that these popular categorization schemes often lump similar types together, without space for subtle variations.

Seventy-two social-technical characteristics were identified, categorized, and documented. These represent the material makeup of the different carpet components, the type of loom, the types of tools used, the frequency and order of tool use, the physical structure of the carpet, the skill and idiosyncrasies of the weaver, social structure of the workshop, and location. For each carpet, these variables were filled in based on observations of the weaver, their loom, and their process, tool checks, information reported by the weaver in their interview, and a physical examination of the carpet structure. These seventy-two variables do not count some extra metadata variables, including the age of the carpet and the presence of visible weft

rows. A complete database of all the documented characteristics for all the carpets (historic and modern) can be found in Appendix C.

Due to the natural limitations of working with human informants and historic pieces with limited or nonexistent production data, not all characteristics could be identified for every carpet. Lack of time, translation errors, personal availability of the weavers, privacy concerns, and other factors affected how much information could be collected from weavers. Similarly, my limited ability to refine the weaver pool during the COVID-19 pandemic means that it was not as diverse as originally intended: some characteristics, while recorded, do not provide any separation in the data (ie, all the weavers gave the same response or use the same technique). The combination of missing and non-separating data resulted in only a reduced selection of the characteristics (34) being included in the statistical analyses.

The subset of characteristics used in statistical analyses is given in Table 7.4. A detailed description of all the variables and abbreviations, their social-technical application and relevance, the definitions of categories, and the coding scheme are given in Chapter 6, from pg. 295. Refer to the Glossary (Appendix F) or to the wider explanation of weaving in Chapter 6 for additional information on terms, structures, history, and conventions. To visualize the classification values, see the diagrams of each carpet's structure in Appendix B.

Note that in the characteristic system defined here and represented in the database (Appendix C), 'None' is a distinct answer from zero (0) or blank cells (shown with a dash). *None* is used for categorical variables when the characteristic was checked but is not present, applicable, or relevant. Zero (0) is used for numeric variables where the item was counted, but the count is

null. Cells are left blank (-) when the characteristics could not be checked, and their values therefore might exist but are unknown. Also note that characteristics are described from the front of the carpet, not the back, based on the weaver's perspective while making the piece. Diagrams and illustrations are given from this same perspective. Photographs, analyses, and results are given from the back, as this is the side accessible for photography and measurement (see Fig. 6.7).

In the text, names of production characteristics are given in **Bold** to remind the reader that I am referring specifically to the classificatory variable defined for this study, and not the application or context of that feature in the wider carpet-weaving or textile world.

Variation Data

Besides the material, technical, social, and idiosyncratic descriptors, the other primary data type in this study was a measurement of variation in the physical knots. This included quantification of both their size and shape. The knots were selected as the unit of analysis because 1) knots appear as discrete units, which provide standardized boundaries for measurement, 2) knots are measurable without damaging or dismantling the weaving, 3) knots are hand-tied individually, meaning that they have potential for individual variation, and 4) a single carpet has thousands or even millions of knots, allowing for large sample sizes and robust analysis.

To measure the knots, a methodology from a prior study (V. Sluka 2017) was adapted. The original study recorded a similar type of data but on a much smaller scale. To expand the

sample size and manage time requirements, an updated methodology was used here. All the carpets from both the ethnographic and historic sample are documented following the same general methods, with some corrections made for special cases. These special cases are described as they come up in the following text.

First, as in V. Sluka 2017, the backs of the carpets were photographed. These photos were taken from a short distance to maximize clarity and resolution. This is particularly important for very fine carpets with knots only a few millimeters across. There was no resolution, zoom, or distance standard set for this study, but rather I just ensured that the knots were visible in the photos taken – depending on the quality of the carpet and size of the knots, the requisite distance changed between carpets. The relative scale between carpets is accounted for in the analysis, and therefore it was not necessary to ensure consistency in the photographs themselves. The backs of the carpets are photographed because only the pile (knot tails) is visible on the front, which obscures the underlying warp-weft grid as well as the knot bodies on that side. From the back, the knot bodies are clearly visible in the warp-weft grid, but the pile does not get in the way.

Some of the carpets in the historic sample, mostly ones from the so-called "Bactrian group" and held in the Al-Sabah collection, have double-sided knots.[22] This means that the weaver(s) tied knots on both the front and back planes of the carpet during production, so both sides are obscured by pile. In all of these cases, there is still a distinct front and back: the fronts use finer-spun and more homogenous wool in bright dyed colors, and the knotting creates a

[22] MU-AS 1, 4, 5, 7, 9, 14, 16, 17, 18

decorative design. The backs use course- or even un-spun wool, usually undyed, and usually without any decorative pattern (a few simple stripes of alternating light and dark wool are present). The fronts also use a consistent all-over knot density, while the backs are usually a kaunakes-type where fewer rows of knots are added, but with a longer pile to cover the gaps. To maintain comparability between this important and rare set of fragments and the rest of the sample, I only documented the "front" knots which have the same decorative and materials characteristics as the rest of the sample. In order to view the "back" properly for photography and analysis, the pile of the back knots was held out of the way (Fig. 7.1). Moving the back-side pile was necessary to variable degrees, as not all the carpets have the same density of knots on that side. Some have only a low-density of knots, which did not need to be moved at all to reveal the underlying structure. Others have denser and more evenly distributed back-side knots which had to be pulled back for every photo. One carpet (MU-AS-15) had to be excluded from the study entirely because it is in such a good state of preservation and has such densely-packed back-side knots that they could not be pushed aside sufficiently for photos.

Because of their fragile state, some historic carpets could not be flipped over for photography. One additional historic carpet was sewn to its support frame and was not reversible. These carpets were photographed from the front, and the resulting measurements are digitally inverted in the data transformation & cleaning stage to match the rest. Because the data analysis is based on proportional variation rather than absolute size (see discussions of the analysis in Chapters 6 and 7) there was no reason to expect that measuring the knots from the front vs. the back would affect the results, as long as the individual knot bases were visible. The



Figure 7.1: Photographing Double-Sided Carpets

The back of a double-sided carpet, where the pile is made up of raw, unspun, and undyed clumps of wool and hair. In its natural position, the back-side knots completely obscure the underlying warp/weft grid, and the base of the front-side knots. However, the back-side pile can be pulled back to reveal the underlying structure.

Carpet: MU-AS-9ab. Photos by author.

extreme age of these carpets results in a threadbare surface, so the bases were often visible through the pile.

In the original trial study (V. Sluka 2017), only the major design motifs were photographed. This dissertation expanded the photos to include the entire carpet where possible. Of the 30 ethnographic carpets studied, 18 were photographed with 100% coverage and 8 with 75% or better coverage. The carpets with lower coverage are those that were documented in the field instead of commissioned, and time, space, and lighting constraints made full-coverage photography impractical. Commissioned carpets were photographed fully in my home, under comparable conditions. Of the 52 historic pieces, 30 carpets have 100% coverage and 22 have 75% or better coverage. All the historic carpets were photographed in their institution's storerooms. All photographs include at least one scale bar (in centimeters), and notes were kept recording the position of each photo on the carpet. Wherever possible, photographs were taken with at least a 25% overlap: this allows the images to be more easily tiled together later, and helps to double-check their accurate positioning within the carpet. The photos were always taken in the same order, starting at the upper-left corner of the carpet and moving horizontally to the upper-right corner, then moving downwards one photo-height, and working back towards the left side. The photos continue in this snaking pattern until the whole carpet has been photographed. By working in a consistent pattern and using the edges of the carpet as row markers, it is possible to position images even when there are identical, repeating motifs. Additional details such as the carpet ID number, photography location, and carpet

dimensions were included in reference photos taken immediately before and after the analysis photos.

While photographing the carpets, I took note of their direction by including an arrow in a reference image. The direction refers to the orientation of the carpet while it was woven on the loom, with the weaver starting at the bottom and weaving upwards. This is separate from the pictorial orientation of the design, which may be woven sideways or even upside-down. The vertical and horizontal axes of a carpet can be easily distinguished by the woven structure, and within the vertical axis, the orientation of 'top' and 'bottom' can be estimated by the knap of the pile. When weaving, the pile is packed downward or towards the weaver by the beater (Collingwood 1968:229; Spooner 1986:205). This packing gives the pile a preference for remaining in this downward orientation, and it is less soft and more ruffled when brushed the other way (like petting an animal against vs. with the natural grain of its fur). Although there is no absolute way to confirm the weaving direction without witnessing production, feeling the knap of the pile is a reasonable approximation. The top of each carpet was indicated in notes, and all transformations and analysis thereafter orient the carpets in their original weaving position (top of the carpet at the top of the screen, diagram, or measurement scheme). It is important to note that the photographs were taken from the back of the carpets, flipped horizontally. This means that while up/down are preserved in the analysis, left/right are inverted (see Fig. 6.7). As there is no inherent structural difference between left and right in carpets, there is no reason to expect this to affect results or conclusions. If a difference is ever identified, these results can be easily corrected by flipping them horizontally. Similarly, the pile/knap direction,

knot directions, and knot variants (see Fig. 6.22) are the only structural difference between up/down, so it would be simple to invert that axis too, if needed. Since all the carpets in this study were oriented the same way, any conclusions can be considered valid, even if they must be inverted.

After photographing, the images for each carpet were named with the carpet ID and a unique photo reference number. In most cases, these numbers reference an imagined grid, where the photo's location in the carpet is given as a column & row number. The carpet photos are never used individually however, so these names are purely for reference and file organization. From here, the method for carpets with high photo coverage and lower photo coverage diverge.

Images from carpets with high photo coverage (e.g., images of the whole surface with few or no gaps) were digitally re-sized by matching the scale bars to remove variation in photo distance. Perspective distortion is also removed in this step by ensuring that the scale bar boxes are squares and not rectangles, parallelograms, trapezoids, or other quadrilaterals. The re-sized photos were then positioned over a full-carpet reference image to approximate their locations. Because the analysis photos were taken with overlapping edges, they can be matched to their neighbors. In most cases, very high precision in matching the reference and data images was possible, as the knotted designs are very distinct and detailed. The resized photos were merged into a single panorama. The resulting panoramas are undistorted views of the entire carpet (Fig. 7.2). Each photo retains its individual scale bar, and these are used to scale each photo individually in analysis – this eliminates and distortion or perspective errors created in generating

the panorama. Small segments of missing photos appear in some of these carpets where the photos do not overlap, but these are very small areas that did not hugely affect the analysis. Once generated, the image was checked for proportional accuracy against the measurements of the original carpet. The resulting image is marked with two embedded yellow dots in the upper corners to indicate the top, to ensure the photo could not be accidentally re-oriented in analysis. The image retained its original resolution, and was zoomable for precise data collection.

Carpets with less complete photo coverage had to be prepared a different way. Gaps between the photo areas meant that there was no overlapping data to match the photos together with. Instead, I took a reference photo of the whole carpet (from the reverse). The perspective angle was digitally removed and the image re-sized to match the measured proportions of the original carpet. A straight-on reference photo from above would have been preferable, but the field and museum conditions made that type of imaging impractical, particularly for large carpets which would have required specialized equipment suspended from the ceiling. The tile photographs were then positioned over the corresponding area of the carpet. Although not a perfect mapping system, this method gives a good approximation of the position of the photographs within the carpet (Fig. 7.3). These photos were re-sized to generally match the reference photo, but were not perfectly matched, nor were they distorted or scaled as a group. They each retain their individual scale bars, and these were used to scale each photo individually in analysis. The tile images were saved for analysis as a single isometric view of the carpet, and the distorted reference photo removed. As above, yellow dots in two corners indicate the top of the carpet, and the image was still zoomable for high-resolution data collection.

For some carpets in the historic sample, there was an added complication of fragments where it was not always possible to orient the pieces relative to each other. Where it was clear how the fragments were originally oriented (via connected threads or a continuation of the pattern), the fragments are positioned in their approximate locations and the photo-merge represents that. These continuities were identified by the owning institution, not by me. In these cases, several fragments (labeled a – *n* in catalogue numbers) could be condensed into a single unit and carpet ID for this study (e.g., fragments a-e were all orientable, and so were grouped together simply as MU-AS-11: see Table 7.2). Where the fragments could not be oriented relative to each other, they were treated separately in this study and were differentiated with additional letters at the end of their carpet IDs (e.g., MU-AS-2a and MU-AS-2b). The additional letters in the carpet IDs match the letters assigned to the fragments by the cataloguing institution, and therefore do not always start with *a*.

Once a panoramic image was generated, a systematic sample area was selected. Initially, the target was 25% of the carpets' knotted area (not including selvedges, side bindings, or fringe). However, the immense time requirement of measuring a 25% area led me to create a differentiated sample, where carpets smaller than 1 m^2 were sampled at 25%, while those larger than 1m^2 were sampled only half as much, at 12.5%. For consistency of sampling within groups of similar carpets, some pieces were sampled at the opposite rate than their size would suggest. For instance, carpets UZ-KH-2 and UZ-KH-3 are both slightly larger than 1m^2 (1.015m^2 and 1.035m^2 respectively), but as the seven other carpets produced by the same workshop are all under 1m^2 and were sampled at 25%, the two larger carpets were as well. Similarly, some of the

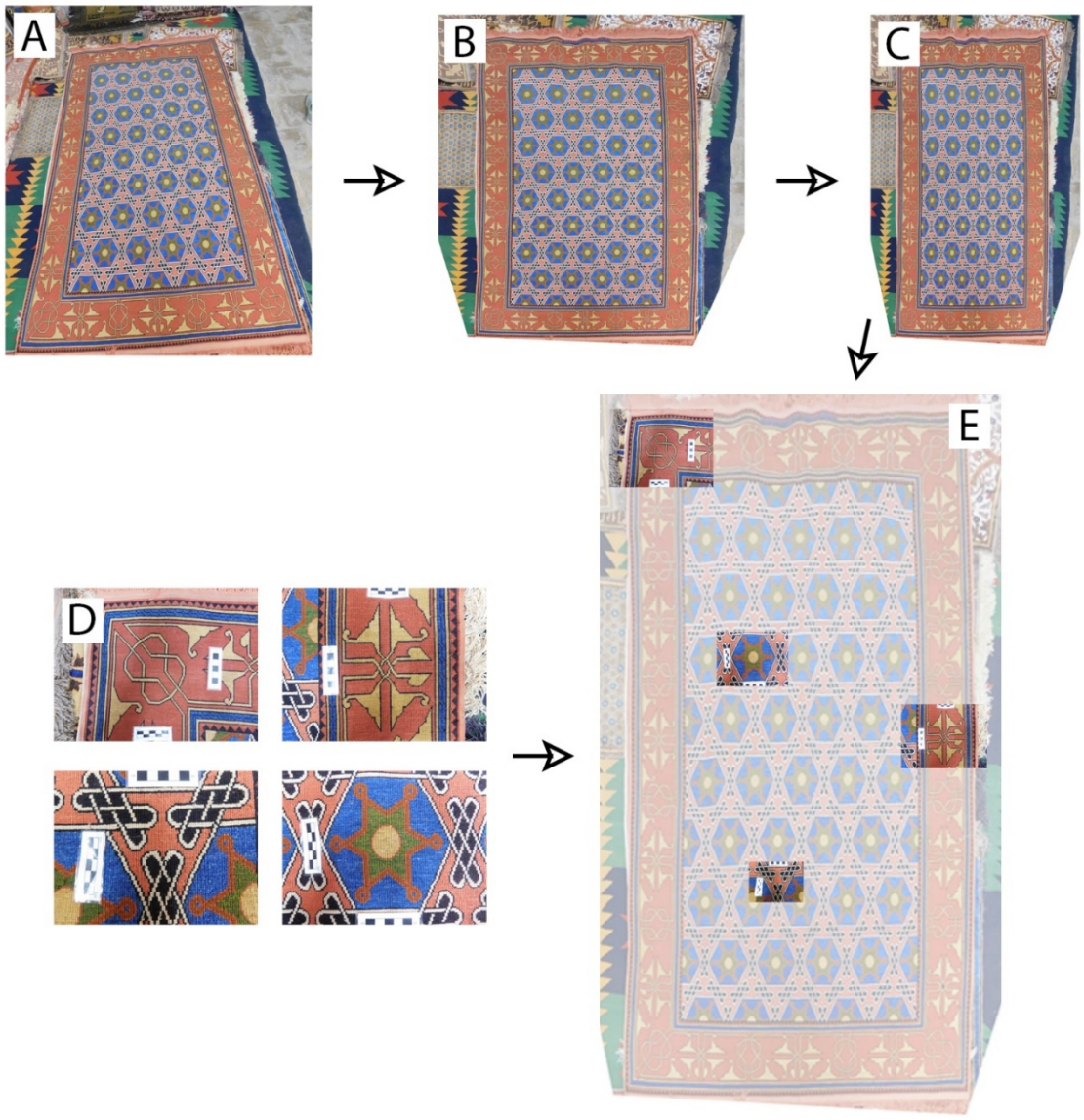

Figure 7.3: Low-Coverage Panoramas

A: A photo of the full carpet (reverse), with perspective distortion.
B: Photo perspective is removed to create a rectangular carpet.
C: Measurements of the carpet indicate that the width is 68% of the height, so the image is stretched to match.
D: Individual, close-up images of the carpet are taken. 4 of 127 shown here.
E: Detail images are resized and positioned individually on the carpet reference. Details in the design, consistent imaging order, and written notes ensure that photos are mapped to the correct position. Each detail image retains its original scale bar(s).

Carpet: UZ-KH-13. Figure by author.

more degraded historic carpets were sampled at the higher rate despite being larger than $1m^2$, to ensure a sufficient sample survives and was visible. Although it may seem counterintuitive that larger carpets have a reduced sample, it is important to note that the unit of study here is the individual knots, not the absolute or proportional square meterage of the carpet. Most of the larger carpets are also higher quality, and therefore have more knots per square meter. While a 12.5% sample is a smaller proportional area than a 25% sample, the density of knots means that a 12.5% sample of a larger, higher-quality carpet still represents a similar total number of knots. In fact in many cases, the reduced proportional sample on a large carpet contains considerably more knots than a larger proportion of a small carpet. Of the 30 ethnographic carpets, 21 were sampled at 25% and 9 at 12.5%. Of the historic carpets, 33 were sampled at 25% and 19 at 12.5%. Sample sizes for each carpet are shown in Table 7.5.

The sample areas were marked directly on the panorama images using a proportional grid. By using a proportional grid rather than an absolute grid, it was possible to compare areas of carpets based on their relative position. For instance, the 50% gridline in a large carpet and the 50% gridline in a small carpet both represent the middle, whereas a gridline 50cm from the left edge would not necessarily be the middle on every carpet. This allowed for comparisons of the relative parts of a carpet, without requiring additional scaling for carpet size.

Each sample box was scaled to represent 5% of the carpet's width and 5% of its height (0.25% of the square area). This means that the boxes were the same proportional shape as the full carpet, and almost always portrait rectangles. Because of the knots' interactions with the side binding and selvedges, I chose to reduce the proportional sample on the edges of the carpets

where knots were more likely to be outliers, and to focus data collection on the central field. Therefore, sample boxes on the edges (top, bottom, left, right) of the carpet were half-size (0.125% of the square area), and the boxes in the four corners of the carpet were only one-quarter size (0.0625%). This reduced their weight in the total sample, without eliminating these areas completely. Full-size boxes represent the same proportion of the total carpet (0.25%) regardless of whether they are part of a 25% or 12.5% sample. In order to achieve this proportional breakdown, the carpets sampled at 25% are represented by 121 boxes organized in an 11x11 grid, while the carpets sampled at 12.5% are represented by 64 boxes organized in an 8x8 grid (Fig. 7.4)

Sample boxes were organized on a regular grid of columns and rows. The sample boxes, regularly referred to as clusters, were embedded in the carpet panoramas as hairline cyan boxes: these box outlines were visible in analysis but were not thick enough to obscure the underlying knots. The clusters were embedded in the carpet panorama to ensure they could not be accidentally repositioned or deleted in analysis. Grids and therefore the sample boxes were measured from the edges of the carpets, excluding the selvedges at the top and bottom. In fragments where there was significant loss and the size/shape of the original piece is unknown, the edges of the fragment were used instead. Because many carpets do not have perfectly straight edges or 90° corners, an approximate edge-line was used on each side to best represent the shape. Clusters are calculated from and always sit on the perpendicular lines, but sometimes hang off the edge of the carpet where the weaving was particularly off-axis.

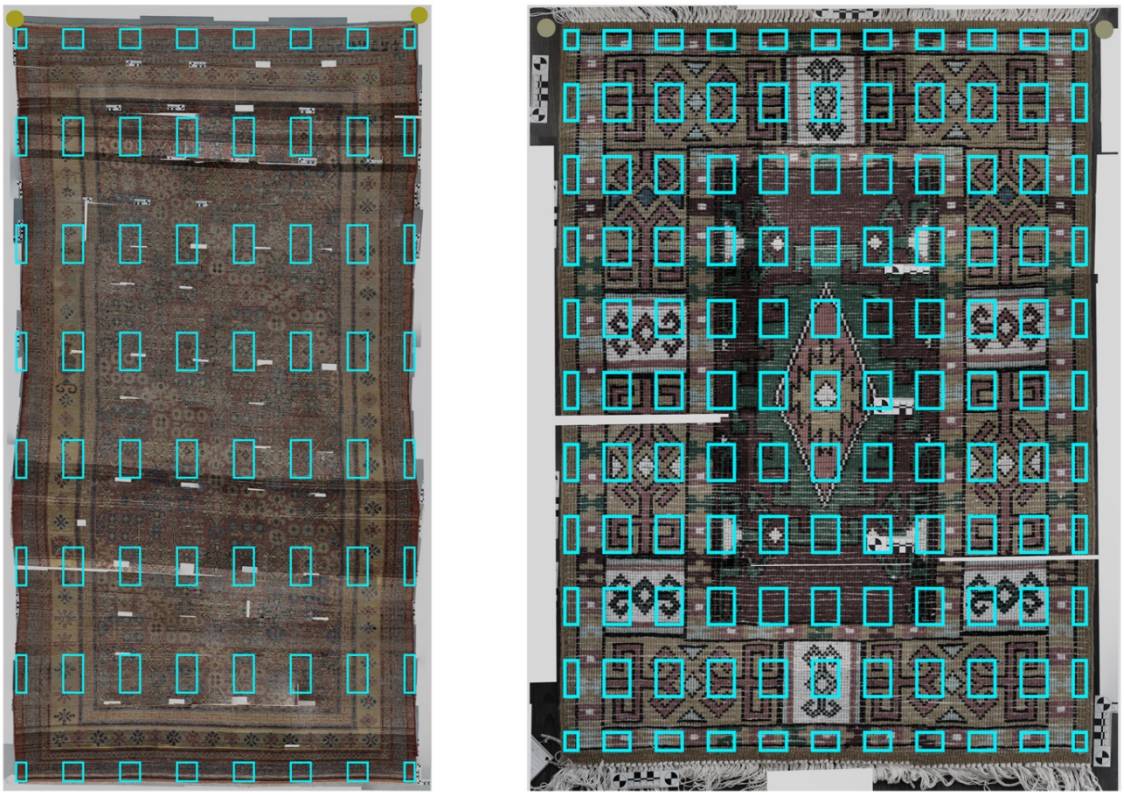

Figure 7.4: Sampling Grids

A carpet sampled on a 12.5% / 8x8 grid (left) and on a 25% grid / 11x11 grid (right). Note that the boxes on the edges are half-size, and those in the corners are quarter-size. Carpet images have been desaturated to highlight the sample boxes.

The left carpet is MU-CH-3, which is 6.42m^2. The sample boxes are 9x17 cm, containing approximately 2,000 knots each. In total, 88,244 knots were measured.

The right carpet is UZ-KH-8, which is 0.93m^2. The sample boxes are 4x6 cm, containing approximately 200 knots each. In total, 19,834 knots were measured.

Figure by author.

For most of the carpets, this regular sampling grid was used. However, for very small or particularly degraded fragments in the historic sample, the already limited number of surviving and visible knots disincentivized a reduced sample. In these carpets, any knot that is visible and that the analyst felt confident about was marked, anywhere in the carpet (Fig. 7.5). Because any visible knot was marked in these cases, the proportional sample varies wildly, from <10% to nearly 100%. Clusters of arbitrary size were then drawn around groups of closely-positioned marked knots. The same grided sampling system that was used in the other carpets was projected over the fragmented carpet, and the nearest grid-cluster to each arbitrary-cluster was used to map the arbitrary clusters. That is, if an arbitrary-cluster sat approximately at the point where cluster 24 would have sat in the grid, then the arbitrary-cluster was numbered as Cluster 24. This ensured that the cluster numbers used in both the systematic and random/arbitrary groups represent the same general position on the carpet. However, because the fragmentary carpets are not complete, the clusters do not represent position in quite the same way as they do on a complete carpet. The clusters represent the edges and middle of what is available, not necessarily the edges and middle of the original textile. This should not be an issue: any spatial trends identified in the fragmented samples should mirror those found in complete samples, they may just be at a smaller or more gradual scale of variation. Information on the system in which each carpet was sampled is given in Table 7.5. This completes the preparation of the carpet images.

Once an integrated image of each carpet was produced and the sample boxes marked, the knots within the boxes were measured. This was done using the open-source program QGIS. This software was designed for geospatial analysis of maps, borders, hydrology, topographies,

etc. Although not designed for this type of small-scale artefact analysis, the built-in features for measurements on a 2-dimensional plane made QGIS well-suited for this project. Each carpet was loaded into QGIS as an image. GQIS's default settings display the image without distortions or re-orientation, setting the image's upper-left corner at the (0,0) point on the system's arbitrary internal coordinate plane. The default plane is a global spatial reference system assuming a spherical surface. Since this coordinate system had the potential to introduce artificial variation/drift in measurements of a 2D plane, the reference system was changed to be one designed for flat systems (drawn maps, arial photographs, etc). The system WGS 84 / UTM zone 41N was selected for analysis of all carpets. The UTM system is based on flat projections, reducing risk of distortion. It breaks Earth up into sixty slices, each 6 degrees of longitude wide. These slices are numbered from 1 on the east side of the International Date Line/longitude 180°W and count incrementally eastward from there, finishing at zone 60 on the west side of the Date Line/180°E. A north/south designation cuts each slice in half at the equator, resulting in 120 total zones. This projection is designed to maximize local cartographic consistency while minimizing intra-zone errors with flat projections on a sphere. Zone 41N is one of the two zones that covers the Central Asian study region where the carpets were made: since the carpets did not actually represent geographic positions, they could have been measured equally well in any zone, so selection of 41N was merely for personal satisfaction. Because the UTM zones are based on Mercator projections, they do have the possibility to introduce spatial distortion as you approach the "poles": however, this does not come into play at the tiny scales represented by the carpets,

and since they do not ever need to transpose onto a sphere. QGIS also positions the images by default at the “equator”, where the Mercator projection is most accurate and least distorted.

Once the carpet photo was positioned in the coordinate plane, a shapefile was created to record measurements for that carpet. Shapefiles are a native feature of QGIS and provide a visual render of points, lines, and/or polygons on the “map” view, while simultaneously recording information about the geometry in a data table. The dual-recording system means that, in this case, the researcher could ‘draw’ the measurements on the carpet image where they see knots, and the associated positional and geometric data were rendered automatically and could be exported as a .csv file for analysis. The shapefiles used here record single points, not lines or more complex shapes, and each carpet had its own shapefile.

In this analysis, the base unit of measurement was points (usually called ‘dots’), where each dot represented one corner of a knot. Each dot was hand-marked, using a mouse or stylus, and a visual render was shown over the carpet image on-screen. The corners of every knot that appeared inside one of the embedded cluster boxes were marked. These dots appear as a grid of points within each cluster, following the underlying grid of warps and wefts in the carpet. Depending on the knot type and warp pattern (see the **Knot-Warp Pattern** variable, Chapter 6, pg. 326), the knots sometimes appear as one discrete blob of color, or two (Fig. 7.6). Double-blobs usually occur when the warps are all on the same plane of the carpet/none are depressed, and when the weaving is less tightly packed horizontally. In these carpets, it is possible to see the half of the knot wrapped around the left warp and the half wrapped around the right warp, so a single knot appears as two linked blobs. Single-blobs usually occur when alternate warps are

depressed compared to the visible plane of the carpet: in this case, the half of the knot that is wound around the depressed warp is buried 'inside' the carpet and is not visible. This leaves only the raised/un-depressed warp visible, and only half the knot appears (as a single blob). Wrap knots that only use one warp also occur as single-blobs. Note that because the warp patterns and other technical characteristics are described from the front of the carpet but the knots are drawn from the back, the "depressed" warps are inverted: a depressed warp as described from the front is the raised/un-depressed warp when viewed from the back. This has been accounted for in the analysis. A similar inversion applies to the weft patterns and knot directions.

I decided to mark only the corners of knots as dots rather than to outline each knot individually as a polygon (Fig. 7.7). While QGIS is readily capable of recording polygons, it did not seem efficient. By marking only the corners, I reduced both the time requirement and the human-introduced variation. When only the corners are marked, 16 dots are required to represent a 3x3 grid of 9 knots. When drawn as polygons, 36 vertices and 24 lines are required to represent the same 9 knots. Consecutive knots abut and should share vertices at exactly the same points, and boundaries on exactly the same lines. Because a person would be drawing the vertices/lines, however, it was not realistic to think they could put the point at the exact same pixel twice, and therefore marking the vertices separately would have introduced variation into the data. As marking only the corners took a full year, it was also not realistic to mark 3x more data. To speed up the process, a volunteer was trained to mark the dots and completed some of the carpet measurements.

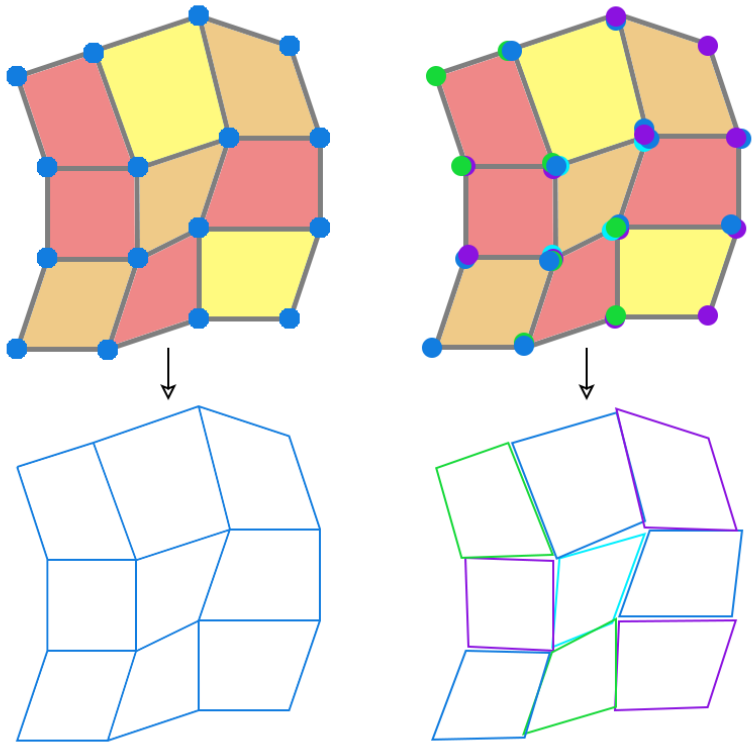

Figure 7.7: Marking Knot Corners

A spread of 9 knots in red, orange, and yellow. Figure by author.

Left: Only the corners are marked, with consecutive knots sharing the same dot at their corners. When connected, the dots create a neat grid without variation that represents the shape of the original knots well.

Right: Each knot is marked individually, without sharing vertices or edges. Human error creates a variable grid with inconsistent boundaries between knots. The shapes of the original knots are less clearly recorded.

By employing a system where consecutive knots share corners, the data are naturally self-correcting for human error. If a particular dot was drawn too far inside of Knot X, it will make X measure as smaller than it actually is. But because knots share corners, a dot that is too far *inside* X will also be too far *outside* of Knot Y. This will make Y measure as bigger than it really is, by the

same amount as X is measured small. Taken together, the slightly-too-small X and the slightly-too-big Y will average each other out perfectly. Whereas if each knots' corners had been marked individually and were not shared between consecutive knots, it would have been possible for *both* knots to be measured as too small or too big, and the error would be amplified in analysis rather than cancelled out.

Depending on the number of weft picks used between rows of knots and the weight of the yarn, some wefts are visible between rows of knots, and some are not (see the **Weft Rows** variable, Chapter 6, pg. 340, and Fig. 6.30). When the weft rows are not visible, each knot shares all four of its corners with the knots around it. When the weft rows are visible, knots share corners with the knots to the left and right, but not with the knots above, below, or on the diagonal (Fig. 7.8). This likely means that the carpets with a visible weft have a higher vertical variation rate than the weftless group, as the dots are not shared and can therefore be in error without the self-correction mechanism. Unfortunately, there was little to be done about this. A calibration test was conducted on myself and the volunteer which used a drawn artificial grid of known size in place of a carpet. Dots were marked on the grid corners in QGIS the same was as is done on the carpets, and the measurements calculated from the dots were compared to the real measurements known in the test diagram. Although both myself and the volunteer had an error rate of about 25%, the error was very consistent. We made the same type of mistake, at the same approximate scale, in every knot. Because this study is interested in relative size & shape, not absolute size and shape, an error of this kind should not be an issue as long as it was consistent (which the calibration test show it was). I therefore propose that the weft-row carpets, even

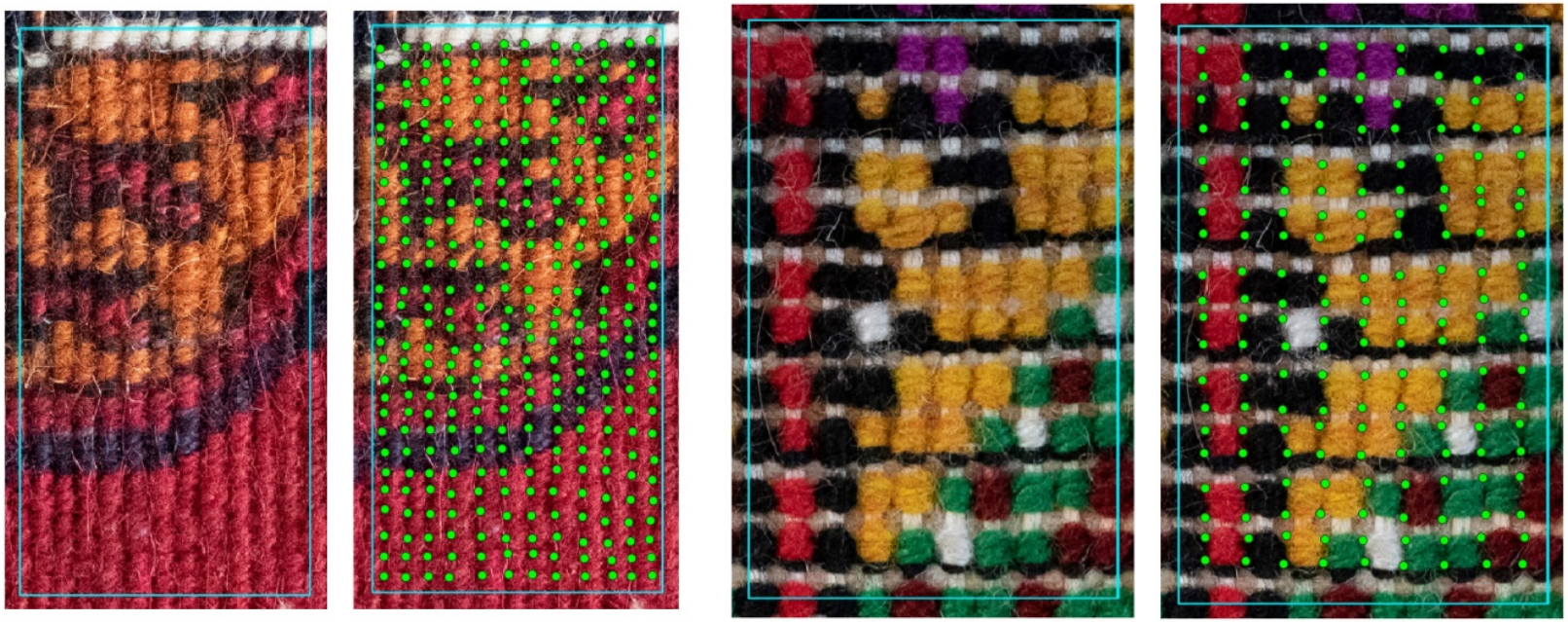

Figure 7.8: Marking Knot Corners: with and without Visible Weft

Left: A carpet without visible weft rows. Knots share corners with their neighbors to the left, right, top, bottom, and on the diagonals. Carpet TK-MA-6, Cluster 73.

Right: A carpet with visible weft rows, which appear as gaps between consecutive vertical knots. Knots share corners with their neighbors on the left and right, but not on the top, bottom, or diagonals. Carpet UZ-KH-2, Cluster 25.

Knot corners marked in green, cluster boxes marked in cyan. Screenshots from QGIS. Figure by author.

without the self-correcting benefit of shared vertical corners, do not cause inordinate distortion of the overall data.

Each dot was initially associated with five fields in the QGIS shapefile data table. The first two fields are the *X* and *Y Coordinates* of the dot, measured in the UTM-41N reference system. These were recorded in "meters", as that is the reference system's default unit of measurement. The unit of measurement does not matter here: the carpet data were all re-scaled after collection was complete, so the native scale did not matter as long as it was consistent. It was therefore simplest to use QGIS's default setting. The *X* and *Y Coordinates* are generated automatically by QGIS when each dot is drawn, and the coordinate is given to 6 decimal places. QGIS has a useful locking mechanism that prevents editing of coordinates after they are generated. This prevents accidental changes to accurate dots. To fix an inaccurate or misdrawn dot, it had to be completely deleted and re-drawn.

A *Cluster ID* field was used to record the position of the dot in the carpet. The clusters (sample boxes) were numbered in a consistent text-direction pattern starting with 1 at the upper-left corner, and finishing with 64 or 121 (depending on sample size) at the lower-right corner. Clusters with the same number on the same sampling grid are always in the same position. Eg, cluster #16 in a 25% sample is always in the upper-left, regardless of the carpet's total size. However, clusters of the same number from different sampling grids do not represent the same point on the carpet: cluster #50 in a 25% sample is just north of center, while cluster #50 in a 12.5% sample is near the lower-left corner. This difference is accounted for later in the data transformations. The *Cluster ID* field in the shapefile recorded the dot's cluster of origin as an

integer, and these values were added manually by the research team. All the dots in a single sample box will have the same *Cluster ID*.

Another field was added to the shapefile to aid with data manipulation after the dots are drawn. This was called *Warp Max*, which gave the total number of dot-columns in the cluster. Although not actually counting the warps, the *Warp Max* field is a count of vertical lines of dots conceptually related to the warps. The *Warp Max* is represented by an integer, and all the dots in a cluster have the same *Warp Max* value. The two carpets shown in Figure 7.6 have *Warp M*ax values of 6 and 11, counting the number of dot-columns. This field is counting the dots themselves, not the spaces between the dots (the knots). The *Warp Max* values were added manually by the research team, and its function in the analysis is described more below.

Finally, I added the *Scale* field. This is another metadata field, and it was filled with a typographic code. Because the carpets themselves are all different sizes, their panoramic photos are all different sizes, each tile photograph has its own scale bar, and QGIS measures the coordinates in meters, it was necessary to embed a re-scaling system directly into the data. As discussed earlier, photographic scale bars of the original photographs were included in the panoramas, one for each tiled photo. Because these scales are already embedded in the photo loaded to QGIS, it was simplest to mark the corners of the centimeter scale boxes in the same way that the knot corners are marked. All four corners of a one-centimeter scale box were therefore marked, and QGIS automatically recorded the x-y coordinates just as it did for the knot corners. These coordinates were used later to calculate the vertical and horizontal re-scaling factor for that specific photograph and any dots drawn on that photograph.

Because each 1cm scale box has four corners, the vertical and horizontal factors were calculated separately. The distance between the two left-side corners was averaged with the distance between the two right-side corners, giving a final vertical re-factoring value. Similarly, the distance between the two top corners and the distance between the two bottom corners were averaged, giving a final horizontal re-factoring value. This accounted for human error in marking the corners of the scales.

The *Scale* field in the data table was used to differentiate the scale dots from the knot dots. 'R' (real) was used to identify real knot measurements. For scale dots, a two-character code was used to link dots from each individual tile photograph to the scale from that same photograph. This was done in reference to the cluster box ID number. For example, scale 'SV' is correlated to cluster 30. The scale dots themselves were marked with 'SV' in their *Scale* field, the cluster 30 real knot dots were marked with 'R', and the analytical code used to clean the data later matched the two together using the *Scale* and *Cluster ID* fields. This scales each original tile photograph individually, and removes any lingering photo distortion.

Although the *Scale* field was initially created just to differentiate the scale dots from the measurement dots, it ultimately was used for one more purpose. Although every attempt was made to measure every dot in every cluster on every carpet, it was not always possible. Grainy photos, debris on the carpets, damaged knots, bad lighting, shadows, low color contrast, or gaps in the photo tiling sometimes prevented data collection. These areas were initially left blank/unmarked in the dot-drawing phase. However, when data manipulation started, it became clear that these missing data were a problem for the data transformations, because the

transformations expect complete grids of dots without gaps. Therefore, artificial data were generated in the form of additional dots in the missing zones (Fig. 7.9). These dots generally fit into the established grid of dots in each cluster, but don't represent real information and were added without direct reference to the carpet photo. The "complete" data set can then be run through the data transformations, and then the false data were removed before statistical analysis was begun. The *Scale* field was therefore used to differentiate these false data points from the real ones, and the false points that represent gaps or missing data were labelled 'M' (missing).

In order to maintain the alternating knot-weft-knot pattern in carpets with a visible weft, the missing dots had to be drawn more carefully in those carpets. The initial round of data transformations expected the odd rows to always be knots and the even rows to always be wefts. When horizontal gaps appear in the real dot grids, one or two lines of missing dots must be added to ensure that the odd rows always represent knots and the even rows always represent wefts (Fig. 7.10). These missing rows were added during initial measurement, and then were re-confirmed before data transformations began. Similarly, in order to ensure that knots always appear in odd rows and wefts in even rows, the top-most row of each cluster always had to represent knots.

Data Transformation & Cleaning

After all the dots in all the carpets had been drawn and labelled, the data were exported as .csv files (one per carpet): this is a native feature of QGIS. Before statistical analyses could

begin to answer the research questions, several data transformations were required. These were performed by custom code (C. Sluka 2024a, with minor alterations by author) written and executed in the open-source program R. This file was written originally to draw territorial boundaries in wildlife tracking data in Wyoming (C. Sluka 2025) but was repurposed here to achieve a similar goal of linking vertices into polygons based on a visible pattern.

This first round of transformations converted the individual dots into polygons, each representing a single knot. The code first filtered out the scale points using the *Scale* field, as these points are not knot measurements and do not need to be transformed the same way. Then the code used the *Cluster IDs* to sort the dots into their separate clusters. It used the dots' *X* and *Y Coordinates* to replot them into their spatial rows and columns. The *Warp Max* field told the code how many columns there should be in each cluster, from which it could calculate the number of expected rows by dividing the total number of knots in that cluster by the number of columns. Knowing how many rows and columns to except, the code used spatial positioning and distance between dots to label each dot with a row and column number. The code then linked dots in consecutive rows and columns to produce four-sided polygons, where each polygon represents a single knot. Using the *Coordinate* points of the four corners, the area of each individual knot was calculated and recorded in a new data table. Metadata is included in the new data table referencing the cluster where the knot sits and its position within that cluster (referenced by Row and Column, starting from [1,1] in the upper-left corner and resetting in each cluster). This allows the dots to be placed not only in the appropriate cluster, but to be re-organized into their original row-and-column grid if needed. Next, an average vertical and

horizontal rescaling factor was calculated from the *Scale* points associated with each cluster. These factors were used to scale all the knot data, converting the area measurements from arbitrary QGIS meters into real-world square centimeters.

The code built polygons between consecutive dots that pass over the weft rows: the computer does not know the difference between a polygon drawn over a knot and one drawn over weft. It was therefore necessary to include instructions in the code to manually throw out the weft-polygons, which are not part of the study analysis (Fig. 7.11). Because rows of knots always alternate regularly with rows of weft, and because the code is already numbering the rows of polygons consecutively, it was straightforward to remove the weft rows. The top row of polygons in each cluster was Row 1, and the code saved polygons in odd rows (knots) but discarded polygons in even rows (wefts). In order to ensure accuracy, the top row of polygons in every cluster represents knots, never weft. I checked this manually in every cluster in every carpet. A toggle-switch in the code allowed me to turn this weft-removal system on and off, as needed for different carpets. Because the area of the weft-polygons is calculated and scaled before the code removed them, they were saved as separate dataset rather than deleting them completely. This was done both to maintain a thorough reference dataset, and also as it may be useful for further research: it is an accurate, large sample of weft measurement variation, of the same type as the knot variation prioritized here. However, the weft data were not used in this project.

The code next used the original dot metadata to identify polygons with one or more "missing" dots (i.e., one or more corners with an 'M' in the *Scale* field). If even one of the four

corners is “missing”, the entire polygon was deleted (see Fig. 7.11). Because the missing points are drawn only to fit the grid pattern and not with any direct relationship to the carpet, they cannot be used to outline a knot’s shape or calculate its area. Removing the artificial points couldn’t be done until after the polygons were drawn however, because the code uses the regular grid to draw the polygons and cannot handle missing points. The missing weft data were removed as well, so as not to pollute that dataset. The knot dataset at this point contained single knots with calculated areas and no artificial or unscaled data remaining.

In addition to producing a new .csv file with the polygon areas for each carpet, the R code also generated visual renders of each cluster. These were used as a visual check of the code’s accuracy in drawing polygons. Improperly drawn clusters are very clear (Fig. 7.12). The cause of these errors appears to be that the dots deviate too much from a regular, straight-line 90° grid, or that the rows/columns get too close together and the algorithm can’t cluster them properly. This caused the code to mistakenly jumble dots between columns and rows, creating shapes that were not four-corner polygons or which do have four corners but were drawn with dots that do not sit consecutively in the grid. A single carpet can have both successful and unsuccessful clusters.

To fix these polygonising problems, I returned to the QGIS data and added a sixth field to the data tables. This field, *Warp ID*, manually records which column each dot is in within its cluster. While the code sometimes had trouble constructing the grid, it is very clear to the human eye which dots belong in which columns, particularly with reference to the underlying carpet photo. In the *Warp ID* field, columns of dots were numbered sequentially from left to right,

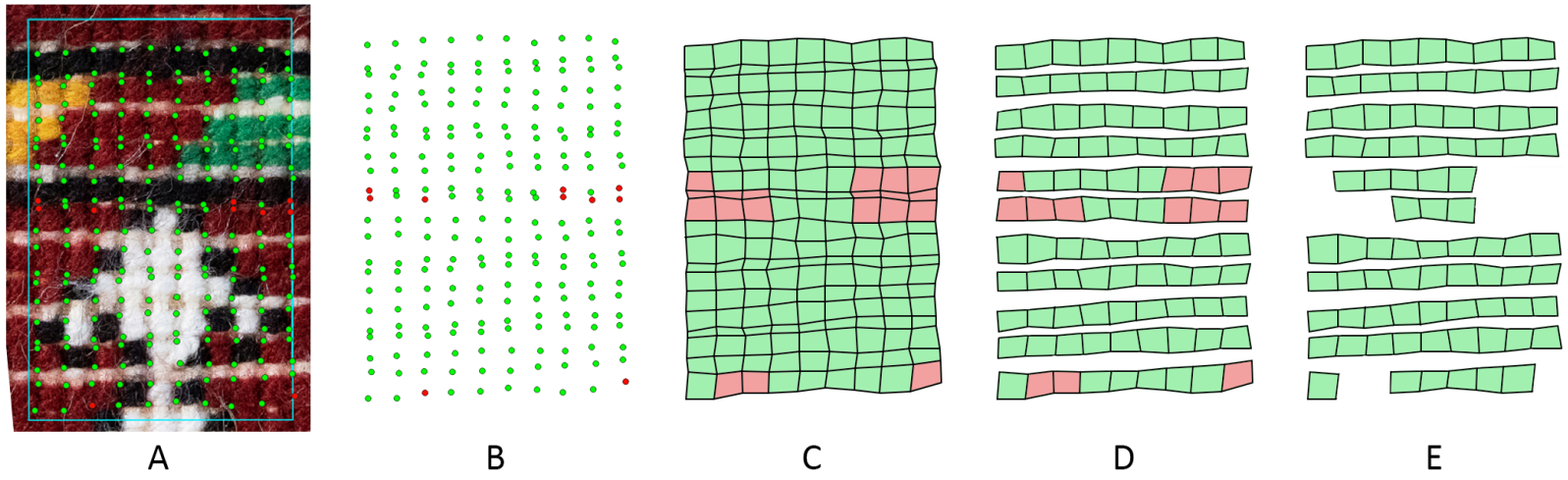

Figure 7.11: Polygonising & Removing Weft Rows

A: Dots marked in a carpet cluster. Real dots in green, missing data in red. Carpet has visible weft rows (white).

B: Without the carpet photo, the dots themselves do not indicate if there are/are not weft rows included.

C: Without intervention, the R code will draw and record all possible polygons, including over weft rows. Notice that the polygons over the weft are significantly narrower than the knot polygons. Polygons that will ultimately be removed for having missing corners are shown in red.

D: With intervention, the code removes even-numbered rows to ensure that only knots are represented.

E: Finally, any polygon with one or more missing corners is removed, leaving only "clean" data.

Cluster box marked in cyan. Screenshots A/B from QGIS. Carpet UZ-KH-3, Cluster 17. Figure by author.

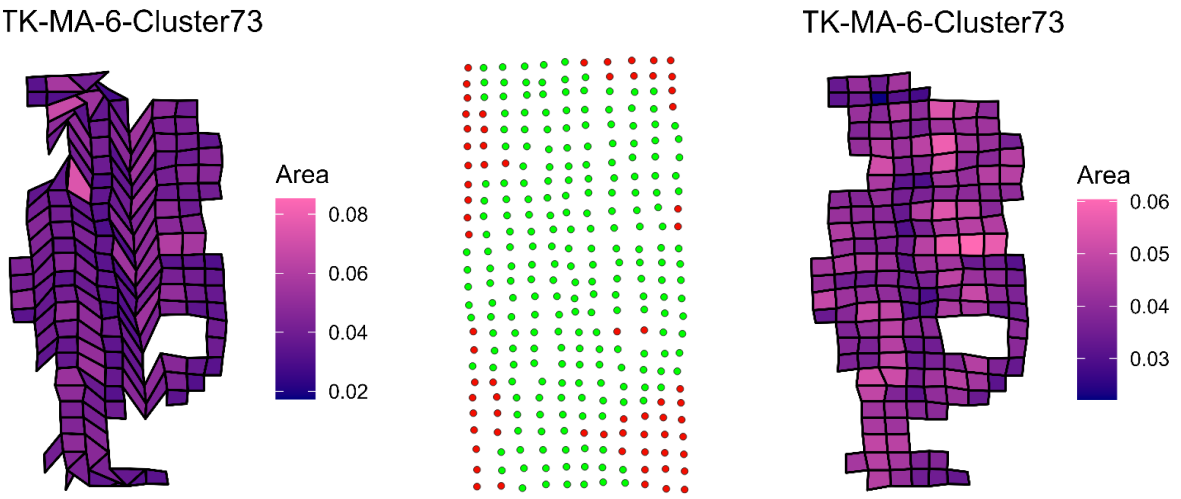

Figure 7.12: Polygonization Errors

Left: A render of the knots in a particular cluster following the first round of transformations. Notice the two columns of significantly angled knots in the center, and the many 3-sided polygons.

Middle: The original dots on which the polygons are based. The grid looks relatively regular to the human eye, and it is not clear why the code has had trouble separating some rows & columns but not others. Real analytical dots are shown in green, and 'missing' data in red.

Right: A re-rendering of the knots in the same cluster, after the dots have been labelled by column (Warp ID). 'Missing' data already removed.

The area shading is in cm^2. Carpet TK-MA-6, Cluster 73. Figure by author.

starting at 1 and resetting in each cluster. This helped the code accurately construct the grid by showing it which dots belong in which columns. I found that just numbering the columns was enough to correct the polygons, and numbering the rows was unnecessary. Fortunately, there were usually fewer columns than rows and the columns tend to have better separation than rows, so although time consuming, it was not difficult to label the columns. The data were then run through an updated version of the R code (C. Sluka 2024b, with minor alterations by author)

which used the new *Warp IDs* to draw the polygons on the correct grid. These calculations are quite resource-hungry and slow, so only the clusters that failed in the initial transformations were given Warp IDs and re-processed. The original and re-processed data sets were combined into complete sets for each carpet. Beyond acting as visual confirmation of accurate polygonization, the cluster renders shown in Figure 7.12 do not have an onward function in the analysis.

Because the analysis intended to look at both horizontal and vertical distortion within the carpets, it was necessary to devise a new mapping system whereby those two axes could be treated separately. While it is possible to derive horizontal and vertical positions from the original cluster numbering system, it is not easy or intuitive. It was also necessary to develop a system for plotting both sample-grid types (12.5% / 8x8 and 25% / 11x11) on the same plane efficiently and accurately, to allow the two groups to be directly compared and included in the same analyses. A traditional coordinate plane was used for this, with the original cluster numbers being converted into (X, Y) coordinates (Fig. 7.13). These coordinates are referred to as the universal coordinates, as they accurately map all sampling grids into a unified system. Because the original grids are based on proportions rather than absolute measurements, the simplest way to organize the coordinate plane was with a range of 0-100 on each axis, with each step on the axis representing 1 percentage point. The lower-left cluster and lower-left corner of the carpet in both systems (cluster 57 in 8x8 and cluster 111 in 11x11) sit at point (0,0), and the upper-right cluster and upper-right corner of the carpet (cluster 8 in 8x8, cluster 11 in 11x11) sit at (100,100). In the universal system, each incremental step in the coordinate plane can be understood to mean 1% of the carpet's length or width further away from the lower-left corner.

The larger cluster grid (11x11) sits at intervals of 10% (0, 10, 20…90, 100) in both the X and Y-axes. The smaller cluster grid (8x8) sits at intervals of approximately 14% (0, 14, 29…86, 100). Because 100 percentage points do not divide evenly into 8 incremental steps, these coordinate points are rounded to the nearest whole number. The two systems overlap only on the edges, x = 0, 100 and y = 0, 100. Within the range of 1-99, the clusters are interlaced but none exactly overlap.

Seven of the historic carpets (see Table 7.5) were photographed and sampled from the front instead of the back[23]. This was due to fragility concerns or permanent mountings that prevented them from being flipped over for imaging. The final transformation in the data cleaning stage was to digitally invert these carpets' data, so that they are oriented the same way as the rest of the set. This involved inverting their cluster names and universal X coordinates, as well as the column numbers within each cluster. This was done in R with custom code written by me, and both the original and inverted datasets are saved. Note that because the imaging system inverts only left-to-right and not up-to-down, only positions in the X-axis needed to be inverted: Y-axis data remained the same.

Because the knots represent different carpets with different quality and materials, it was necessary to normalize the data for inter-carpet comparisons. The knot data within each carpet are approximately normally distributed (as expected) and checked with histograms. To assist with normalizing the data, outliers were removed. A z-score standardization ($\frac{x-\mu}{\sigma}$) was applied to all the knots in a carpet, and knots with a z-score more than 3 standard deviations above/below

[23] MU-AS-10, 12, 13, 16, 17g; MU-DY-2a, 2b.

the carpet mean were eliminated as outliers. Most carpets had only few outliers (<50). Several carpets had no outliers, and the most outlier-heavy carpet only had approximately 2% outliers in the sampled area. The z-scores and outliers were calculated per carpet, to avoid introducing artificial bias or skewed results.

The analysis described in the next section makes extensive use of coefficients of variation (CVs). A z-score is not an effective option for normalizing these data despite its widespread and preferred use in scientific and social analyses. CVs require that all values be the same case, either positive or negative. A CV therefore cannot be calculated based on raw z-scores, as they necessarily include both positive and negative values. This limitation made z-scores ineffective here. Some studies use the absolute value of z-scores to eliminate the negative values and correct this issue. This process eliminates directional data by obscuring which values fell above and below the mean. This is fine in cases where the only interest is in deviation from the mean and not direction of deviation. This dissertation, however, is explicitly interested in both the deviation and the direction, so a correction by absolute value was not useful. Instead, I used the min/max standardization method ($\frac{x-min}{max-min}$) to normalize the data and allow for comparison between carpets. This method compares each knot measurement to the largest and smallest knots recorded in the same carpet (not counting outliers already removed from analysis), and quantifies that relationship as a positive number between 0 and 1. Because the data are normally distributed, the mean knot size always falls at or very close to 0.5; knots with a min/max value <0.5 are smaller than average, and those with a min/max value >0.5 are larger than average. These standardized values are calculated within each carpet, and not across the entire dataset.

By standardizing the values, I was able to compare proportional or relative change in knot size between carpets, without confounding factors of actual size.

The data transformations are now complete. The data from all carpets (modern and historic) are now formatted and oriented the same way, all have the same metadata, all missing/artificial data and weft rows have been removed, and the knot areas have been normalized and standardized for inter-carpet comparison.

The analyses presented in the next chapter are based on two different aspects of the knots: the size/square area and the shape. In order to clarify the outcomes of these two dependent variables, they were treated entirely separately from this point, although both are built on the same underlying data whose collection and cleaning procedures were described in this chapter. The initial rounds of tests and comparisons in both knot size and shape are based solely on the ethnographic sample of more than 500,000 measured knots, representing 30 carpets and 18 weavers.

Figures: Chapter 7

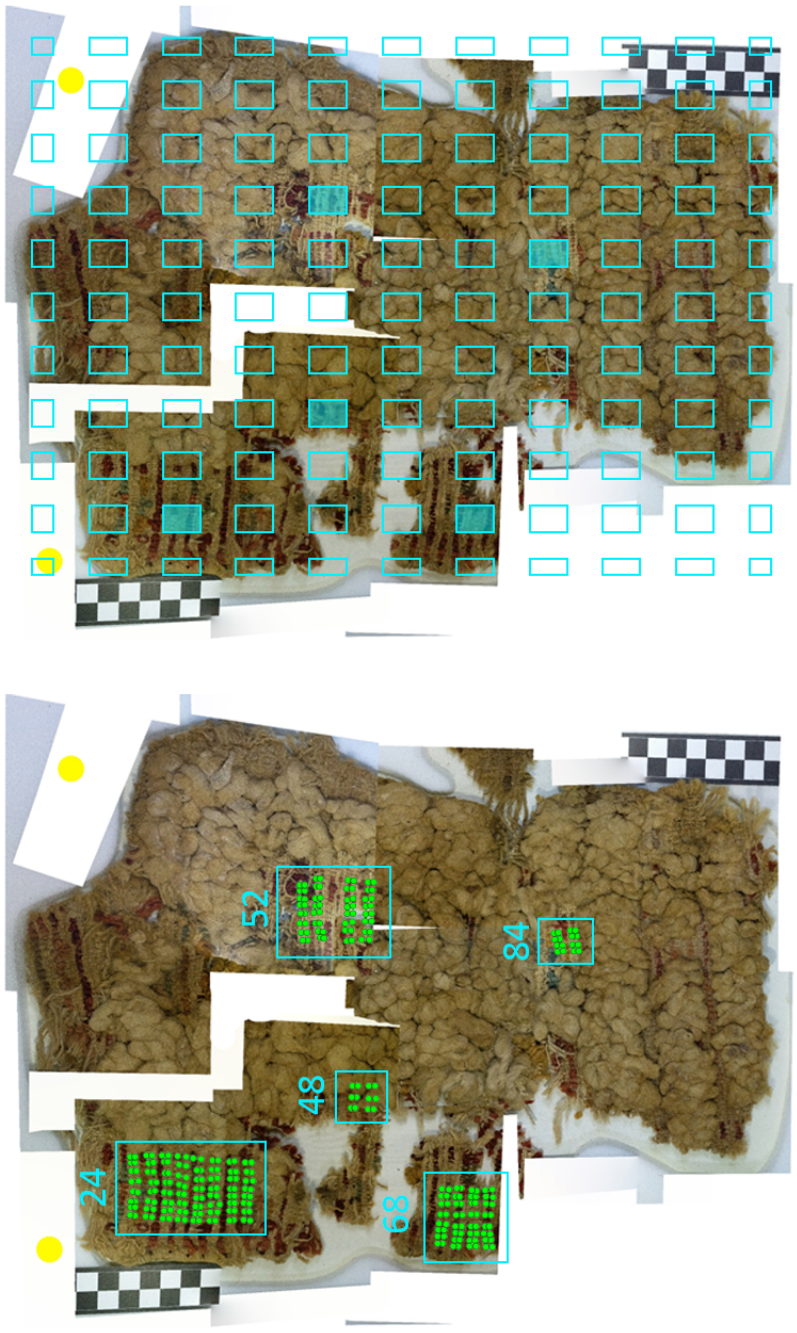

Figure 7.5: Non-Standard Grids

The visible knots in the carpet fragment are marked (green, at left). Cluster boxes are then drawn around distinct groups of knots. Fitting a 25% sample grid over the fragment (right), the new groups are numbered with the cluster ID of the box that best represents their position in the grid (shaded in cyan at right).
Carpet MU-AS-17ef. Figure by author.

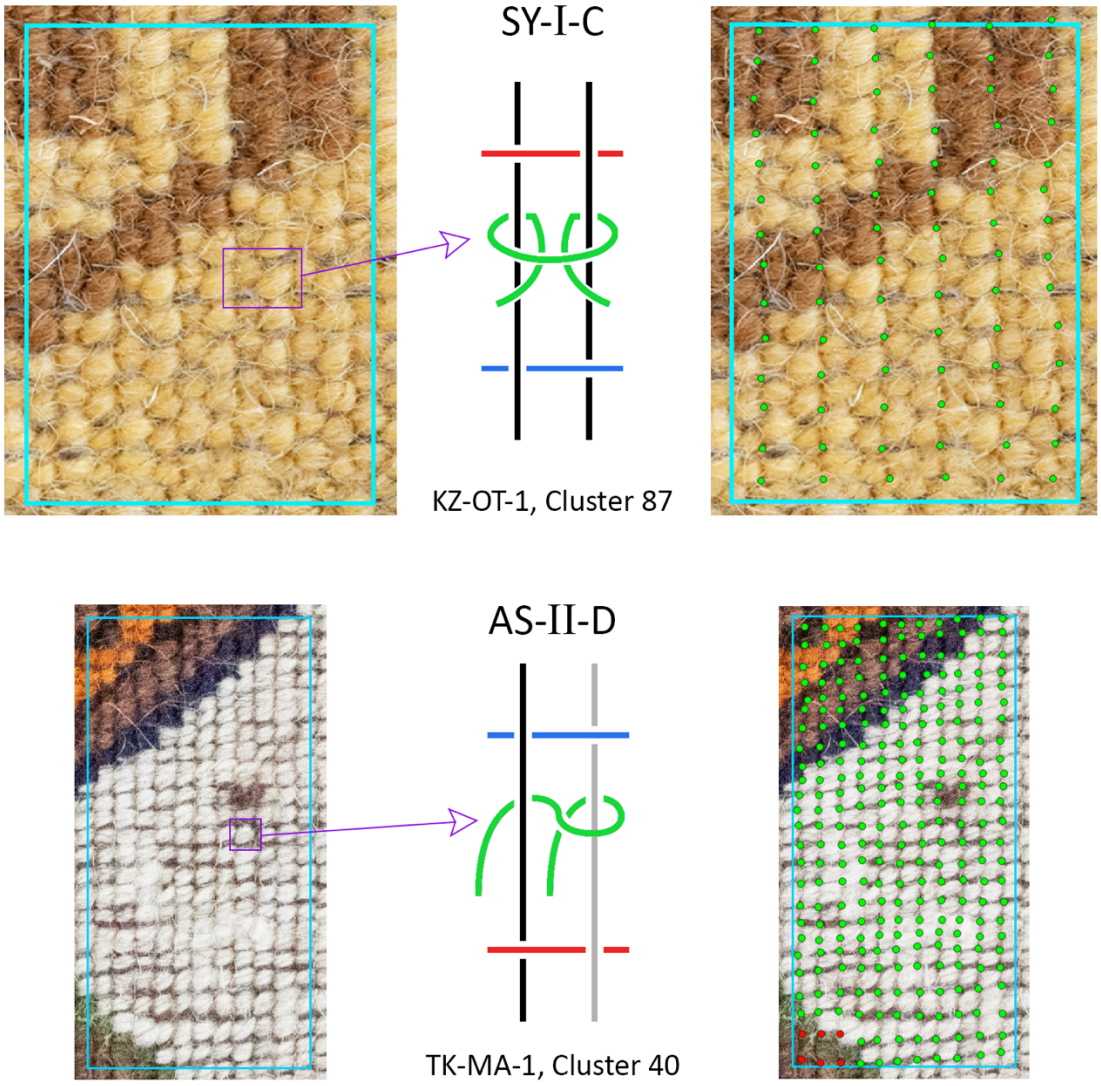

Figure 7.6: Marking Knot Corners

Top: A carpet with all warps on the same plane (warp pattern I), where symmetric knots appear as two blobs sitting side by side in a figure-8 or yin-yang shape.

Bottom: A carpet with alternate warps depressed (warp pattern II), so that only one is visible from the back. The half of the asymmetric knot on the visible warp appears, but the half on the depressed warp is buried in the structure and is not visible.

Knot corners marked in green on the right; cluster boxes marked in cyan.
Screenshots from QGIS, figure by author.

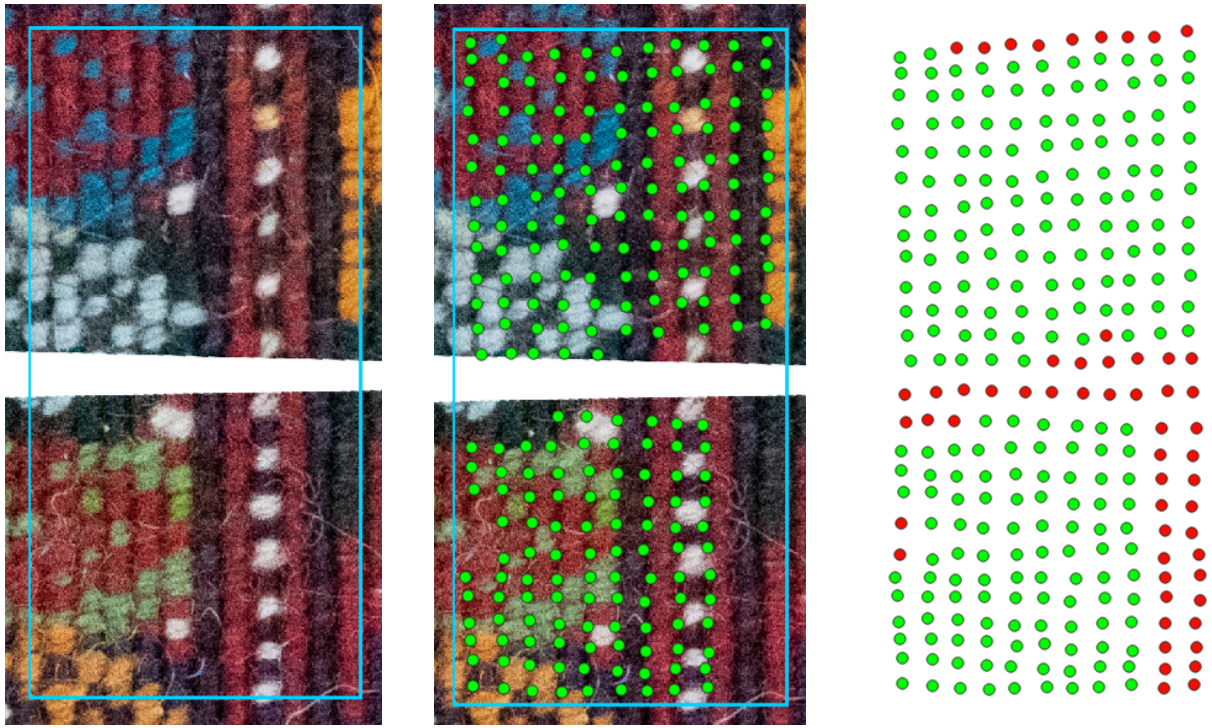

Figure 7.9: Missing Dots

Left: A sample box is missing imagery in the center, where the photo tiles didn't quite overlap.

Middle: The corners of visible dots are marked, with a gap left in the white bar. Also note that a few other dots are missing, where fuzz on the carpet and low color-contrast makes the knot-corners hard to pinpoint.

Right: The grid of real dots (green) is filled in with artificial data points (red). This makes a complete grid where all rows and columns have the same number of dots, as is required for the first round of data transformations. Missing dots have no direct elation to the carpet image, but need to generally fit the established grid pattern.

Cluster boxes marked in cyan. Screenshots from QGIS. Carpet TK-MA-1, Cluster 25. Figure by author.

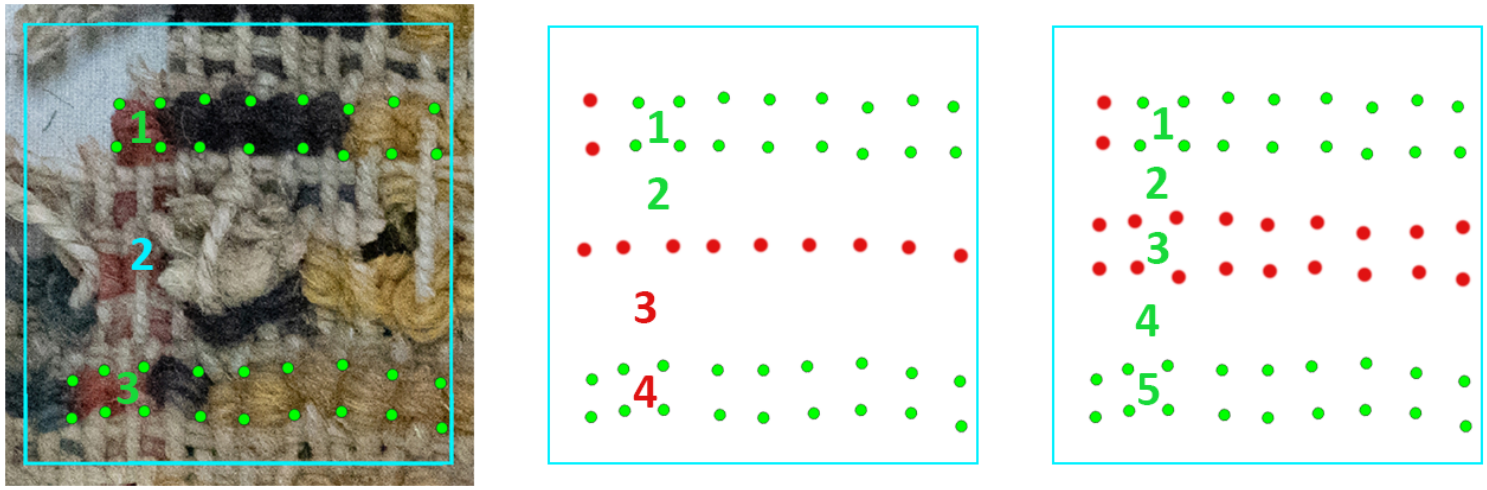

Figure 7.10: Dealing with Missing Dots when Weft Rows Visible

Left: A sample box with the real knot corners marked in green. The rows created by the knots are numbered 1-3: odd rows are real knots, and even rows should be weft. Here, 2 is not strictly a row of weft but rather an artificially wide gap left because the interceding row of knots is too badly damaged to mark: it does not represent one weft row.

Middle: A row of missing (red) dots must be added to break up the artificial gap, because this large space does not represent a single weft row in the carpet. If a single row of missing dots is added, it alters the row count. The odd rows should be rows of real knots, which is true of row 1 but not row 3. The even rows should be rows of weft, which is true of 2 but not of 4. This will cause the data transformations to mistakenly treat row 3 as a row of knots, and row 4 as a row of weft, which they are not.

Right: If two rows of missing (red) dots are added, this corrects the row count. The odd rows are all rows of knots, and the even rows are all rows of weft. Rows 2, 3, and 4 will eventually be thrown out as artificial/missing rows, but correct numbering is required to ensure the real rows are treated properly.

Cluster boxes marked in cyan. Screenshots from QGIS. Carpet MU-AS-4, Cluster 43. Figure by author.

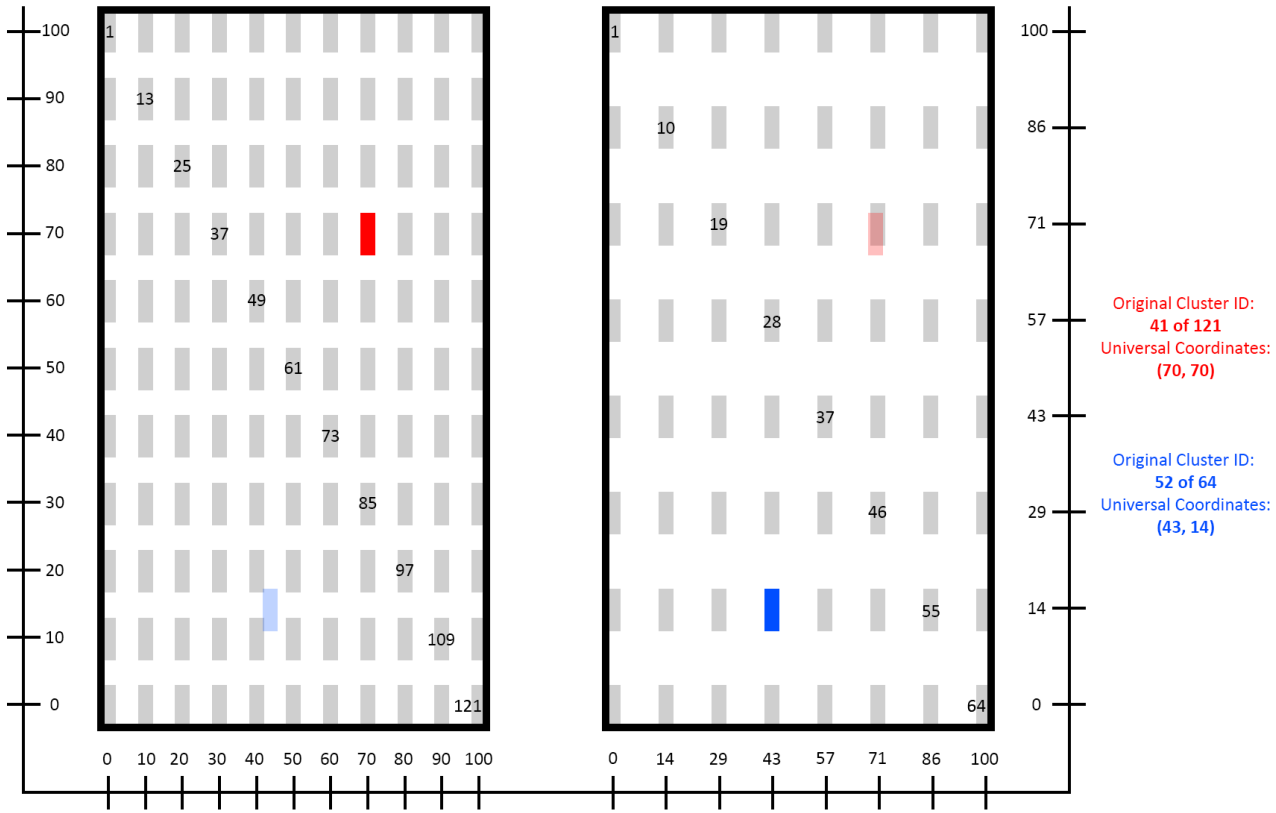

Figure 7.13: Universal Coordinates

A map of the sampling grids, with a 25% (11x11; 121) grid on the left, and a 12.5% (8x8; 64) grid on the right. Each grey box is one cluster. The black labels on the cluster boxes represent their original cluster IDs, which follow a text-direction path starting at the upper-left corner and finishing at the lower-right corner. The axes for the universal coordinates are shown. The red and blue boxes are labelled as examples. A shadow of each colored box is shown on the opposite grid, to show where it would align on a single plane. Figure by author.

Carpet ID	Production Country	City	Village	Weaver	Cost (USD)	Post-Study Location
KZ-OT-1	Kazakhstan	-	Shauldir	Sholpan [Kate]	$235	HLATC, UW-M
KZ-OT-2	Kazakhstan	-	Shauldir	Sholpan [Kate]	$235	Private Collection
KZ-OT-3	Kazakhstan	-	Shauldir	Sholpan [Kate]	NP	Private Collection
KZ-SH-1	Kazakhstan	Shymkent	-	Madina [Margaret]	$150	Private Collection
KZ-SH-2	Kazakhstan	Shymkent	-	Kulyash [Teri]	$50	Private Collection
TK-MA-1	Turkmenistan	Mary	-	[Christina]	$78	Private Collection
TK-MA-2	Turkmenistan	Mary	-	[Anna]	$78	HLATC, UW-M
TK-MA-3	Turkmenistan	Mary	-	[Barbara]	$78	Private Collection
TK-MA-4	Turkmenistan	Mary	-	[Barbara]	$78	Private Collection
TK-MA-5	Turkmenistan	Mary	-	[Anna]	$78	Private Collection
TK-MA_6	Turkmenistan	Mary	-	[Anna]	$78	Private Collection
TK-MA-7	Turkmenistan	Mary	-	[Christina]	$78	Private Collection
TK-MA-8	Turkmenistan	Mary	-	[Eleanora]	$78	Private Collection
TK-MA-9	Turkmenistan	Mary	-	[Dorothy]	$78	Private Collection

Table 7.1: Ethnographic Carpets' Logistical Data (continues to next page)

Weaver's analysis pseudonyms are given in brackets. 'NP' used for non-purchased carpets studied in the field. The Helen Louise Allen Textile Collection at the University of Wisconsin-Madison is listed as HLATC, UW-M.
Table by author. Continues to next page.

Carpet ID	Production Country	City	Village	Weaver	Cost (USD)	Post-Study Location
UZ-KH-1	Uzbekistan	Khiva	Angarik	Durdiposhsha [Ginny]	$150	Private Collection
UZ-KH-2	Uzbekistan	Khiva	Angarik	Durdiposhsha [Ginny]	$150	Private Collection
UZ-KH-3	Uzbekistan	Khiva	Ingilis	Mehribon [Monica]	$150	Private Collection
UZ-KH-4	Uzbekistan	Khiva	Ingilis	Mehribon [Monica]	$150	Private Collection
UZ-KH-5	Uzbekistan	Khiva	Gondimiyon	Dilbar [Jennifer]	$150	HLATC, UW-M
UZ-KH-6	Uzbekistan	Khiva	Gondimiyon	Dilbar [Jennifer]	$150	Private Collection
UZ-KH-7	Uzbekistan	Khiva	Gondimiyon	[Stephanie]	$150	Private Collection
UZ-KH-8	Uzbekistan	Khiva	Gondimiyon	[Stephanie]	$150	Private Collection
UZ-KH-9	Uzbekistan	Khiva	-	Halima [Janina]	NP	-
UZ-KH-10	Uzbekistan	Khiva	-	Halima [Janina]	NP	-
UZ-KH-11	Uzbekistan	Khiva	-	Maloxat & Nazokat [Alexandra & Jean]	NP	-
UZ-KH-12	Uzbekistan	Khiva	-	Maloxat [Alexandra]	NP	-
UZ-KH-13	Uzbekistan	Khiva	-	Nazokat [Jean]	NP	-
UZ-SK-1	Uzbekistan	Samarkand	-	Nigora [Mairead]	NP	-
UZ-SK-2	Uzbekistan	Samarkand	-	Muftuna [Carol]	NP	-
UZ-SK-3	Uzbekistan	Samarkand	-	Bashorat [Kathleen]	NP	-

Carpet ID	Catalogue Number	Institution	Storage Location	Object Date	Object Origin
MU-AS-1	LNS 63 R	Al Sabah Coll.	Kuwait City	380-540 CE [2]	Maymana, Faryab, Afghanistan
MU-AS-2a MU-AS-2b	LNS 58 R a-b	Al Sabah Coll.	Kuwait City	1010-1160 CE [2]	Samangan, Afghanistan
MU-AS-3	LNS 51 R a	Al Sabah Coll.	Kuwait City	378-598 CE [2]	East Persia?
MU-AS-4a MU-AS-4b MU-AS-4c	LNS 71 R a-c	Al Sabah Coll.	Kuwait City	543-638 CE [2]	East Persia?
MU-AS-5	LNS 70 R	Al Sabah Coll.	Kuwait City	540-585 CE [2]	East Persia?
MU-AS-6	LNS 54 R	Al Sabah Coll.	Kuwait City	1150-1260 CE [1]	Samangan, Afghanistan
MU-AS-7	LNS 64 R	Al Sabah Coll.	Kuwait City	130-270 CE [2]	Maymana, Faryab, Afghanistan
MU-AS-8	LNS 61 R c-f	Al Sabah Coll.	Kuwait City	565-655 CE [2]	Samangan, Afghanistan
MU-AS-9ab MU-AS-9c MU-AS-9d	LNS 47 R a-d	Al Sabah Coll.	Kuwait City	220-410 CE [2]	Samangan, Afghanistan
MU-AS-10	LNS 62 R a-b	Al Sabah Coll.	Kuwait City	415-640 CE [2]	Maymana, Faryab, Afghanistan
MU-AS-11	LNS 48 R a-e	Al Sabah Coll.	Kuwait City	535-680 CE [2]	Samangan, Afghanistan
MU-AS-12	LNS 74 R	Al Sabah Coll.	Kuwait City	332-430 CE [2]	Samangan, Afghanistan
MU-AS-13	LNS 44 R	Al Sabah Coll.	Kuwait City	17th cent. CE [1]	Herat, Afghanistan
MU-AS-14	LNS 73 R	Al Sabah Coll.	Kuwait City	280-340 CE [2]	Samangan, Afghanistan
MU-AS-15	*LNS 67 R a-e*	*Al Sabah Coll.*	*Kuwait City*	*390-540 CE [2]*	*Samangan, Afghanistan*

Table 7.2: Historic Carpets (continues to next pages)

Object dates & origins given as listed in museum documentation and references. Shaded objects were excluded from the study due to poor photo quality. (1) Dates given as calibrated C14 estimates, from Spuhler 2012 (2) Dates given as calibrated C14 estimates, from Spuhler 2014. Table by author. Continues to next pages.

Carpet ID	Catalogue Number	Institution	Storage Location	Object Date	Object Origin
MU-AS-16	LNS 61 R b	Al Sabah Coll.	Kuwait City	500-699 CE [2]	Samangan, Afghanistan
MU-AS-17ef MU-AS-17g	LNS 47 R e-g	Al Sabah Coll.	Kuwait City	220-410 CE [2]	Samangan, Afghanistan
MU-AS-18	LNS 47 R h	Al Sabah Coll.	Kuwait City	114-348 CE [2]	Samangan, Afghanistan
MU-CH-1	Lot 213	Christie's	London	c. 1800 CE	Khotan, China
MU-CH-2	Lot 214	Christie's	London	late 18th cent. CE	Tarim Basin, China
MU-CH-3	Lot 216	Christie's	London	late 18th cent. CE	East Turkestan
MU-CH-4	Lot 229	Christie's	London	late 17th cent. CE	West Turkey
MU-CH-5	Lot 271	Christie's	London	early 17th cent. CE	Beijing, China
MU-CH-6	Lot 272	Christie's	London	1662-1722 CE	North China
MU-CH-7	Lot 273	Christie's	London	18th cent. CE	North China
MU-DY-1a MU-DY-1b MU-DY-1c MU-DY-1d	1986.90a-d	De Young Museum	San Francisco	16th cent. CE	Ushak, Turkey
MU-DY-2a MU-DY-2b MU-DY-2c	2019.84.1a-c	De Young Museum	San Francisco	418-602 CE	Central Asia or West China
MU-DY-3	*2001.173*	*De Young Mus.*	*San Francisco*	*17-18th cent. CE*	*Central Asia*
MU-DY-4	*1969.16*	*De Young Mus.*	*San Francisco*	*c. 1600 CE*	*Iran*
MU-DY-5	*1975.4.3*	*De Young Mus.*	*San Francisco*	*17th cent. CE*	*Iran*
MU-DY-6	*1997.142.6*	*De Young Mus.*	*San Francisco*	*late 17th cent. CE*	*Central Asia*

Carpet ID	Catalogue Number	Institution	Storage Location	Object Date	Object Origin
MU-IN-1	1996.25	Indianapolis Museum of Art	Indianapolis	c. 1875 CE	Torbat-e Heydarieh, Khorasan, Iran
MU-IN-2	1996.65	Indianapolis Museum of Art	Indianapolis	late 19th cent. CE	Qaen, Khorasan, Iran
MU-IN-3	1996.22	Indianapolis Museum of Art	Indianapolis	c. 1870 CE	Torbat-e Heydarieh, Khorasan, Iran
MU-IN-4	1996.63	Indianapolis Museum of Art	Indianapolis	late 19th cent. CE	Qaen, Khorasan, Iran
MU-IN-5	1996.28	Indianapolis Museum of Art	Indianapolis	c. 1875 CE	Torbat-e Heydarieh, Khorasan, Iran
MI-IN-6	1996.21	Indianapolis Museum of Art	Indianapolis	mid 19th cent. CE	Torbat-e Heydarieh, Khorasan, Iran
MU-IN-7	1996.30	Indianapolis Museum of Art	Indianapolis	late 19th cent. CE	Torbat-e Heydarieh, Khorasan, Iran
MU-SO-1	Lot 156	Sotheby's	London	17th cent. CE	Ushak, Turkey
MU-SO-2	Lot 159	Sotheby's	London	19th cent. CE	East Turkestan
MU-SO-3	Lot 157	Sotheby's	London	17th cent. CE	Ushak, Turkey
MU-SO-4	Lot 158	Sotheby's	London	17th cent. CE	Isfahan, Iran
MU-VA-1	859-1902	Victoria & Albert Museum	London	17th cent. CE	Turkey
MU-VA-2	T.30-1956	V&A Mus.	London	early 16th cent. CE	Tabriz, Iran
MU-VA-3	LOAN:STEIN.536	V&A Mus.	London	150 BCE – 60 CE	Loulan, China
MU-VA-4	LOAN:STEIN.647	V&A Mus.	London	150 BCE – 60 CE	Loulan, China

Weaver	Pseudonym	Country	City	Village	Organization	Experience	Survey #
Sholpan Zhycinbek (Шолпан Жүсінбек)	Kate	Kazakhstan	-	Shauldir	-	10 years	15
Kulyash Aidarbekova (Куляш Айдарбекова)	Teri	Kazakhstan	Shymkent	-	Altyn Orda	20	14
Madina Ahmetova (Мадина Ахметова)	Margaret	Kazakhstan	Shymkent	-	Altyn Orda	9	14
Anonymous A	Anna	Turkmenistan	Mary	-	-	2	16
Anonymous B	Barbara	Turkmenistan	Mary	-	-	8	16
Anonymous C	Christina	Turkmenistan	Mary	-	-	1	16
Anonymous D	Dorothy	Turkmenistan	Mary	-	-	9	16
Anonymous E	Eleanora	Turkmenistan	Mary	-	-	6	16
Durdiposhsha Omonova	Ginny	Uzbekistan	Khiva	Angarik	-	48	6
Dilbar Omonova	Jennifer	Uzbekistan	Khiva	Gondimiyon	-	30	12
Anonymous F	Stephanie	Uzbekistan	Khiva	Gondimiyon	-	30	-
Mehribon Haitova	Monica	Uzbekistan	Khiva	Ingilis	-	20	11
Halima Matyaqubova	Janina	Uzbekistan	Khiva	-	Khiva Silk	3	7
Maloxat Qurbonova	Alexandra	Uzbekistan	Khiva	-	Khiva Silk	2	8
Nazokat Aminova	Jean	Uzbekistan	Khiva	-	Khiva Silk	8	9
Bashorat	Kathleen	Uzbekistan	Samarkand	-	Samarkand Silk	2.5	4
Muftuna Narzulloeva	Carol	Uzbekistan	Samarkand	-	Samarkand Silk	15	2
Nigora	Mairead	Uzbekistan	Samarkand	-	Samarkand Silk	6	1

Table 7.3: Weavers

Basic information about the modern weavers referenced in this study. Note that every weaver was given a pseudonym, but most were happy to share their real names as well. Table by author.

Variable	Variable Type	Categories	Class	Visibility
Total Height	Numeric-Continuous	0+	Structural	Visible*
Total Width	Numeric-Continuous	0+	Structural	Visible*
Total Area	Numeric-Continuous	0+	Structural	Visible*
Warp Material	Categorical	Wool Cotton Silk Synthetic (blends)	Structural	Visible
Weft Material	Categorical	Wool Cotton Silk Synthetic (blends)	Structural	Visible
Pile Material	Categorical	Wool Cotton Silk Synthetic (blends)	Structural	Visible
Strands per Knot	Numeric-Continuous	1+	Structural	Visible
Knot Type	Categorical	Asymmetric Symmetric Wrap	Structural	Visible
Knot Direction	Categorical	Left Right S-Twist Z-Twist	Structural	Visible
Knot-Warp Pattern	Categorical	I II III	Structural	Visible
Knot-Weft Pattern	Categorical	A-R	Structural	Visible

Table 7.4: Variables used in Analysis (continues to next pages)

The subset of defined variables used in statistical analyses *Carpets in fragments without original edges are measured only in Knotted Dimensions. †Only the pseudonyms are used in statistical computer code, but real names are used in the wider discussion of results. Table by author. Continues on next pages.

Variable	Variable Type	Categories	Class	Visibility
Knotting Shed Position	Categorical-Ordinal	Open Partial Closed	Technological	Invisible
Weft Rows	Categorical	Y N	Metadata	Visible
Weft Shot Pick Count	Numeric-Discrete	1+	Structural	Visible
Weft Offset Pattern	Categorical	Regular Alternate Pattern Random	Structural	Visible
Weft Addition Rate	Categorical	Continuous Broken	Technological	Invisible
Shed Rods	Numeric-Discrete	0-1	Technological	Invisible
Single-Shed Heddles	Numeric-Discrete	0+	Technological	Invisible
Double-Shed Heddles	Numeric-Discrete	0+	Technological	Invisible
Tension Rods: Top	Numeric-Discrete	0+	Technological	Invisible
Tension Rods: Bottom	Numeric-Discrete	0+	Technological	Invisible
Knotting Order	Categorical	Directional R-L Directional L-R Pattern Color	Technological	Invisible
Hook	Categorical	Y N	Technological	Invisible
Knife Type	Categorical	Curved Straight	Technological	Invisible
Cutting Direction	Categorical-Ordinal	(paired cardinal directions)	Idiosyncratic	Invisible
Scissor Type	Categorical	Standard Offset	Technological	Invisible

Variable	Variable Type	Categories	Class	Visibility
Trim Frequency	Numeric-Discrete	0+	Technological	Invisible
Oversight	Categorical-Ordinal	Production-Regular Production-Sporadic Post-Production None	Social	Invisible
Cartoon Use	Categorical-Ordinal	Continuous Sporadic None	Social	Invisible
Experience	Numeric-Continuous	0+	Idiosyncratic	Invisible
Workload	Numeric-Continuous	0+	Idiosyncratic	Invisible
Number of Weavers	Numeric-Discrete	1+	Idiosyncratic	Invisible
Weaver/Pseudonym†	Categorical	(individual names)	Idiosyncratic	Invisible
Production Setting	Categorical-Ordinal	Domestic Collective Workshop	Social	Invisible
Country	Categorical	Kazakhstan Turkmenistan Uzbekistan	Idiosyncratic	Invisible
City	Categorical	(city names)	Idiosyncratic	Invisible
Village	Categorical	(village names)	Idiosyncratic	Invisible
Community	Categorical	(community names)	Social	Invisible

Carpet ID	Carpet Type	Area (m^2)	Sample Size	Sample System	Imaging Side
MU-AS-1	Historic	0.226	-	Random	Reverse
MU-AS-2a	Historic	0.094	25%	Grid	Reverse
MU-AS-2b	Historic	0.017	25%	Grid	Reverse
MU-AS-3	Historic	0.255	25%	Grid	Reverse
MU-AS-4a	Historic	0.252	25%	Grid	Reverse
MU-AS-4b	Historic	0.017	-	Random	Reverse
MU-AS-4c	Historic	0.014	-	Random	Reverse
MU-AS-5	Historic	0.040	-	Random	Reverse
MU-AS-6	Historic	0.027	-	Random	Reverse
MU-AS-7	Historic	0.376	-	Random	Reverse
MU-AS-8	Historic	1.070	25%	Grid	Reverse
MU-AS-9ab	Historic	1.870	-	Random	Reverse
MU-AS-9c	Historic	0.099	-	Random	Reverse
MU-AS-9d	Historic	0.229	-	Random	Reverse
MU-AS-10	Historic	2.805	-	Random	Obverse
MU-AS-11	Historic	1.495	25%	Grid	Reverse
MU-AS-12	Historic	0.995	-	Random	Obverse
MU-AS-13	Historic	2.572	12.5%	Grid	Obverse
MU-AS-14	Historic	0.843	25%	Grid	Reverse
MU-AS-16	Historic	0.027	-	Random	Obverse
MU-AS-17ef	Historic	0.105	-	Random	Reverse

Table 7.5: All-Carpet Sampling Reference Data (continues to next pages)

Samples were taken on a systematic Grid, or at Random wherever knots are visible in a degraded object. Randomly-sampled carpets do not have a standard sample size. Carpets are photographed from the Obverse or Reverse. Table by author. Continues to next pages.

Carpet ID	Carpet Type	Area (m^2)	Sample Size	Sample System	Imaging Side
MU-AS-17g	Historic	0.033	-	Random	Obverse
MU-AS-18	Historic	0.030	-	Random	Reverse
MU-CH-1	Historic	1.495	12.5%	Grid	Reverse
MU-CH-2	Historic	1.715	12.5%	Grid	Reverse
MU-CH-3	Historic	6.422	12.5%	Grid	Reverse
MU-CH-4	Historic	2.075	12.5%	Grid	Reverse
MU-CH-5	Historic	1.905	12.5%	Grid	Reverse
MU-CH-6	Historic	4.150	12.5%	Grid	Reverse
MU-CH-7	Historic	8.221	12.5%	Grid	Reverse
MU-DY-1a	Historic	0.146	25%	Grid	Reverse
MU-DY-1b	Historic	0.148	25%	Grid	Reverse
MU-DY-1c	Historic	0.245	25%	Grid	Reverse
MU-DY-1d	Historic	0.057	25%	Grid	Reverse
MU-DY-2a	Historic	0.351	-	Random	Obverse
MU-DY-2b	Historic	0.137	-	Random	Obverse
MU-DY-2c	Historic	0.042	-	Random	Reverse
MU-IN-1	Historic	2.158	12.5%	Grid	Reverse
MU-IN-2	Historic	1.623	12.5%	Grid	Reverse
MU-IN-3	Historic	1.661	12.5%	Grid	Reverse
MU-IN-4	Historic	1.422	12.5%	Grid	Reverse
MU-IN-5	Historic	1.471	12.5%	Grid	Reverse

Carpet ID	Carpet Type	Area (m^2)	Sample Size	Sample System	Imaging Side
MU-IN-6	Historic	1.471	12.5%	Grid	Reverse
MU-IN-7	Historic	0.921	12.5%	Grid	Reverse
MU-SO-1	Historic	2.130	12.5%	Grid	Reverse
MU-SO-2	Historic	1.226	12.5%	Grid	Reverse
MU-SO-3	Historic	5.884	12.5%	Grid	Reverse
MU-SO-4	Historic	2.767	12.5%	Grid	Reverse
MU-VA-1	Historic	0.133	25%	Grid	Reverse
MU-VA-2	Historic	0.588	25%	Grid	Reverse
MU-VA-3	Historic	0.029	-	Random	Reverse
MU-VA-4	Historic	0.040	-	Random	Reverse
KZ-OT-1	Modern	0.334	25%	Grid	Reverse
KZ-OT-2	Modern	0.327	25%	Grid	Reverse
KZ-OT-3	Modern*	0.330	25%	Grid	Reverse
KZ-SH-1	Modern	0.379	25%	Grid	Reverse
KZ-SH-2	Modern	0.178	25%	Grid	Reverse
TK-MA-1	Modern	0.473	25%	Grid	Reverse
TK-MA-2	Modern	0.549	25%	Grid	Reverse
TK-MA-3	Modern	0.547	25%	Grid	Reverse
TK-MA-4	Modern	0.521	25%	Grid	Reverse
TK-MA-5	Modern	0.540	25%	Grid	Reverse
TK-MA-6	Modern	0.521	25%	Grid	Reverse

Carpet ID	Carpet Type	Area (m^2)	Sample Size	Sample System	Imaging Side
TK-MA-7	Modern	0.544	25%	Grid	Reverse
TK-MA-8	Modern	0.552	25%	Grid	Reverse
TK-MA-9	Modern	0.556	25%	Grid	Reverse
UZ-KH-1	Modern	0.907	25%	Grid	Reverse
UZ-KH-2	Modern	1.015	25%	Grid	Reverse
UZ-KH-3	Modern	1.035	25%	Grid	Reverse
UZ-KH-4	Modern	0.955	25%	Grid	Reverse
UZ-KH-5	Modern	0.922	25%	Grid	Reverse
UZ-KH-6	Modern	0.912	25%	Grid	Reverse
UZ-KH-7	Modern	0.932	25%	Grid	Reverse
UZ-KH-8	Modern	0.932	25%	Grid	Reverse
UZ-KH-9	Modern	1.700	12.5%	Grid	Reverse
UZ-KH-10	Modern	2.400	12.5%	Grid	Reverse
UZ-KH-11	Modern	2.299	12.5%	Grid	Reverse
UZ-KH-12	Modern	1.422	12.5%	Grid	Reverse
UZ-KH-13	Modern	3.100	12.5%	Grid	Reverse
UZ-SK-1	Modern	2.160	12.5%	Grid	Reverse
UZ-SK-2	Modern	1.783	12.5%	Grid	Reverse
UZ-SK-3	Modern	3.060	12.5%	Grid	Reverse

8. Analysis of Ethnographic Data

Size Analysis

The goal of the knot size analysis was a complex one. Based on more than half a million ethnographic knots and 34 independent variables, I needed to identify patterns in the spatial distribution of knot-size variation. In other words, I was interested in determining if the density of the carpet changes between the centers and edges, top and bottom, or left and right sides of the carpet, and whether those patterns are linked to any of the production characteristics.[24] Any (or all) of the independent variables might have contributed, might have compounded each other and overemphasize outcomes, might have contradicted each other and obscured outcomes, or might not have contributed at all. Any contributions that exist might occur in either or both the horizontal and vertical axes or may be distributed randomly without a spatial pattern. This analysis therefore took an exploratory approach, where many methods and comparisons were used to identify patterns that might be worthwhile topics for more focused further study. Unless otherwise noted, all the measurements discussed in this section are the standardized knot-area values derived from square-centimeters using the min-max method, and a statistical confidence level of $\alpha = 0.05$ is used throughout. This section of the analysis was built on only the

[24] Knot density and knot area/size should be considered interchangeable here, as they are perfect correlates.

ethnographic data, where knot-size trends could be correlated directly to the documented production characteristics. The 30 ethnographic carpets are represented by 530,816 individual knots (from which the outlier knots are already excluded).

The first and simplest step was to generate summary statistics for each carpet. These include the mean, standard deviation (SD), minimum, maximum, and coefficient of variation (CV) values for each carpet. These are calculated per-carpet, not on the entire ethnographic sample. Results are given in Table 8.1. The summary values are calculated on the unstandardized area data, as the standardization method eliminates the comparative meaning of the mean (always 0.5), minimum (0), maximum (1), and range (1). However, as these data are unstandardized, direct comparison between the carpets' means, minimums, and maximums is not meaningful. These statistics are simply to illustrate the natural differences between the carpets, and to show why using proportional rather than absolute variation is an important component of this study. The standard deviation and CV, however, can be meaningfully compared in this state.

Although there is significant variation between individual carpets, they do tend to clump by community of manufacture. This makes sense, as communities generally share techniques, materials, and quality of output: they usually have more similarities than differences. It also suggests robusticity in the mental models, that weavers can stick to a particular quality level consistently enough to distinguish their carpets easily in the sample, even without being able to compare their materials, sizes, or designs. Although the inter-community divisions are relatively obvious and suggest a consistent overall outcome within each community-of-practice, it is notable how much variation there is at the smaller scale. The largest/smallest knots in a carpet

can be as much as 3x bigger/smaller than the mean: this is an impressive range of variation for a hand-formed item, and especially one that has structural limitations imposed by the warp and weft. A knot 3x bigger/smaller than its neighbors would be readily apparent to the human eye.

Lower standard deviations are generally linked to smaller absolute knot sizes, but not necessarily to smaller CVs. This indicates that while there is less absolute variation in small knots, there is not less proportional variation – the rate and proportional breadth of variation remains approximately constant in all knot sizes, sitting around 20% CV.

It is immediately apparent that none of these carpets seem to approach the proposed physical limit of variation in master artisans discussed in a previous chapter (Chapter 4, pg. 152). That number is usually given as a CV of 2-5%, with non-masters and eventually novices reaching up all the way to 50% in standardized work. It may initially be surprising that none of the weavers in this study reach "master" status, particularly those working in luxury workshops under tight quality controls. However, we must remember that the estimated 2-5% CV range is derived from two other values: the Weber Fraction for length, and the percent variation between each observation and the target.

The Weber Fraction for length is 3%. That metric measures only single-dimensional size estimation and cannot be applied to multi-dimensional qualities like area or shape. The compound variation in area for a rectangular object with a 3% variation in each length and width would be 6%. This means that objects within 6% of the target area are as standardized as objects with 3% variation in length and 3% in width. This value is the measure of variation, or the mathematical difference between a single object and the target ideal. This is a measure of only

one object: to evaluate variation across a whole sample, a coefficient of variation (CV) is used. The two variance measures are not 1:1. If all the objects in a sample had 0-3% random individual variation from the target, the group CV would be ~1.6% (following equations from Eerkens 2000:664). The individual-observation variance for highly-skilled production is generally considered 4-8%, which means the CVs are 2-5%.

Returning to the CVs listed in Table 8.1, the values are clearly still far above the expected 2-5% range for CVs. But again, this has not accounted for the two-dimensionality measured represented in the knot areas. Although the mathematical relationship between CV and two-dimensional composite area is not simple, the CVs of the underlying length/width can be approximated for normal distributions by dividing the CV in half. This is a quick ballpark number used for rough evaluations, not a perfect quantification. The average CV of these carpets is around 21%, so the underlying average variances for knot length and width are ~10% each. This is about what I would have expected: a reasonably well-standardized number for a group of mixed non-professional, semi-professional, and professional weavers working to different standards, where the range for high standardization is usually given around 2-5%.

Dividing the CV in half like this assumes that the x- and y-axes linear measurements have the same variance. This is purely an assumption, and other combinations of x- and y-axes variation are equally plausible if they add up to 20%. For instance, it could be that the x-axis widths of the knots have 6% variation, while the y-axis heights of the knots have 14% variation. This rough calculation also assumes that knots tend to be either bigger or smaller in both axes (i.e., a knot with an unusually small x-dimension has a correspondingly small y-dimension). It does

not work if the two dimensions are matched more randomly. Again, the relationship between single-dimensional CVs and a two-dimensional composite area CV is not a simple one.

As the numbers given in Table 8.1 are quite static, mostly not comparable between carpets, and not directly relevant to the goals of this project, they truly are summary statistics. While the average variance of the ethnographic group puts them towards (but not at) the highly-specialized end of what is expected in archaeological assemblages, their individual rates of standardization are not the point of interest here. Therefore, more time was spent on exploring A) whether different traits divide the data in significant ways, and B) if those differences follow a spatial pattern. The first question was whether or not the observations of each characteristic created distinct groups. To determine this, I first divide the data into several groups based on a specific production characteristic: for example, the **Warp Material**. Three traits were observed in this characteristic: cotton, silk, and wool. The data are divided into groups using cotton, silk, and wool warps, and statistical tests are used to estimate if those groups represent meaningful divisions in the data.

To test the data division, I used a comparison of the variances, also known as an ANOVA. F-tests are often used in archaeology and the wider social sciences as the underlying computation in an ANOVA (Kvamme et al. 1996:116). However, there is some concern in archaeological studies of standardization that f-tests should not be used to compare assemblages because it is an evaluation of standard deviation. This can be hugely distorted by differences in absolute size and sample size (Eerkens & Bettinger 2001:498). However, as these data have already been standardized using the min/max method, it is now a measure of proportional area, not absolute

area. This eliminates the first concern about absolute size variation: all the samples vary between 0 and 100% (0 and 1), and outliers are mathematically impossible.

The variation in sample size is a bigger issue, as some of the groups in this study differ by hundreds of thousands of knots (for instance, there are 72,491 ethnographic knots built on a cotton warp; 316,603 on a silk warp; and 139,036 on a wool warp). This imbalance can overemphasize the variance in the larger group(s) and increase the chances of type 1 errors. To combat this, I subsetted each group to a random sample of 5,000 knots. This number should still be large enough to capture any existing variance, but is small enough that the maximum difference in sample size is only a few hundred knots, or about 6%. Where a group has more than 5,000 knots, a random subset is therefore used. In the few cases where a group has fewer than 5,000 knots (lowest n = 4,696), the entire group is included without subsetting. To minimize the potential sampling issues of a random subset, I repeated these tests with twenty different random samples. These random subsets were selected by R's built-in statistical random subsetting capabilities. The average and median p-values of that repetition are included in Appendix D, and I reference the median value in the written discussions.

Using a random subset also corrects another small concern relating to the interdependence of the knots. Although they are treated as individuals with no interdependence in this study, that is not strictly the case. Because all of the knots necessarily share their left and right sides with their horizontal neighbors, and many also share their top and bottom sides with their vertical neighbors, the size of one knot can affect those around it. If one knot is tied particularly large, it will encroach on its neighbor's space. Those neighbors either have to get

smaller to accommodate the large knot, or they have to encroach into *their* neighbor's space too, passing the distortion down the line. As this part of the analysis is looking only at knot size (measured in standardized cm^2), how the knot "reacts" to its neighbor's encroachment has a measurable effect on the data. A knot that is tied smaller to accommodate a large neighbor will be an unusually small data point, while a knot that transfers the big knot's encroachment along to its own neighbors will not. The knots are therefore neither wholly independent nor wholly dependent, as the size of one knot can have ramifications for one other knot or for hundreds of knots, with no clear way to distinguish the two. The random subset eliminates this problem for the most part, by measuring knots that probably do not touch, and probably are some distance apart. While effects of a single outlier knot could theoretically radiate across the whole carpet, the effect should get comparatively weaker the further from the cause a measurement is taken.

In addition to their poor tolerance of different sample sizes, f-tests are also very sensitive to departures from normality. The knot data are generally normal, but some of the data groups did have a slight right-skew. Although the skew is very weak and does not appear in all groups, I elected to use a different test for variance anyway: Levene's test. This test also assumes normality, but it requires only a more general normality and is less sensitive to minor departures. This makes it a more robust measure of this data set.

When Levene's test generates a p-value lower than the defined confidence interval ($\alpha = 0.05$ here), we can reject the null hypothesis that the different samples represent data from the same parent distribution. In our **Warp Material** example, a significant Levene's p-value would indicate that the knots built on cotton, silk, and wool warps have meaningfully different variance

in size, and that these three groups are likely to represent distinct production outcomes. This style of f-test would often be followed-up by a round of mean testing (t-tests) to determine if the means, not just the variances, differ between groups. In much social and scientific research, checking both dimensions is valuable. However, establishing a difference in means is not a meaningful step here. The data have already been standardized for inter-carpet comparison. Because the mean values of normally-distributed data calculated with the min-max method are always 0.5, and because all the carpets fit those assumptions, I already know that the means of each carpet population and that they do not differ. T-tests would have no meaning here as it is mathematically impossible for a t-test to return a statistically-significant p-value on these data.

It should be noted that some characteristics measured here are non-differentiating, in that multiple traits break down the data in the same way. Any results measured from those divisions cannot be statistically linked to either trait as an exclusive or even contributing cause. Correlation, not causation, is the most that can be identified here.

These differentiation-of-population-variation tests are joined by single-variable spatial distributions. These tests conglomerate the standardized area measurements from all the ethnographic carpets and subsets them by spatial position within the carpets. These distribution checks were performed twice, once for horizontal/x-axis patterns, and once for vertical/y-axis patterns. The same procedures apply to both: I will describe the process for horizontal/x-axis distributions here, and the procedure for vertical/y-axis distributions can be inferred.

All of the ethnographic measurements are organized into vertical “columns” representing their position in the carpet as a measure of proportional distance from the left vertical edge. The

columns were organized using the cluster coordinates already linked to the data. These coordinates represent the original sample clusters marked on the carpets and from which measurements were drawn, and sit in the range of 0-100. In this system, each incremental step in the x-axis can be interpreted as an additional percentage point away from the left vertical edge. That is, a column sitting at x = 38 represents the vertical strip of carpet that is 38% from the left edge, as a proportion of the carpet's full width. The same principle applies to the y-values, although they measure up from the carpet-bottom. Because the sampling clusters sit on regular grids, not all possible values 0-100 are represented, but data are distributed evenly across the range. This distribution is on an artificial proportional scale, so all the x- and y-values are whole integers, and negative values and those over 100 are not possible.

Once the individual knots were organized into columns, they were divided into their trait-groups for a specific characteristic (e.g., cotton/silk/wool for **Warp Material**). An average knot size is found for each x-value in each trait group. Because there are more than half a million knots in the ethnographic sample, it would not be clear or useful to plot them all at once. To clarify any patterns, averages were used instead. Each column is also represented by a coefficient of variation (CV) to visualize changes in variation/consistency across the width of the carpet, as is common in studies of standardization in material culture (after Arnold 1991; Blackman et al. 1993; Eerkens & Bettinger 2001; Martinón-Torres et al. 2014). The mean and CV are plotted together on the same plot. A trend line is added between the values to highlight changes across the carpet width. Each production characteristic has its own set of plots, and each trait-group has its own calculations. None of the calculations are reused or generalized across categories or

characteristics. Because an average is not affected by sample size, a 5,000-point random subset is not required here and the full groups are represented in these plots.

The following sections discuss the more interesting results of the production characteristics' knot-size analyses, executed using the analytical methods and statistical tests just described. Plots, p-values, and other statistical information referenced below can all be found in Appendix D, which is organized in alphabetical order by production characteristic. Although not included in the text, the statistical results for the less interesting production characteristics are still included in the appendix.

Tension Rods

The loom and warping characteristics are of particular interest in carpet research, as there is such a strong popular link between carpets, tribal horizontal looms, and the timeless nomads of imagination. As we have already seen, the direct evidence for horizontal loom use in knotted-pile weaving is scarce before the Victorian era, and entirely nonexistent before the Middle Ages. Although no weavers could be found working on a horizontal loom for this study (which itself does not bode well for the romantic narratives of nomadic weavers), other loom & warping characteristics were observed. **Tension Rods** were used in most of the ethnographic carpets to take up slack in the warp, to move crossing-points, and to change the size of native sheds.

The means of these groups are very consistent, both within a category and between them. Sharp changes in knot size between consecutive columns/rows is common, although no overarching pattern emerges. The CVs similarly jump around. Most likely, this means that the use

of tension rods is not a strong predictor of knot size, or of rates of variation. Levene's test for variance confirms this, showing no difference between the 0 and 1 tension rod-groups at the bottom of the carpet.

One of the plots does stand out from the rest: the use of a **Tension Rod** at the top of the loom. This group has much smoother gradients and more consistent knot sizes and rates of variation. These knots are, generally, slightly bigger than the knots made without a top rod, and have slightly lower average variance across the width of the carpet. The knots are bigger, but more consistent. I initially thought that this must be a stabilizing factor of the tension rod, which takes up slack and theoretically minimizes movement in the underlying structural grid which could cause variation in the knots. However, this can't entirely be the case, as a similar pattern does not appear when tension rods are used at the bottom of the carpet. Here, the rod doesn't seem to make a notable difference compared to carpets woven without the bottom rod. That suggests that it is not so much the tension rod itself that makes a difference, but specifically its position at the top of the weaving zone. Levene's test strongly suggests a statistical difference in variation between using and not using a top tension rod, with a p-value of <0.001.

When working on a carpet loom, particularly the belt-warped ones documented in this study, the top of the weaving zone is less clearly defined than the bottom. While the belt warp itself is naturally directionless and any part could, theoretically, be the starting point for weaving, the weaver sets the "bottom" point immediately. The very first thing she does is weave the selvedge that is the bottom of the carpet. Throughout the entire weaving process, the bottom is defined. And indeed, a solid foundation is critical to the success of the onward work, as the

weaving needs a base against which to compact. The top is less clearly defined. Certainly, the weaver would have a general intuition for where the top will eventually land depending on her personal weaving density and the type of carpet she is planning to make, but the exact point isn't known until the weaving is finished. When a particularly large carpet is woven, as is the case for all of the silk carpets here, rotation of the warp around the warp beams can also shift the "top" point, as each individual end of warp will wind at a slightly different rate around the warp beams. I therefore suggest that while it is easy and almost intuitive to add a tension rod at the bottom and to work away from it, it is less so to estimate the top and add a rod there. But when a weaver chooses to do so, the top tension rod acts as a homogenizing force, helping to distribute variation in tension and winding, and creating a more uniform horizontal grid of warp threads on which to weave. This could be expected to reduce measured variation.

Although the matching trait in the vertical axis is not so distinctly different, it is still slightly smoother than the other observations. I would not expect the tension rods to have as much effect in this direction, as their influence would presumably act on every row equally.

Knot Type & Knot Direction

The **Knot Type** is where the first sharp distinction between variable categories appears (Fig. 8.1). Both symmetric and asymmetric knots produce knots of approximately the same size across the width/length of the carpet and they have generally the same range of variation (confirmed by a Levene's test, $p = 0.220$). However, the asymmetric knotted carpets see a smoother, more subtle shift in knot size across the carpets, while the symmetric knot change size

more sporadically. This may seem counterintuitive: why would the balanced knots be more inconsistent than the lopsided knots! But this would seem to confirm the idea, posited by many weavers and carpet historians, that asymmetric knots are higher quality. Exact measures of "quality" vary from strength, speed, squareness, and density, but certainly these data suggest that there is some truth to the idea that asymmetric knots produce a more even and consistent weave. This may be because they pack more tightly together, leaving less space for knots to shift or pull loose, or it may be because their asymmetry allows them to nestle together in a more secure formation (like the increased strength of triangular braces in bridges and skyscrapers). Regardless of the exact reason, it is interesting to see that there may be some truth to the widely-held belief that asymmetric knots are inherently better-quality on some dimension.

There is a slight parabolic trend in the asymmetric knot area averages across the carpet width that implies the knots are slightly bigger on the left and right sides of the carpet, and

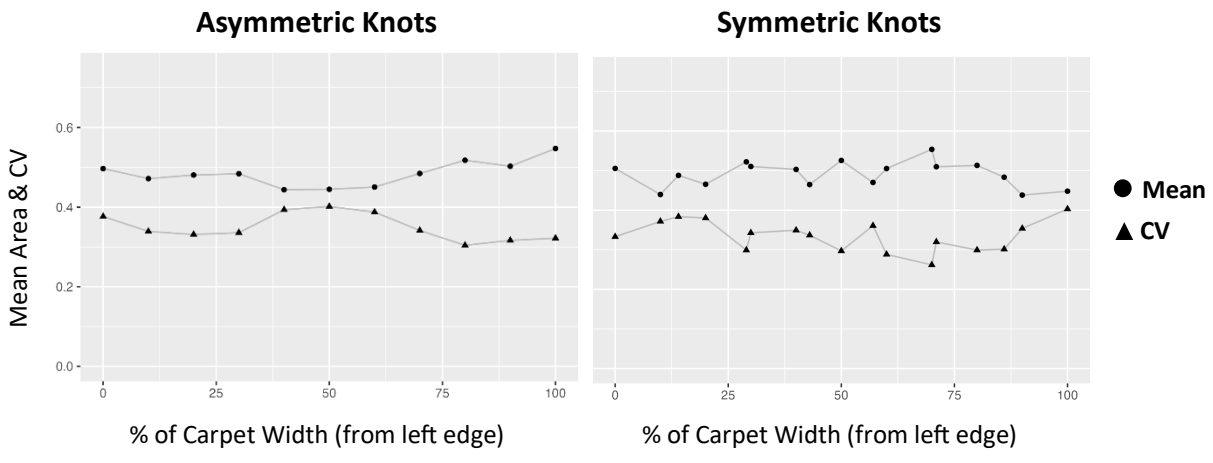

Figure 8.1: Mean Knot Size and CV on the Horizontal Axis, by Knot Type

The average knot size and CV of all the ethnographic carpets by the horizontal position on the carpet. Grouped by type of knot. Figure by author.

smaller in the middle. To confirm this, I performed a Wald-Wolfowitz (WW) runs test. This test estimates the likelihood that features occur in a specific A/B sequence. This can be used in several ways. First, it can estimate whether the original population from which the samples were drawn had an even distribution of features A and B, compared to the null hypothesis that they do (e.g., does the sequence of heads/tails coins flips suggest that this coin is weighted or rigged). It can also be used to quantify sampling bias, by indicating where a sequence appears non-representative even when drawn from a balanced population (e.g., is a social scientist preferentially stopping male informants on the street, even though passersby were equally male and female). A variation of the test can be used to estimate if two samples were drawn from the same original population, based on how the two samples fit together in sequential order (e.g., do the heights of random people on the street in London suggest that Londoners derive from distinct racial or nutritional populations). Relevant to this study, a Ward-Wolfowitz test can be used to confirm that spatial patterns that appear in data are non-random, and therefore possibly explanatory. WW tests are non-parametric, meaning they do not rely on normally-distributed data (although most of the knot data are generally normal). The WW tests are also not sensitive to sample size in the same way that f-tests are, and so are calculated on the entire dataset instead of the 5,000-knot random subset described already.

Here, the question is whether or not the slightly parabolic valley in the **Knot Type-Asymmetric** plot is random noise that coincidentally looks like a parabola, or a statistically-significant pattern. To calculate this, I assigned the column means either an A or B, representing whether they are higher or lower than the all-column mean. The column means are then placed

in sequential order in their left-to-right/bottom-to-top positions on the carpet. Reading through the A/B values in order, the number of times the sequence switches from A to B or B to A is counted, and the WW test is performed on that number and some other summary statistics. The resulting p-value was 0.032, which is below this project's confidence level of $\alpha = 0.05$. This means that this sequence of values is unlikely to be random, and therefore the visible parabola may be a real pattern in changing knot sizes across the width of the carpet. In other words, it is unlikely that bigger/smaller columns would occur in this order if they were positioned randomly. The WW test cannot say that it is specifically a parabolic pattern versus some other regulated sequence, only that this distribution is unlikely to have occurred at random.

I have no explanation for why asymmetric knots might be smaller in the center of the carpet than on the right and left edges. It might be a result of weft shortening – this occurs when a weft pick is pulled too tight, and it pulls the warps inward and out-of-vertical. This redistribution of warps can cause the warp spacing (and therefore the knots) to be different on the edges than in the middle. If weft shortening was the cause here though, I would expect it to apply equally to the symmetric knots, as it is not specific to the asymmetric ones. Since a similar pattern doesn't appear in the symmetric knots, I think it is unlikely that this pattern is caused by weft shortening. It could be a coincidence that the weavers using symmetric knots are more adept at preventing weft shortening, but I think that is very unlikely. The only carpets with visible weft shortening in this study (KZ-OT-1-3) are all made with symmetric knots. This pattern is therefore a result of some intrinsic property of the asymmetric knots, or of some other variable that only appears with or affects asymmetric knots. A WW test was also performed on the symmetric knot data, but it

was distinctly insignificant (p = 0.495), indicating that distribution is statistically random. The statistical-significance of the asymmetric sequence but not the symmetric sequence reinforces the idea that the asymmetric knots are producing a distinct patterned effect on knot size.

A similar parabolic pattern is not present in the length data, indicating that the knots stay generally the same size as they move up the carpet, without an apparent spatial trend. This is confirmed by another WW test, p = 0.450.

The **Knot Direction** follows the same pattern as the **Knot Types**, because they represent the same division of the data. As a right-opening knot can only be an asymmetric knot, the opening directions following the same pattern as the type is not surprising or notable. It would be interesting to have a wider range of asymmetric and wrap knots to compare to.

Knot-Weft Pattern

In the carpet width, all five observations for **Knot-Weft Pattern** represent approximately the same range of means: no observation has bigger/smaller knots than the others overall. Despite this top-level consistency, these distributions are clearly different. The test for equal variances does support a difference in variation (p = <0.001). The most obvious outlier is A/D, which has far more proximal variation than the others, where knots that sit side-by-side can be very different sizes, and the regional variation swinging sharply between high and low variance. The **Knot-Weft Pattern** is a direct description of how the knot interacts with the weft picks immediately before and after it, but its deeper descriptive power is in describing how the knot

might be angled out-of-plane by the pressures exerted on the warp by the weft picks (see Fig. 6.31). The A/D carpets have not one but two consistently-applied weft patterns, and those two patterns are of different types (A has horizontal-line symmetry, D has diagonal-line symmetry). If these had been two versions of the same type, they might have cancelled each other out; as they are two different symmetric types, they compound each other and the knots are at different but not symmetric angles to the weaving plane. These angles in turn affect how much (if any) of the knot is buried in the structure, and how much (if any) visible parts of the knot are magnified. This inconsistency is apparent in the plot.

The C/D observation also has regular occurrences of two different weft patterns, but because both C and D have symmetry on the diagonal, and because the two patterns are mirror images of each other, their distortions tend to cancel each other out and the resulting means and CVs mimic a single-pattern observation. Observations C/D and C end up clumping conceptually, with both having a visible parabolic pattern where the central knots are a difference size than the edge knots. Interestingly, only pattern D is a statistically-significant order according the WW tests though ($p = 0.032$). However, as pattern D nearly but not quite duplicates the asymmetric **Knot Type** data too, I would again suggest that this pattern is more likely an artifact of the asymmetric knots, and that weft pattern D on its own is probably more similar to C/D. The slight parabola in C/D is not statistically significant ($p = 0.147$).

The last two observations (C and D) show similar but inverted patterns, where the knots are smaller on one side of the carpet than the other, with a drop almost exactly at the midline. This is particularly clear in C. I cannot think of any reason why the weft pattern would cause a

non-symmetric lateral difference like this, as it should affect knots the same way across the whole carpet. The only explanation I can suggest requires comparison to the plot for the weaver Kulyash (Teri), available on the **Weaver/Pseudonym** page (pg. 862). The Kazakh weaver Kulyash was the only one interviewed who used a C-style weft pattern. It is therefore possible that this pattern is not a result of the weft pattern, but rather of some other characteristic specific to Kulyash. As this pattern doesn't duplicate under any of the other variables tested, it must be some variable I did not document, or one of the 30+ documented variables excluded from this study due to low sample size. The stark pattern and its correspondingly stark statistical significance ($p = 0.004$), plus the exclusive link to a single weaver, is intriguing.

In the vertical, the distributions are not the same. The A/D observation is less distinct from the others in this axis, and its higher local variation is more explainable. Because both the A/D and C/D observations are used for an alternating structural sequence between rows, it makes sense that they might follow a "back-and-forth" pattern. However as a similar inconsistency is present in the horizontal data, it seems more likely that these jagged distributions are a result of some other factors, and not a depiction of an alternating weft sequence.

Just as in the horizontal data, the vertical distribution made by Kulyash (Teri) stands out. While an inversion of the mean and CV does happen occasionally in other distributions, it is rare for them to intersect three times. Kulyash's weaving shows a reasonably steady downward trend, where the knots woven at the beginning of the carpet are bigger than those woven at the end. Again, I do not think that this is a result of the **Knot-Weft Pattern** but probably a result of some other characteristic specific to Kulyash. If it was a result of the C-pattern weft, I would expect the

D-pattern to have a similar one, as they are mirrored versions of the same diagonal plane shift. Instead, I suspect that this is a result of weft-shortening, as Kulyash's carpets are the only ones where that flaw is visible to the naked eye. Weft-shortening causes the weaving to get tighter and therefore the knots to get smaller as the work progresses, creating a carpet that is narrower at the top than at the bottom.

Knotting Order

Most of the weavers interviewed were taken aback by the question of what order they tie their knots in. It seems to be a mostly unconscious personal choice, rather than one imposed by workshop regulations or the technology itself. While there is no structural reason that the knots must be tied in any particular order, and no reason that a weaver would need to be consistent even within a carpet much less across her weaving life, this characteristic is one of the more engrained "techno-gestures" measured here. Most of the weavers did not even seem conscious of the choice or their method, and had difficulty articulating it. While tying knots in different orders is not limited structurally by the technology or tools, it does seem to have an outcome on the final product. Of the three knotting patterns observed, the two that require counting across empty warps and tying knots when their neighbors are variably absent or present seem to increase variation in the knot sizes both vertically and horizontally. This seems intuitively reasonable: knots tied with empty warps on either side can be bit more relaxed/bigger, while those tied between two existing knots have to wedge into a smaller space. There is no universal spatial pattern in where differently-sized knots fall, because both a color-organized and pattern-

organized methos are driven by the carpet's design, and would change between rows and carpets. This "jumping around" pattern appears in the plots. Although the total range of variation in the mean and CV is on the lower side compared to other characteristics, the transitions between neighboring regions is distinctly choppy. This notable inconsistency in variation is supported by the equal-variances test ($p = 0.004$), indicating that these three treatments are unlikely to represent the same population of knots.

Because most carpets have a simple or solid-color border around their entire perimeter, I thought there might have been reduced variation in those areas in the pattern and color methods. In sections where all the knots are the same color or they follow a less complex pattern, I anticipated that there would be less variation. This does not seem to be the case in either the horizontal or vertical axes: we would expect to see reduced CVs at the right and left edges ($x = 0$, 100) in the width-ways distributions, and reduced CVs at the top and bottom edges ($x = 0$, 100) in the length-ways distributions. Although a few points seem to follow this idea, others do not. The simplified borders do not have a clearly-defined advantage in reducing variation for weavers working in a design-limited way. Of the characteristics discussed so far, I think that this trio is one of the more interesting despite a lack of statistically-significant spatial sequences.

These two design-driven observations (color-based and pattern-based) are contrasted to the more regular and predicable directional observation, where the weavers add knots in consecutive order across the carpet without consideration of the color or design motifs (right-to-left, in this case). This means that each knot (except the very first and very last) is added with a neighbor already in place on its right, and empty warps on its left. Each knot therefore has the

same pressures exerted by its neighbors. The result is a more subtle and gradual shift in knot sizes across the carpet, and an even rate of variation. As the weavers always worked in the same direction (right-to-left), there is no difference between rows, and therefore no spatial pattern in the vertical distribution either. It may be surprising to see that all the weavers working in a consecutive order work from right-to-left, not left-to-right as might be expected for people whose native languages are written in that direction. When asked about this, one weaver (Mehribon/Monica, working in Kazakhstan) told me that the right side is lucky so given the choice, she would always choose to start from that side (Survey 11).

Cartoon Use

Another interesting pattern appears in the use of a drawn cartoon. Particularly relevant to the study of specialization, standardization, quality control, and workshop social organization, the question of cartoon use has provided useful insights into many historic carpets. The Pazyryk carpet, for instance, has general consistency in complex shapes but not exact replication, suggesting the weaver followed a drawn pattern, but not a gridded one. The exact replication of several carpets in a 16th century Cairene workshop gives us a view into the early days of carpet mass-manufacture under the Ottomans and suggests tight adherence to a gridded or otherwise unambiguous reference. To be able to estimate or quantify cartoon use in a wider range of carpets could be a very useful tool. The three observations recorded here, representing continuous/regular reference to a cartoon, occasional/ad-hoc reference to a cartoon, and no cartoon use at all, are the first group to follow a consistent progression across ordinal categories.

In the same order that continuous, sporadic, and no-use represent a decrease in external reference, the means and CVs shown here indicate a decrease in variation along both geographic axes.

This seems counterintuitive at first glance: doesn't reference to aids usually increase standardization, even allowing artisans to push past their physical limitations in some cases? Generally, yes. But that doesn't seem to be the case here. Here, increased use of the cartoon seems to create less consistent work. More extensive and focused testing would be required to confirm this, but my hypothesis is that weavers who work from memory are able to get into a "rhythm", where the repeated movement (the techno-gesture) results in more consistent knots. Weavers who have to stop every few knots, lean across to check a cartoon, and then recompose themselves to start weaving may not find that same rhythm. Any "start-up" or "warm-up" variation wouldn't occur only at the beginning of a carpet or row, but would re-occur again and again as they continually stop and start. The weavers who use the cartoon more sporadically would presumably have sections that are well-memorized mixed with sections of less confidence, explaining why both high- and low regional variation appears in those groups.

It is important to note that this pattern is not a result of weaver skill, experience, or production setting: the use of cartoons is more consistently linked to the complexity of the design than to idiosyncratic or social-economic factors. The different patterns used, and the weavers' differing confidence in those patterns, likely also contributes to the rate and distribution of the variation. An interesting follow-up might be to have many weavers produce the same design from

the same cartoon, where some weavers are familiar with the design and have portions memorized, while others are weaving it for the first time.

The effects of a “rhythm” would only work in the x-axis, as only one row can be tied at a time. It isn’t possible to get into a groove when working vertically. Vertically adjacent knots are necessarily separated by the weaving of the weft shot and binding, beating the weaving down, and trimming the pile. The rhythm of the techno-gestures therefore can’t explain the distribution pattern that appear down the length of the carpet, although they show a similar decrease in variation as the cartoon is used less often. Although none of these distributions follow a statistically-significant sequence, there is a visual trend in the continuous cartoon-use group of decreasing knot size as the weaver progresses through the carpet. I wonder if this may be due to a reduced dependance on the cartoon towards the end of the carpet, when the weaver may have memorized some of the motifs or sequences used over the last weeks/months of work. The end-stage weaving with continuous cartoon use approaches the type of distribution seen when cartoons are used sporadically, and these may be continuations of the same effect.

Despite the clear visual pattern and the possible explanatory power of the techno-gestural rhythm, these groups do not have a statistically-significant difference in variation ($p = 0.190$). In combination with the evidence already discussed, this suggests that regardless of reference to a cartoon, weavers generate approximately the same range of variation, and it is only the distribution of that variation which is affected by the cartoon.

Weft-Shot Pick Count

The **Weft Shot Pick Count** follows a similar progression through the observed values. Although not as distinct as the pattern in the cartoon data, there is a general progression of reduced variation with more picks of weft. The weft shot has a "resetting" effect, where each subsequent row of knots is built on a new base of weft, rather than being built on the preceding row of knots. Unlike the **Cartoon Use** data, the number of picks used does create a significant difference in variation (0.033). This could mean that the ability of variation in one row to affect the next is reduced: each new row of knots gets a fresh start. The more picks woven, the more robust the base and the more consistent the row of knots. This would particularly affect the vertical distributions. However, it does seem to effect horizontal variation too, likely because knots in the same row will be built on the same weft base. The 2-pick pattern in the width-ways distribution has a slightly parabolic shape where knots are smaller in the center than on the edges; this may be due to the increased bulk of winding multiple picks into the side bindings, stretching and distorting the nearby knots. The sequence is statistically significant according to the WW test ($p = 0.027$). Interestingly, the 1.5-pick pattern is also statistically significant ($p = 0.024$), despite its apparent randomness.

Community

The weaver **Communities** are perhaps the most consistent way to divide these data. All the organizations, except perhaps the 'none' group which represents a single hobbyist working

alone, have high internal consistency between members, relatively low ranges of mean and CV, and gradual differences between neighboring regions. The visual consistency in each community-of-practice is backed up by Levene's test, which indicates that it is very unlikely that these groups represent the same population ($p = <0.001$).

It is particularly interesting to look at these plots from the point of view of my ethnographic experience. The group who seems to be most consistent is the Khiva collective, producing very consistent knots both horizontally and vertically. They are an informal network of weavers who work independently on ad-hoc commissions, but who act as a support system to share tools, techniques, and sales leads. Although their carpets have a shared character that makes them easy to identify, they are not the most cohesive or centralized group studied, nor the one facing the most consumer pressure. Their organization is not clearly defined and is an amorphous group with members up to 130 km apart. It is unlikely that every member can even name every other. And yet, they produce very consistent work. The two silk workshops in Khiva and Samarkand, despite being trained professionals working in a centralized location on elite products with strict quality controls, are less consistent!

There could be an easy explanations for this. It relates to the absolute knot size. It is a generalized trend in archaeological study of material culture that larger objects have larger absolute variation, but smaller *proportional* variation. Weavers working with larger knots are able to weave more consistently, as they can better see, grab, and control the larger forms. The largest knots in this study, by a considerable margin, are those made by the Khiva collective. Their carpets average only 4.5 knots/cm^2, compared to an average of 24.2 k/cm^2 between the two silk

workshops. The Mary collective and Altyn Orda studio average 21.3 and 14.3 k/cm^2 respectively, which matches the visible pattern in the distributions. The only community that doesn't seem to follow this pattern is the 'none' group, representing a single Kazakh weaver and the only domestic artisan in the group. Relatively lower training, oversight, and economic pressure may disincentivize strict consistency for her, despite the relatively larger average knot density (11.0 k/cm^2). The consistency of some organizations over others may therefore have more to do with their weaving density, and not an underlying skill or technological issue.

Of the different communities, only the Mary collective and the Samarkand silk workshops have a statistically-significant spatial pattern, and only in the x-axis according to the WW test ($p = 0.032$ and 0.031 respectively). The Marian weavers have a slightly parabolic distribution with smaller knots in the center of the carpet and larger knots on the vertical edges, and the Samarkandian weavers have a more linear trend of larger knots at the left and smaller knots at the right. To be clear, I do not think these patterns are an intrinsic property of either of these groups, or either of these cities. Instead, I would interpret these patterns as indications that these communities of practice share a technological, social, or idiosyncratic trait that is causing this pattern. It may be one of the ones included in this study (the Marian distribution is almost synonymous with the asymmetric knot distribution), or it may be one of the variables I documented but excluded from analysis due to low sample size, or it may be a completely unknown characteristic that I have not thought of.

Although not statistically significant, the Altyn Orda and domestic hobbyist weavers have a slight tendency to make smaller knots at the top of the carpet than at the bottom. One of the

two carpets from Altyn Orda and all three carpets woven by the hobbyist are the only ones in the sample with a visibly trapezoidal shape, suggesting the weavers struggled with overtightening the weft (weft shortening). As this problem is repeated between consecutive rows, the carpet gets narrower and narrower, so that the knots woven at the end are smaller than those woven at the beginning. Once this weft-shortening occurs, it is difficult or impossible to correct in subsequent rows, and the best a weaver can usually do is to not let it get worse.

Country, City, & Village

Other characteristics that are conceptually linked to the **Community** are the location variables. These represent the physical location of the weavers in terms of modern geo-political units. It is important to remember that while communities of weavers (workshops, collectives) usually live/work in the same places, they do not have to, nor do weavers working in the same place necessarily belong to the same community-of-practice. The location data are broken into three hierarchical tiers: **Country**, **City**, and **Village**. Although they have a distinct character and two of the three have significant inter-group differences in variation (City and Village, both $p = <0.001$), none of these distributions appear to provide good explanation for spatial variation in the carpets. While I never thought that the specific location would have a direct impact on the weaving, I included these almost "metadata" variables as ways to capture traits that an artist community, ethnic group, or geo-political unit might share but which was not included in this study. Similarity of patterns in these geographic groups should therefore not be interpreted to mean that, for example, being in Khiva inherently makes your knots more locally variable, but

rather that there is some unknown trait shared by Khivan weavers that makes their knots more locally variable. That trait may be a shared cultural tradition, a quirk of locally-accessible materials, an unusual regional market pressure, etc.

The weavers in Angarik, outside of Khiva, Uzbekistan, produce an unusual pattern in the y-axis **Village** data. The sudden increase in variation about two-thirds of the way through the carpet and steady decrease thereafter makes me wonder if that is the point at which the warp had to be wound because the weaving zone was too far above the weavers' shoulders, or the point at which the weaver switched from sitting on the floor to sitting on a chair to reach the rising weaving zone. Although I can't confirm this to be the case, it would explain such a sharp change only visible in the vertically-spatial data. As the Angarik carpets represent the work of a single person, it makes sense that she might have a consistent winding or seating rhythm that appears in all her work, where she performs some technical change in position at a consistent distance from the carpet's bottom based on her specific arm-span and mobility level. The distinct shift in the first third of the Ingilis data may have a similar explanation, as it also represents multiple carpets by the same person (although a different person than in Angarik). The lack of a similar pattern in other locations can be explained by multiple weavers working to different personal comfort, or by larger/smaller looms which are wound more/less often out of convenience instead of personal comfort.

Finally, note the widthways data for the Ingilis carpets also in the **Village** group. It is broken into three distinct sections, where the left and right thirds are very consistent, but the central third is notably different. Again, the two carpets represented in this graph were both made by the

same person (Mehribon/Monica). But I posit that this distribution is better explained by the designs used in these two carpets (Fig. 8.2). Both have thick borders around the perimeter, which take up approximately two-thirds of the total carpet width. Maybe Mehribon follows a different technique when weaving the repetitive borders vs. the more unique central medallions. The distinct distribution may be an exaggerated effect of many factors, like increased attention to a cartoon, a tendency to change her weft-addition pattern, more careful beating, working through some sections in a single sitting vs. being interrupted by children or chores, etc. While many of the carpets from Mehribon's community-of-practice (Collective-Khiva) have wide borders of a similar style, the data suggest that she treats her borders and central field in distinctly different ways, which the other weavers don't seem to do.

As the borders go around the full perimeter of the carpet, we might expect a similarly sharp distinction between the top and bottom thirds and the center in the lengthwise data, which we do not. I think this is because although the carpet design is consistent and symmetric in both directions, the weaving process is not so. The weaver can only work on rows, not columns, meaning that the left and right borders are woven in the same rows as the central field, while the top and bottom borders are woven in rows of exclusively border. The differentiation between the borders and central field would not be present in those rows, meaning that there would be no consistent difference in the y-axis. It may be that the sudden increase in variation about 20% of the way into the carpet may be a small remnant of the same border pattern, where her working pattern changes in the first few rows that incorporate the central field. As she gets used to the

central field pattern, this variation drops away again and does not reappear as she weaves the duplicate border at the top of the carpet.



Figure 8.2: Carpets from Ingilis, Khiva, Uzbekistan

Both designs feature a clear division between border and central field, with the borders taking up approximately one-quarter to one-third of the carpet's width each. Carpets UZ-KH-3 (left) and UZ-KH-4 (right). Photos by author.

Weaver (Pseudonym)

When organizing horizontal variation by **Weaver/Pseudonym**, we can imagine the distribution as a sort of "signature" that encompasses all their techniques, tools, materials, social pressures, and individual idiosyncrasies. The range of distributions is therefore just as wide as the range of contributing factors. In general, the **Weaver** data have higher internal ranges of both mean and CV, but smoother transitions between neighboring sections of carpet. So while each

individual's overall weaving may not be especially consistent, their knots trend smoothly from one area to the next without sharp changes. The weavers are, for the most part, spatially consistent, with the same style of distribution appearing in both the horizontal and vertical axes. There is a significant difference in their variances (Levene's p-value = <0.001), reinforcing the idea that their weaving patterns are unique signatures and not drawn from the same universal population.

Many of the weavers have statistically-significant spatial patterns in the horizontal axis. These include negative parabolas, where knots are smallest in the center but get bigger towards the left and right edges (Anonymous A/Anna [p = 0.027], Anon. C/Christina [0.027], Anon. D/Dorothy [0.032], Anon. E/Eleanora [0.027], Mehribon/Monica [0.032]).[25] Positive parabolas also occur more rarely, where knots are largest in the center but get smaller towards the right and left edges (Madina/Margaret [0.027]). One weaver (Kulyash/Teri, p = 0.004) shows the distinct lateral pattern already discussed, where her knots are consistently small on the left side of the carpet and consistently big on the right side. The common occurrence of parabolic change in the x-axis mimics the results of my previous, smaller-scale study of Turkmen carpets (V. Sluka 2017). In that project, I attributed the pattern to weft shortening or over-tightening, which I think is still a good explanation.

[25] Many of the p-values derived from the Wald-Wolfowitz tests are identical. This is not because the data are identical. Instead, it means that the summary statistics used in the test (n, n_a, run count) are identical. But because the same summary statistics can represent different patterns, distributions, and underlying data, the numbers being the same is not inherently meaningful and should not be interpreted as an error.

A few weavers have statistically-significant spatial patterns in the vertical axis too. The odd shift in the last third of Durdiposhsha/Ginny's carpet is significant ($p = 0.032$), as is Halima/Janina's distribution ($p = 0.023$). However, while Durdiposhsha's work seems to represent a real (if hard to explain) pattern, the statistical-significance in Halima's work is likely down to just the outlier at $x = 14$ near the bottom of the carpet. Her work is otherwise reasonably consistent in both axes, so it may be that something unusual happened just in those few rows of weaving.

Eleven of the eighteen weavers represented here contributed more than one carpet (Maloxat/Alexandra, Anonymous A/Anna, Anon. B/Barbara, Anon. C/Christina, Durdiposhsha/Ginny, Halima/Janina, Nazokat/Jean, Dilbar/Jennifer, Sholpan/Kate, Mehribon/Monica, Anon. F/Stephanie). When comparing the groups by number of carpets contributed, there is a slight tendency for the 2+ carpet group to have smother curves, but not a substantial one. This is likely due to an averaging affect where random variation is flattened out by a larger sample size. However, both groups contain distinct "signatures", both contain different distribution types, and both have statistically-significant and non-significant spatial patterns across both spatial axes. While the exact explanations for these distributions may not be clear, it would be interesting to see if we could match other of the weavers' works simply by matching the spatial signatures.

Experience & Workload

Finally, there are two variables that are truly numeric-continuous rather than categorical: **Experience** and **Workload.** Some other variables (e.g., **Number of Weavers** or **Shed Rods**) are numeric-discrete, and the low number of observations makes it practical to compare the different groups as if they were categorical-ordinal. While these variables are not technologically limited to only 0 or 1 observation, they are culturally limited to 0/1, so treating these characteristics as numeric values when only two values are really possible is a bit misleading. In these cases, the type of distribution analysis discussed thus far makes sense. While **Experience** and **Workload** are included in the categorical analysis as categorical-ordinal bins for completeness, the gaps in the data and the meaningful deviation from whole numbers mean that this is not the best way to measure or visualize the changes in mean/CV. I therefore include a separate visualization which plots the means and CVs as a function of the characteristic in question (Fig. 8.3). These plots are non-spatial, in that they do not represent change across the carpet's surface. The plots suggest that neither weaving experience nor daily workload are good predictors of the amount of variation present in the carpets. Neither dataset could be modelled effectively with linear regression either: no R^2 value was greater than 0.1, which is abysmal. Even using polynomial and even cubic models did not improve the results beyond $R^2 = 0.3$.

Therefore, I conclude that neither weaving experience nor daily workload are good predictors of knot size or variation. Weavers of all backgrounds are able to hold a relatively stable average knot size and level of variance. There is perhaps a little more variation among more novice weavers, but even there the difference is minimal, and may actually be an artifact of the

sampling distribution and not a real-world trend. Neither the **Workload** nor **Experience** patterns follow a statistically non-random sequence using the Wald-Wolfowitz test either. All of these results are a little surprising, as the amount of experience and time spent on the craft is generally understood to be a good predictor of standardization. I would hypothesize that because knot-tying is such a repetitive skill and a single carpet has a minimum of tens of thousands of knots, any beginner variation occurs only in the first carpet or two. By the time a weaver reaches their second or third carpet, they have entirely mastered the knot-tying gesture. The visible learning curve would therefore appear on the scale of hours-days, not years-decades. Unfortunately as no true novices were included in this study, that hypothesis cannot be checked.

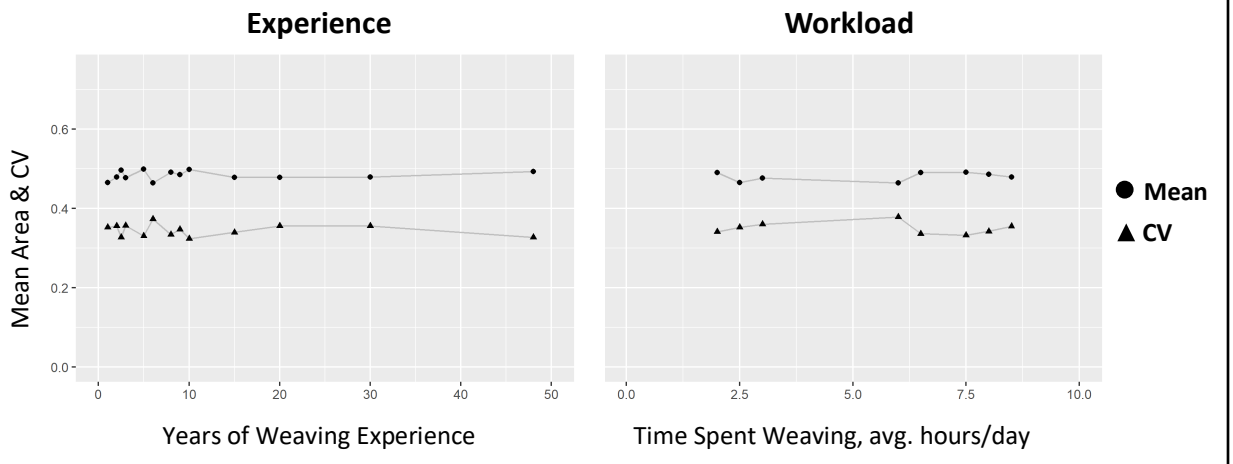

Figure 8.3: Mean and CV by Weaver Experience & Workload

The average knot size and CV of all the ethnographic carpets by the weaver's years of experience and average daily workload. Figure by author.

Other Methods

In addition to the single-variate methods described above, I also attempted multi-variate linear regression and multiple factor analysis. When applied to a system with a large sample size and many independent variables (like this one), these methods can be used to quantify the differential contribution of each variable to the resulting pattern. This can identify which variables have the most responsibility for the observed outcomes, if/how different variables work to compound or counteract each other, which variables are not contributing to the outcome, and if any variables co-vary and are redundant. This would have been an ideal solution to the complex problems presented here, as there are more than 30 independent variables that could contribute to the resulting knot sizes in different ways. Unfortunately, the relatively low ethnographic sample size (30 carpets) and the presence of both overlapping and non-differentiating variables meant that these analyses found a covariance correlation between nearly every pair of variables. Mathematically, multiple variables equally explained the same variation in the data. Usually in statistical and scientific research, this is interpreted to mean that one variable is contributing the variation and the other is simply "along for the ride" as a non-contributing correlate. Although a thorough regression analysis can identify variables that correlate, it cannot differentiate their contributions to the dependent measurements, or determine which is the "driver" of the resulting measurements and which is the "passenger". Differentiation of contributing vs. non-contributing correlates would have to be done in a separate, purpose-built analysis with its own A/B testing and a substantial, well-diversified sample.

In multi-variate studies, these types of confounding variables are normally excluded from the data set. As nearly all of this project's variables fell into that category, excluding correlated variables was not realistic and the multi-variate methods are therefore not useful. While I certainly do not think that all 34 variables actually co-vary, the available sample did not provide enough separation in the independent variables to differentiate their contributions (e.g., the carpets that use a curved knife are the same group as those that do not use a hook; I cannot say whether any visible variation is due to the use of a curved knife, or the lack of a hook). With a larger and more diverse sample, it may be worth returning to these methods for their analytic power in quantifying the input of many independent variables and generating estimates for missing data. These same problems affected the multi-variate methods when applied to the shape data described in the next section: it was therefore not used in any of the explanations or conclusions presented in this paper.

Other methods common for grouping and evaluating data sets in archaeology, including principal components analysis (PCA) and various clustering methods, were also not useful here. PCA can be used to narrow down which variables contribute the most variation to a dataset and which can be discarded as low- or non-contributors. In some cases, this can distinguish between "driver" and "passenger" correlated variables. Unfortunately, the non-differentiating sample problem that effected the other multi-variate methods applies here too. There are too many 1:1 correlates, and too many overlapping groups. As with the other methods, a PCA could not distinguish between them.

In addition to the correlates issue, PCAs require continuous numeric variables. As only two of the production characteristics (**Experience** and **Workload**) plus the knot-sizes themselves are continuously numeric, that severely limits the application of this method. Although some research projects choose to re-code categorical data with numbers to jerry-rig the PCA, I did not think this would result in meaningful conclusions. If the majority of the 35 variables (34 production + knot area) were continuous numeric sets, then re-factoring a few categorical variables might have provided useful insight without excessively damaging the integrity of the analysis. As the carpet data have the inverse distribution (mostly categorical and only a few numeric variables), re-factoring for a PCA was not sensible.

Various clustering methods also appear regularly in archaeological studies of variation and standardization, including the hierarchical and k-means methods. These methods were not used here for the same reasons that PCA was not used. Clustering methods, like PCAs, require continuous numeric data. Again, some research chooses to re-factor categorical data for use in a clustering algorithm, but the more variables are re-factored, the weaker the groupings and any resulting conclusions become. Even if I were to ignore this and go ahead with a re-factored analysis with all the categorical variables, those variables explain more of the data variation than the knot areas do. This makes intuitive sense, as the categorical variables are the independent variables, while the knot area is the dependent variable. A clustering method does not know this, and just sorts the data on as many matching dimensions as it can, i.e. the production characteristics. But this is something that can be achieved simply by looking at the data and does not provide any new insight.

What I would hope to get from a clustering model is a projection of groupings based on the knot areas alone, against which the production characteristics can be matched. Unfortunately, as the knot area is the only dependent variable with nothing to cross-reference or to introduce multi-dimensionality, a clustering algorithm simply sorts the knots by size and divides them into an arbitrary (researcher-defined) number of bins. This, again, is not useful. Even with addition of the shape data described in the next section, there is not sufficient separation between clusters to be meaningful.

Shape Analysis

Separate from the size analysis, a comparison of knot shapes was also performed on the ethnographic data. This is based on the hypothesis that different tools, techniques, and weaver idiosyncrasies could cause the knots to take a different final shape, whether through structural constraints in the carpet, or by weaver-induced variations in style or strength. As the knot-size has already been studied, the shapes are now examined separately. Unlike the study of knot-size, the shape analysis is not spatial. This is due to the standardization and normalization assumptions of size vs. shape.

In order to say that one group of knots is smaller than another, we need to compare the knots directly and without confounding biases: they must be normalized. There are generally two ways to normalize grouped data like the carpets used here. First, the entire dataset can be normalized together, ignoring the groups. While mathematically possible, this method is not conceptually sound in this context. A full-group normalization would overlook compounding

factors like yarn gauge or target carpet quality, and all resulting analyses and statistical tests would measure those and not the production characteristics that are actually of interest here.

Instead, a per-group normalization is required. In this case, the groups are the individual carpets. This removes compounding factors like yarn gauge and target carpet quality by resetting all the knot areas in the same range (0-1) and with the same mean (0.5). It is no longer possible to compare the groups directly to each other because statistically, the knots are all the same size (on average) and fit in the normal size distribution. Instead of comparing the knot sizes across carpets, they have to be compared within carpets, where the standardization factor does not obscure the patterns. The way that they can be compared within each carpet is by comparing different sections, as if each carpet was a longitudinal sample. The knot-size data therefore are studied as change in density across the carpets' surface, and similar patterns of longitudinal change do/do not appear in carpets with similar production characteristics.

The knot-shape data, on the other hand, can be standardized with a whole-sample method. There is a conceptually "perfect" knot shape (square) that applies to all materials, techniques, and weaving targets. The weavers in Ottoman and Mamluk Cairo are particularly remembered as masters not because of a general high-quality output or ties to elite products, but specifically because their knots have a 1:1 aspect ratio: their knots are extremely square. This allows them to create elaborate designs that are not just laterally symmetric, but geometrically symmetric, a feat that is impressive to this day. It requires precise control over the warp spacing, the weft shot, the yarn gauges, and the weaving process itself to maintain the perfect shape in both width and length as weaving progresses. While individual weavers now may be more or less

cognizant of and invested in creating square knots, it is still a useful and objectively-measurable reference shape.

Instead of comparing the knot-shapes directly to each other between carpets, I am really comparing their individual deviation from "perfect" (square). Because all the knots can be compared directly to that ideal shape, there is no need to measure longitudinally: they can be treated as point samples, and the entire sample of 500,000+ knots can be used as one. The spatial distribution therefore does not play into this analysis, as it does not need to. That is not to say that a spatially-distributed analysis of shape is not possible – it is! It just was not the focus in this initial round of experiments and evaluations, due simply to the fact that I cannot test everything possible here. I therefore elected to study the shape data in the whole-group fashion, as a way to experiment with both whole-grouped and sub-grouped data methods. A spatial distribution study of knot shapes would certainly be worthwhile in the future.

The knots' shape deviations were modelled by a Procrustes analysis. This method compares the distribution of points in multi-dimensional space, in a way conceptually similar to other processes that compare the distribution of points in single-dimensional space. Rather than studying the position of individual points in a dataset/scatter plot, a Procrustes analysis studies the position of multiple points acting as a single unit, and how their positions change in relationship to each other as an interrelated group. Here, I used a generalized Procrustes analysis (GPA), where the shapes of objects are measured as deviations from a mathematically derived mean (conceptually similar to many common linear analyses). The amount and direction of

deviation in shape from the "average" shape is the foundation of the analysis. The shape in question here is an individual knot, with four geo-spatial vertices representing its four corners.

I used a GPA method based on a full superimposition of the shapes; that is, I rotated, translated, and scaled the shapes to fit the same general plane before analysis (Fig. 8.4). This is ideal, as it removed several types of possibly confounding factors from the analysis. First, it translated the knots to sit around the same center point. By translating the knots before analysis, mathematically confounding factors of the reference system are also removed. The coordinates used to mark the four corners of each knot are inherently tied to their geographical position on the original coordinate plane, where knots physically closer to the top-left of the carpet have lower (X,Y) values than those at the bottom-right of the carpet.[26] An untranslated analysis would interpret these x-y values as a 5th dependent dimension, when in fact they are an independent dimension. In other words, an untranslated analysis would interpret a perfectly square knot at the top of the carpet as a different shape to a perfectly square knot at the bottom of the carpet, because it sees their position in the carpet as a fifth vertex. It is therefore preferable to translate the knots to sit in the same position, and to discard the positional coordinate data (Fig. 8.4a, b). This means that two knots of the same shape are viewed as identical by the analysis, even if they are from different positions on the carpet.

The superimposition also removed variations in size between the knots. As the size has already been studied as its own dependent variable, it was not necessary to include it in the

[26] The coordinate points of the knot vertices are in QGIS's native reference system, which orients the top-left pixel of the carpet image at point (0,0) on a geographic/cartographic projection. This is separate and unrelated to the coordinates (1-100) assigned to clusters.

shape analysis (Fig. 8.4c). Separating the two allowed for more specific conclusions about their relative occurrence, distribution, and interpretative value to be drawn. Rescaling the knots in this analysis also naturally eliminated the variation in knot size produced by different materials and carpet qualities. The absolute difference in knot size between different carpets is not the subject of this study and therefore removing is preferable.

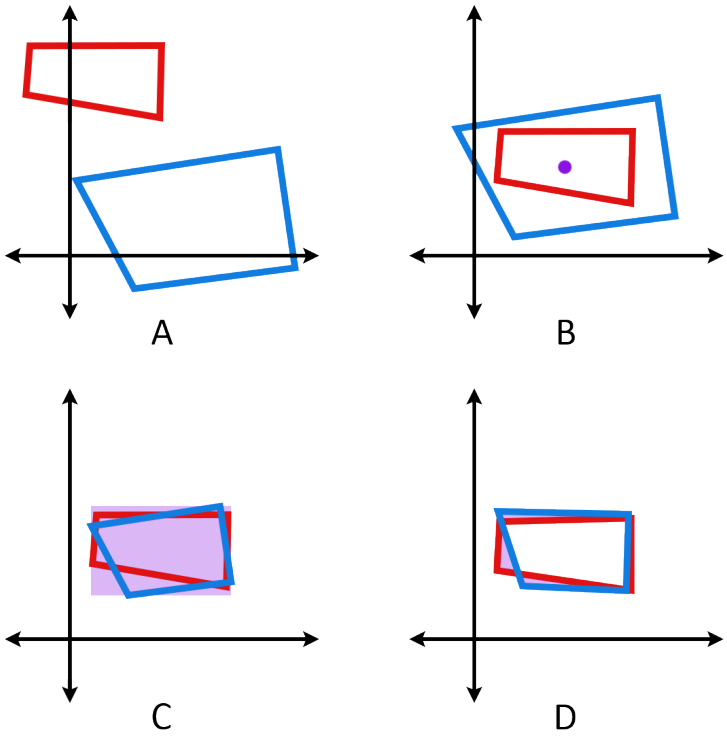

Figure 8.4: Superimposition in Generalized Procrustes Analysis

A: Two knots (red and blue) were recorded at different points in the original plane. Although both four-sided polygons, the two shapes are different in position, size, and orientation.
B: The shapes are translated to sit around the same central point (purple).
C: The knots are resized to represent the same approximate area (shaded in purple).
D: Finally, the knots are rotated to best match the vertices and lines, minimizing the difference between the shapes (shaded in purple). Figure by author.

Finally, the full superimposition method rotated the knots to their best-fit position (Fig. 8.4d). Although the carpets were generally photographed and measured on a 90° X-Y grid with the weft on the X-axis and the warp on the Y-axis, this was done by eye and not in reference to any external standard. This means that many of the carpet data clouds are off-axis by a few degrees. This is not a result of the weaving being off-axis, but rather of misalignment of the data collection and measurements. By rotating the knot shapes to their best-fit position, where the vertices are as close together as possible, this misalignment is removed. In this analysis therefore, any compounding effects of misaligned photos or of uneven weft are removed. All the knots are evaluated as if they are oriented with their base on a flat surface.

A fourth positioning strategy, reflection, is possible in a Procrustes analysis but was not used here. As the hypothesis suggests that there may be directional variation in the knot-shapes (i.e., a conceptually important difference between a left-skewed parallelogram and a right-skewed parallelogram), it was not logical to allow for reflection which might eliminate or confound the directional variation. As all the knot data are taken from the reverse of the carpet with the woven top in the north position, the knots are already 'reflected' the same way. This reflection strategy is usually used when symmetric data need to be aligned in one unit for comparison, such as x-rays taken of a right vs. left hand.

A GPA allows the researcher to set the number of points that define the target shape, as well as the number of dimensions represented. Here, there were four points (each corner of the knot) in two dimensions (X, Y). The "reference shape" on which all the other shapes are superimposed is a mathematically-calculated mean shape, and therefore may not exactly

represent any of the measured knots in the data (nor does it necessarily match the conceptual perfect shape: square). The generalized Procrustes analysis in this study was performed using R, using tools in the open-source package *geomorph*, and code written by me.

The output of the GPA is a new set of coordinate points representing each original measured dot/knot corner. The new points have been translated, resized, and rotated to best-fit the reference shape, and all sit in the same limited range of (x, y) coordinates. Like a z-score or min/max value in single-dimensional data, the new coordinates are standardized to allow for comparison of proportional/relative changes between carpets. Also like a z-score, the new shapes are centered around zero: because these data are two-dimensional, they are here centered on (0,0). Despite its name, the generalized Procrustes analysis should be understood only as a transformation or standardization function: it does not perform any statistical tests, generate any clusters, or otherwise provide any analytical insight into the knot shapes itself. It only lines the shapes up to facilitate further work.

The GPA was performed on the entire dataset, including both the historic and modern ethnographic data. This may see counterintuitive – aren't we trying to derive patterns from the modern data first, to use as a guideline for interpreting the historic data? Yes. But remember, the GPA is only a standardization function. Just as the entire knot-area dataset was standardized with the min/max method to allow for comparison between carpets, the entire knot-shape dataset is standardized with the GPA. The mean shape for the entire dataset (ethnographic and historic) can be viewed in Figure 8.5: this should not be interpreted to have any analytical function beyond being a representative shape for this specific dataset. It could be considered this multi-

dimensional data's z-score of 0. However, you will notice that the calculated average shape for this dataset is promisingly close to the conceptually "perfect" square already discussed. Although the average shape is distinctly rectangular, it has nearly level sides (slopes approaching 0 in the horizontal and infinity in the vertical), and corners of almost exactly 90°. Since any quadrilateral shape was theoretically possible here, it is reassuring that the average knot here is generally rectangular rather than trapezoidal, parallelogrammatic, or otherwise irregularly shaped. It is stretched out-of-square long the x-axis, but this is the only notable deviation from the conceptual ideal.

It is very important to understand that the GPA calculated its points based on several arbitrary references: the alignment of the research photographs in relation to the carpet's warp-weft grid, QGIS's internal reference system based on a global cartesian map measured in meters, the different woven densities and materials of the carpets, etc. Therefore, while the final *shape* of the reference knot (and the data knots) is mathematically meaningful, its *orientation*, *size*, and *position* are not. The GPA re-aligned all these factors at a conceptually arbitrary point, and the newly calculated points are reprojected on an imagined and equally arbitrary X-Y plane. The reference knot shown in Figure 8.5 is arbitrarily centered around the (0, 0) point on the reference grid. There is no mathematical reason that the orientation, size, or position of the data could not be changed, as long as the data were changed en-masse.

Once the shape data had been standardized, they could be analyzed in the same ways as other multi-dimensional data sets. Some of the multi-variate methods already discussed that do

not work for the knot-size data *do* work for the knot-shape data: namely, a principal components analysis.

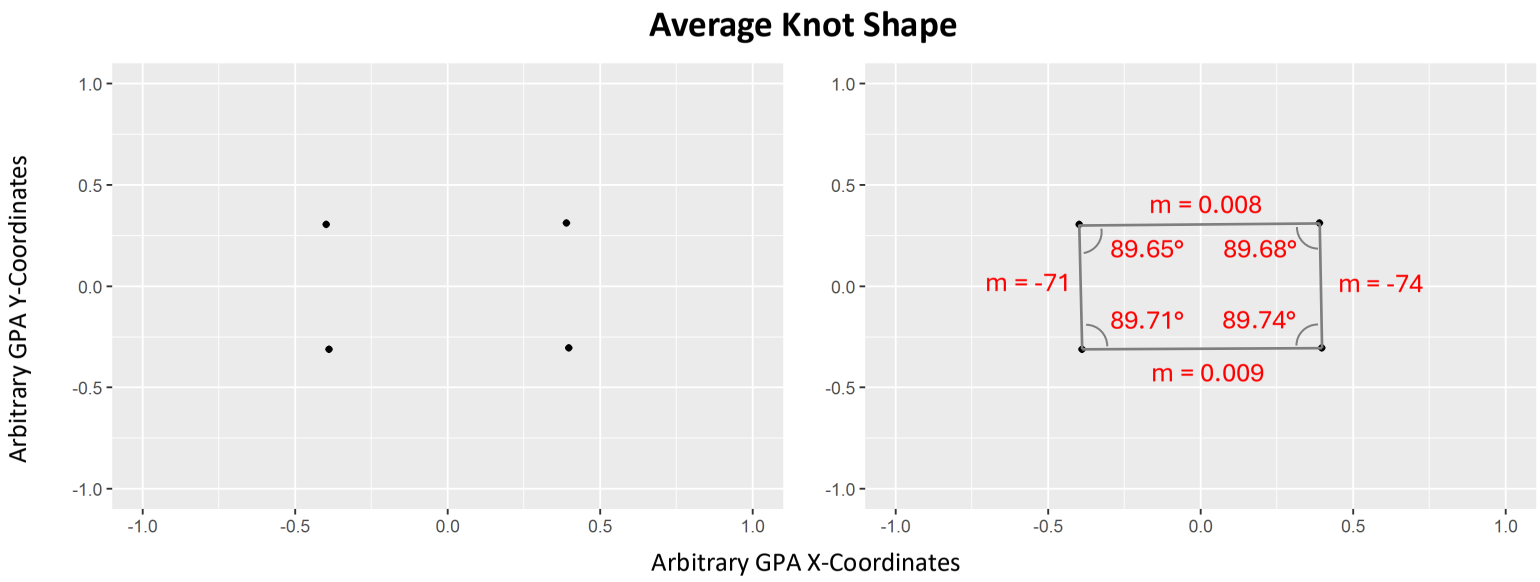

Figure 8.5: All-Data Mean Knot Shape

The average shape of all the measured knots (>800,000) from the ethnographic and historic samples, calculated by a generalized Procrustes analysis. The mean shape is almost perfectly rectangular, representing the idealized knot form and suggesting both that the data were successfully standardized, and that the weavers produce relatively "perfect" knots on average. Figure by author.

Principal Components Analysis

A principal components analysis (PCA) is a method for condensing multi-dimensional data into the minimum number of compound dimensions needed to reasonably represent the variation in the data. It is not strictly an analytical model; that is, it does not provide explanations or hypothesis testing for the data, nor does it perform any statistical tests to comment on differences in mean, variance, standard deviation, range, or any other measures. Instead, a PCA is better understood as an exploratory, modeling, or standardizing method that gives insight into the relative contribution of different variables to the overall distribution. This is useful for multi-variate datasets, as it helps to narrow down which variables are actually contributing to the distribution, and which are less impactful. Once the variables have been narrowed down, the most impactful of them are aggregated into new compound variables (principal components), where a re-factoring equation integrates the values of the original multi-dimensional data into a single new value representing that specific combination of variable weightings. These new data retain the majority of their original variation and explanatory power, but have now been reduced to fewer variables allowing for the use of single-dimension analyses, or simpler multi-variate analyses. I therefore used a PCA to condense the multi-dimensional shape data into a more manageable set.

PCAs have two requirements that restricted their use in understanding the knot-size data. First, PCAs require numeric data, and preferably continuous data. While it is possible to re-code categorical data like the social-technological factors studied here, this is generally inadvisable and should be used sparingly. As the majority of the cultural variables would have to be dealt

with, “sparing” re-coding would not have been possible here. Excluding the categorical variables in the knot-area data left only the weavers’ daily workload and their years of experience, plus the knot-area measurements themselves. As a quick plot (see Fig. 8.3) already tells me that neither the **Workload** nor the weavers’ **Experience** correlates to the knot-sizes, there was no need to perform a PCA for just those variables. With only three dimensions, those data were not complex enough to warrant a PCA.

Second, a PCA cannot distinguish the relative contributions when multiple variables are too closely correlated. In data sets that are poorly diversified (like the social-technological data), a PCA cannot estimate which variables are contributing to the data variation, nor can it distinguish between multiple variables all contributing individually to a compounded result, and a single variable being responsible for the result while others are simply correlating “passengers”. Even if the production characteristics could be meaningfully re-coded into numeric data, the high rate of overlap and correlation in this data set would likely have resulted in PCA results that are not especially helpful at condensing the data.

The multi-dimensional knot-shape data introduce more numeric and non-correlating variables than the knot-area data had. While the categorical production characteristics still can’t be included because they are categorical, the shape data include eight numeric dimensions: an x- and y-coordinate for each of the knots’ four corners. A principal components analysis was run on the entire ethnographic dataset’s shape variables, with more than 4 million values representing the 500,000+ knots. The results of this, including the eigenvectors and the scree plot, can be found in Figure 8.6. The first principal component (PC1) explained 83% of the

variation in the data, and the second (PC2) added another 8%. The recalculated compound values of PC1 and PC2 were used from here to perform a number of exploratory analyses, representing approximately 91% of the original measured variation.

First, Levene's tests for unequal variances were performed on the first principal component, comparing the different groups within each characteristic to see if they are measurably distinct. As already discussed, Levene's test was selected because it requires less rigorous adhesion to normality than do ANOVAs. The shape data, like the size data, are generally normal, but there are some examples of slight skew. Like the size data, these tests were repeated twenty times with different random subsamples of 5,000 knots per trait. The average and median p-values of these repeated tests are given in Appendix D. Unlike the size data where only a handful of groups are distinct, the shape data appear to separate the different production traits quite well in many cases. Almost all of the Levene's tests are statistically significant ($p < 0.05$). However, it is important to be cautious in interpreting this result: because the tests are performed on only the first principal component, only about 83% of the original variation is present. This means that two samples may test as statistically different in PC1, even when the addition of the remaining 17% variation would eliminate the difference.

The compressed dimensionality provided by the PCA means that plots of the data no longer directly mimic the shape of the knot (as it does in Fig. 8.5). Instead, the plots of PC1 vs. PC2 can be understood (generally) as a representation of squareness. Knots that fall toward the left of the PCA plots are squarer, while those that fall toward the right of the PCA plot stretch horizontally into rectangles (Fig. 8.7). You will note from the point clouds in that figure and those

in Appendix D that this ethnographic sample contains knots that are landscape rectangles and approaching square, but few that are portrait rectangles. This seems interesting, but I cannot comment on its meaning beyond assuming that landscape rectangles are more common in the carpet world than are portrait ones.

As in the knot-size section, the following sections talk through each production characteristic in terms of the analysis on knot-shape, using the GPA and PCA-transformed data and statistical tests described above. All of the plots and test results discussed in the following sections can be found on the relevant page in Appendix D, organized in alphabetical order by production characteristic. Just like the size data, it is important to keep in mind that some characteristics duplicate each other nearly or entirely, and so any resulting patterns may be correlative rather than causal. Despite a clearer visual difference in many of the PCA plots, I find it harder to explain the causes of shape variation than size variation.

Tension Rods

The shape data for the **Tension Rods** notably mirror the size data. In both analyses, the bottom tension rod seems to have little if any impact on the knots, while the top tension rod seems to play an important role. The knots built on looms with or without a bottom tension rod show the same general range of knot shapes, from very square to very rectangular. The knots built without the rod are slightly more square-leaning, but it is not a huge difference and their overall range of shapes are comparable. Knots woven without a top tension rod show a similar

wide range of shapes, representing essentially the entire field. However, adding a top tension rod creates a notably right-listing PCA plot, indicating very rectangular knots.

My explanation for this returns to the same premise used to explain the matching variation in the size data. I suggest that the top tension rod stabilizes the warp and reduces overall variation in warp spacing, in turn reducing variation in knot shapes. Carpets woven with this upper rod therefore may consolidate on a smaller range of shapes, creating the pattern shown here. The use of a bottom rod could be less impactful because there is no direct "contact" between the weaving zone and the bottom tension rod(s); they are buffered by the section of already-woven carpet. If the bottom rod has any stabilizing effect, it is likely to be entirely overshadowed by the greater stabilizing effect of the woven section. As the carpet is woven upwards however, there is less stability in the upper section of warps where the top tension rod is placed and where weaving occurs. Adding the top tension rod may therefore add another layer of stability that the bottom of the carpet already has by virtue of the weaving direction. It is notable that despite the minimal visual difference in the PCA plots of the bottom tension rods, that variable still yields a statistically-significant Levene's test. The bottom tension rod may therefore be exerting a similar pressure as the top rod, if more subtly.

Knot Type & Knot Direction

The **Knot Type** is by far the most interesting characteristic thus far. Intuitively, I would expect that different knot types have very different shapes. Technological tradition would generally suggest the same, as many claim that asymmetric knots can pack more tightly due to

their squarer shape, and that they can produce complex designs with more fidelity due to their balanced aspect ratio. Despite this popular lore (among weavers and carpet historians), the data do not support a universal distinction in shape between the groups. The asymmetric knots (AS) even seem to list slightly toward rectangular! In itself, this is not surprising. Truly square knots would be difficult or even impossible to produce repeatedly, but there is no inherently structural reason why either type could not be close to square if proper calibration of warp spacing and yarn gauge was taken. But when compared to the symmetric knots (SY), which achieve a more robust square shape more often, it is certainly interesting that asymmetric knots trend rectangular.

Perhaps a more meaningful way to interpret these data is not in the shapes themselves, but rather in the distribution and range. While the asymmetric knots are surprisingly rectangular, they also seem to be more consistent, with a more centralized distribution and a smaller overall range. This suggests that although asymmetric knots may not be consistently square, they are more cohesive and less variable within themselves. This would support the popular idea that asymmetric knots are higher-quality, and matches the evidence of the size data. It also supports the idea that asymmetric knots could produce more symmetric and balanced designs: not because the knots are square, but rather because they are more consistent and allow the weaver to compensate for distortion issues more effectively.

A final note of interest here is that the test for unequal variances fails ($p = 0.386$). This is surprising, since the data seem to separate visually as well as, if not better, than statistically-significant data viewed in other characteristics There are several possible explanations for this.

First, it could be a result of the testing scheme. Levene's tests can compare only a single dimension of data at a time, which means only the first principal component is compared here. Although PC1 accounts for 83% of the original variation data and is therefore the most robust option, it still leaves 17% of the variation unaccounted for. About half of that missing variation is included in the visual renders as PC2, meaning we can see more separation in the plots than the variance test had access to. Although it is considered appropriate and statistically meaningful to use comparative tests like Levene's on data that have been condensed by a principal components analysis, there is always potential for slight issues like this.

Another possible explanation is that the higher number of knots included in the symmetric group (335,000 vs. 193,000) is creating a fuller, denser visual render and obscuring underlying variation. If the asymmetric sample was larger, it is possible that it would fill out towards the square end in a way more comparable to the symmetric knots. Remember, although the plots include all of the measured knots, Levene's test is applied only to a random subset of 5,000 knots per trait. The mismatch between the visual plot and the statistical test therefore could indicate that the sample size is having a meaningful effect on the plot's appearance.

To refine understanding of the Levene's test result, I performed a set of independent Student's t-tests. While Levene's test compares the variance patterns of two distributions, a t-test compares the means. This test could not be used in the knot-size analysis because the size data were standardized on a matching mean, meaning all t-tests would have suggested that the groups were the same/undifferentiated. However, the shape data are standardized using the PCA, which does not align the means. It is therefore possible to use a t-test here. Like with

Levene's test, the t-tests can be biased by mismatched samples sizes, so the same testing scheme was used here as for the Levene's tests. A random sample of 5,000 knots per group are selected (by a native R function) and the test is performed on only that subset; this is repeated twenty times with different subsets of random knots, and the average and median p-values from the twenty repetitions are given in Appendix D. Student's t-tests are also not applicable to samples with unequal variances: this means that t-tests are only applied when the Levene's test returns a non-significant results (e.g., the Levene's test suggests the groups have comparable variances). Both Levene's test and the Student's t-test can be used to quantify whether two groups were drawn from the same population. Both tests have a null hypothesis that the groups are from the same population, and that they will therefore have comparable variance patterns and means. A significant result in either test should be considered meaningful in this setting.

Here, the non-significant test for unequal variances ($p = 0.386$) is refined with a t-test ($p = <0.001$). This combination suggests that while the overall distribution of knot shapes is generally comparable, the two groups are centered around a different point. This explains the visual difference in the PCA plots. Both groups have some knots reaching across the full range of observations, but they clearly cluster in different locations. We can therefore conclude that there is a statistically meaningful difference between the shape of knots made with asymmetric vs. symmetric knots, reinforcing the traditional carpet lore.

As we saw with the size data, the **Knot Direction** is a perfect duplication of the **Knot Type** data. The right-opening knot cloud is identical to the asymmetric cloud: as right-opening knots can only be asymmetric, this is neither surprising nor meaningful. If more styles of knot direction

were included in the ethnographic sample (left-opening knots, s- or z-wrap knots, etc), then this variable might have been more meaningful.

Strands per Knot

The shape of the knots seems to be affected notably by the number of strands used (**Strands Per Knot**). The most variation in shape appears in knots with fewer strands, while higher-strand knots get more consistent and less variable. This is likely due to the relative robustness of the knots. Knots tied with only a single strand are weaker, and more likely to be shifted or squished by the knots, warps, or wefts around them. As more strands are added, the knot becomes stiffer, resisting pressure from surrounding components and settling on a more unified and consistent shape.

Three of the four observations trend towards rectangular (right side of the PCA plots), while the 1-strand option trends more toward square. I cannot think of a reason why a single-strand knot would be more likely to be square itself, but I suggest that because single-strand knots would tend to be thinner, finer, and smaller, it would be possible to pack them in tighter side-by-side, in turn making them squarer due to reduced space. The single-strand knots might be “crushed” down to the smallest possible size: with even forces applied from all directions, the knot might be condensed as far as possible and evenly in every axis. However, it is also possible that this is at least partially a correlative artifact of another characteristic.

Knot-Warp Pattern

The **Knot-Warp Pattern**, which represents the placement of consecutive warps in relation to the weaving plane, has a distribution similar to the materials variables and a statistically-significant Levene's result of $p = <0.001$. Setting alternate warps slightly behind the weaving plane is known as double warping, and is traditionally thought to improve carpet quality and design fidelity. Most knots (as we can see in all the variables) are rectangular: by shifting half the knot backwards behind the weaving plane, it can be partially buried. This makes it appear horizontally narrower than it is, so that it acts like a square in the design even if it is actually a rectangular knot. Or at least, that is what people think! Again, that does not seem to be strictly true here. There are two double-warped groups represented here (II and III). While one of them (III) seems to trend toward square knots as we would expect, the other (II) does not. The single-warped group (I) does follow our hypothesis though, as it is distinctly rectangular. Despite the sequential group labels, these traits are not a progressive unit where effects would be expected to change incrementally between ends of a scale. Group II is not a halfway stage between groups I and III. Instead, groups II and III should be considered two halves of a single unit (double-warped), while group I is single-warped. The only difference between groups II and III are whether the right or left warp is the one depressed behind the weaving plane. Therefore any squaring-off effects should apply to both groups equally, if they exist.

However, this pattern is probably being affected by a correlating factor. 100% of the carpets woven on a type II warp use asymmetric knots, while all of the symmetric knots studied are woven on warp types I or III (Fig. 8.8). When broken down like this, it seems like there is some

truth to the idea that double-warping creates squarer knots. We have already seen that asymmetric knots trend toward rectangular (right-side of PCA plots). The asymmetric knots used in warp group II may therefore be fighting against the squarifying tendencies of double-warping as seen in group III. It would be interesting to see how right- vs. left-opening asymmetric knots contributed to this pattern: unfortunately, no left-opening knots were included in this study.

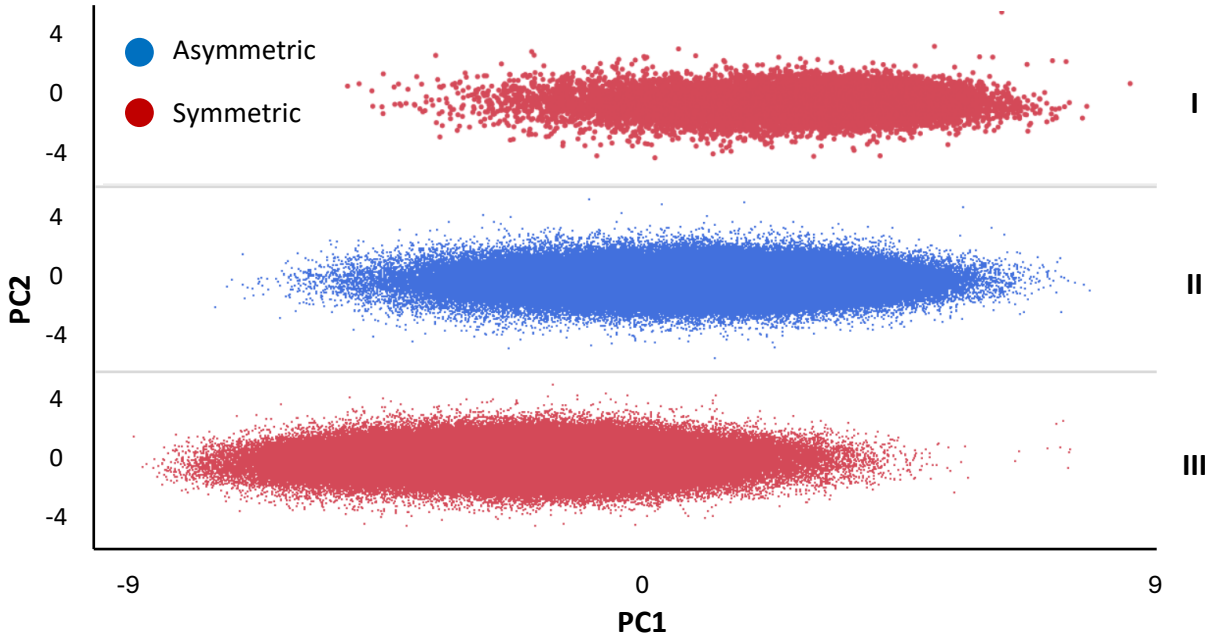

Figure 8.8: Knot Type vs. Knot-Warp Pattern

The rightward tendency of asymmetric knots may be counteracting the leftward tendency of double-warping, resulting in the two double-warped groups (II and III) having different distributions. Figure by author.

Knot-Weft Pattern

I would expect that the **Knot-Weft Pattern** would have a meaningful effect on the shape of the knots, because it describes the way in which the weft picks immediately before and after the knot interact with the warp, and therefore describes pressures that might affect different corners of the knot in different ways. Levene's test for unequal variances returns a non-significant result ($p = 0.127$), but the Student's test for unequal means returns a significant one (<0.001). Like the **Knot Type** data, this suggests a similarity in range and variance between the different observation groups, but that they are centered around different means. This is supported by the PCA plots, where the groups seem to be clustered along different points of the cloud.

The PCA plots are particularly useful here. This variable includes single-type observations (A, C, D), as well as observations where the carpet alternates consistently between two type (A/D, C/D). Individual knots are always one type or the other, but the carpet as a whole has an approximately even distribution of the two. The single-type observations are all relatively distinct: A-knots are trend slightly square, C-knots trend very rectangular with a narrower field of variation, and D-knots trend very rectangular with a larger field of variation. The combination groups seem to be a general middle-ground between their relevant single types. The A/D-knots encompass the full range of square and rectangular knots represented in the individual A and D groups, and the C/D group is similarly rectangular but has a middle-ground of variation compared to the individual C and D groups. Individual knots seem to sit within their expected single-trait range, and the whole group fits within the larger range of possibilities.

Another point of interest here is the difference between the A-knots and the C- and D-knots. The A-group represents knots where the weft picks immediately before and after sit in the same shed. The C- and D-groups represent knots where the weft picks immediately before and after sit in different sheds. It is therefore reasonable to expect that the C- and D- groups would be more similar to each other than either are to group A. And indeed, that is the pattern we see here: the A-group is more square, while the C- and D-groups are distinctly rectangular. I suggest that having both the preceding and following picks in the same shed is less structurally stable, which allows the knots to be squished together more and allows squarer knots to emerge. When the picks are in different and opposite sheds, I guess that the opposing forces create a "locking" effect on the warp and prevent the warp from condensing, in turn stopping the knot from shrinking horizontally and becoming square.

This trait is a particularly good example of why the size and shape data are treated separately. The size data for this characteristic are difficult to interpret, and the groups do not seem to follow the logical pattern of relatedness that we would expect, and that we see here (i.e., group A/D being representative of groups A + D). Shape, it would seem, is a better way to understand this structural trait's effect on the knots.

Knotting Shed Position

Another good example of how the shape data are a better description of knot change in relation to a certain characteristic is the **Knotting Shed Position** data. The three observations in this variable (open, partial, closed) are truly ordinal: they sit in a meaningful order, and represent

a conceptual scale where things would be expected to progress incrementally from one extreme to the other. The size data do not follow this pattern: the ends of the scale are more similar to each other than they are to the middle of the scale. The shape data, on the other hand, do follow the progressive change pattern that would be expected. Knots woven on an open shed are distinctly square, knots woven on a closed shed are distinctly rectangular, and knots woven on a partially-open shed represent both square and rectangular knots in the full range of observations. This visual pattern is backed up by Levene's test ($p = <0.001$).

When the sheds are fully closed, the warps sit side-by-side on a single plane. The space between them is dictated by the target carpet quality, the yarn gauge, and other factors, but it is at its minimum when the shed is closed. Even double-warped carpets, which have alternate warps sitting slightly behind their neighbors, are most tightly packed when the shed is closed. An open shed provides more separation of warps in the z-axis but physically pulling half the warps forward/pushing half back. This increased separation creates the shed, and allows the weaver to pass the yarn, her hands, and any necessary tools between the warps to create a pick of weft. There is no structural-technological reason why the shed needs to be either open or closed to tie carpet knots, and so it seems to be mostly a personal idiosyncrasy whether the weavers choose to open/close it.

The distinct and progressive pattern shown here is tricky to explain intuitively, but I have a theory. From my own weaving experience, I know that moving the knots and/or pick around when the shed is closed is more difficult. Increased friction with the warps and other components make it more difficult to shift, beat, or otherwise alter a knot/pick on a closed shed. The increased

space and reduced friction provided by an open shed allows for more flexibility in placing and repositioning knots and wefts. Since the default shape for a knot is rectangular, it makes sense to me that knots woven on a closed shed would trend towards rectangular: the low maneuverability on the tight warp limits the options and finesse needed to square-up the knot. Similarly, if the knots are very densely packed, rectangular knots can sometimes overlap each other slightly or stack, rather than sitting wholly side-by-side like they are supposed to. The limited space makes it difficult to wedge the knot fully down between its neighbors. This would, I suggest, increase the rate of rectangular knots because they lack the lateral pressure to condense into a square. When the shed is open, there is a bit more opportunity to reposition, re-tighten, or re-pack the knots into a different shape. There is also more room to force a knot down into its correct position, ensuring that it receives the lateral pressure from its neighbors that force it into square (Fig. 8.9). This same logic may also explain why the double-warped knots discussed earlier (**Knot-Warp Pattern**, types II and III) do not seem to be squarer than single-warped knots (type I), despite the popular belief that double-warping squares-up knots. It could be that while the dense double-warping has the potential to produce very square knots due to the high horizontal compression, it is more difficult to actually wedge the knots into their intended positions on a denser warp. The knots may end up stacking or tilting as rectangles, rather than fully sitting in their designated square position.

Knotting Order

The idea of square shapes resulting from having to wedge a knot between its already in-situ neighbors could apply to the **Knotting Order** too. When knots are added in consecutive order (Directional [D]), their two sides are affected differently. One side already has the neighboring knot in place. The new knot has to fit against that existing knot, likely affecting the shape at that end of the knot. The other side of the knot is set against an unwoven warp, where there is no knot yet. This empty space could allow the knot to extend into its neighbor's zone. Where the knot can bleed over into the neighboring space, it would become more rectangular as it stretches sideways. That is the pattern shown in the PCA plots: knots added in a consecutive order across the width of the carpet are distinctly rectangular.

The other two groups, color-based and a pattern-based knotting orders, are much less distinctly shaped. They represent the full range of square/rectangular knots, and are centered near the middle of the point cloud. I believe that this is because when a color- or pattern-matching order is followed, knots are added with all possible combinations of pressure from neighbors. Some knots would be added with empty space on both sides, some with empty space on one side but not the other, and some with knots already in place on both sides. As I suggested already, having to wedge knots into a space already bounded at left and right by knots might tend to make that filler knot more square, as it is compressed to fit in the available space. Since both color- and pattern-based knotting orders would have knots added with both neighbors in place, it makes sense that they could be more square. But as they also have knots added without

neighbors in place, they can also be more rectangular. Overall, this creates a wide distribution encompassing all shapes.

There is a visible bulge just left of center in the PCA plot for the pattern-knotting order. This is most likely not a result of the knotting order, but more likely an artifact of a compounding characteristic. Although no other variables exactly duplicate the **Knotting Order**, some do account for a significant portion of the pattern data. The weaver Bashorat/Kathleen produced more than 63,000 measured knots, representing about half of the pattern-order group. As her knots have a distinct circular distribution just left of center in the PCA plots, her high contribution to this group is creating the bubbling effect. It may be that with better diversification of weavers, the group would fill out to look more like the color-order group.

Number of Weavers

The **Number of Weavers** variable was not included in this study because I expected a change in individual behavior or outcomes when multiple weavers work together, but rather because I was interested in whether any of these methods are capable of noticing when multiple distinct signatures appear in a single item. Unfortunately, I was able to document only one carpet that was woven as a joint-effort. For that reason, the results given by the PCA plots and Levene's test ($p < 0.001$) are not especially meaningful, as they represent these two specific weavers more than any overall trend in multi-weaver work.

In order to tease out if there is any way to see that two people worked on carpet UZ-KH-11, I performed a new principal components analysis. This includes the eight variables included

in the existing PCA (x- and y-coordinates for each of the four knot corners). It also includes the original, unstandardized knot-size data. I use the original sizes here because this is a single-carpet comparison, so there is no need to scale them using the min-max method. This PCA is performed only on the data from carpet UZ-KH-11. Although I have data from both weavers in other carpets, those are not included here. This ensures that there are no confounding factors present, and provides the best chance of distinguishing the weavers. The results of principal components 1 and 2 are plotted, representing 74% of the total data variation (Fig. 8.10). There is not a clear distinction between the two weavers' contributions even when this carpet is analyzed alone. The two distributions are slightly different in the visual plot, with Maloxat's sitting slightly higher and more rectangular (rightward) than Nazokat's. A 3D plot was also produced to include the third principal component: this made no difference and did not provide any additional separation of the data.

Realistically, if I did not already know that there were two weavers here, and did not already know whose knots were whose, I would not be able to tell that these are two different distributions, or that this carpet was woven by more than one person. While it is disappointing that these two weavers are not easily distinguishable, it is interesting that two people can produce such consistent and standardized work in a medium that is often brushed off as unskilled and poorly standardized! It may be that two weavers with more dissimilarities would be more distinguishable: the added pressure and expectation of standard output in Maloxat and Nazokat's professional silk workshop may mean that their work is unusually consistent.

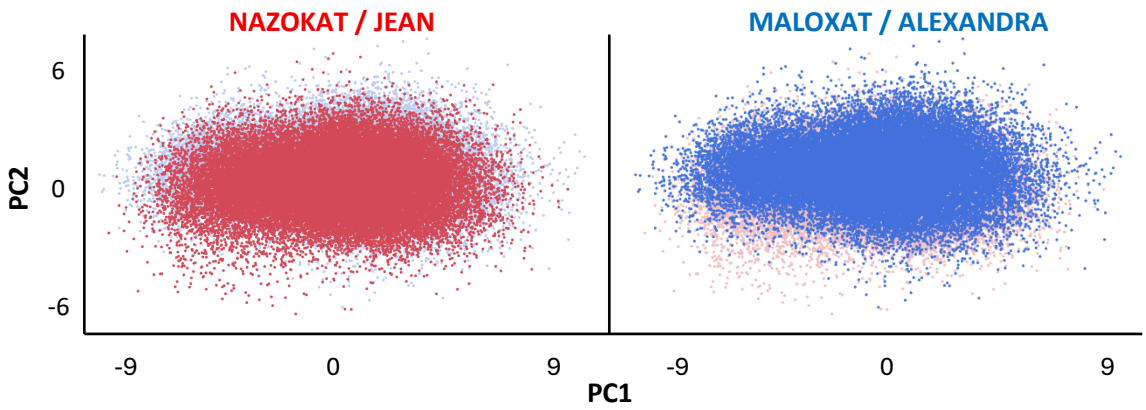

Figure 8.10: Knot Shape & Size – Nazokat & Maloxat

A direct comparison of the knots woven weavers Nazokat/Jean and Maloxat/Alexandra in joint carpet UZ-KH-11. The PCA includes the x- and y-coordinates of the knot corners, as well as the original knot area data (unstandardized). Figure by author.

Oversight

The amount of **Oversight** the weavers receive produces a distinct set of distributions, and one that fits conceptually with my expectations. The weavers who have regular, consistent oversight and quality-control checks (PR) have distinctly square knots. While I do not think that oversight itself causes square knots, I do think it makes sense that weavers working in a more controlled environment might have additional economic and social pressures that result in higher-quality work. As square knots are generally considered the more skilled and high-quality outcome in knotted carpets, this distribution makes sense. Weavers with no oversight at all tend to make distinctly rectangular knots, suggesting reduced external pressure on their work and less impetus for ensuring square knots. Those weavers who receive some oversight, but not continuous or regular checks (PS), fall somewhere in between the two extremes, representing

both square and rectangular knots and covering the entre range of observations. I would suggest that this distribution should be considered a conglomeration of several social-economic factors.

Community & Production Setting

Like with the size data, the **Community** shape data create distinct patterns. These represent weavers working with similar techniques, tools, materials, and social-cultural factors, wherein weavers in the same community are more similar to each other than to those outside their community. This data breakdown could be considered a visual render of the community-of-practice theory. The six community groups included in this study have six different patterns, with some overlapping more than others. It is interesting to see that when plotted like this, the more professional groups (Khiva Silk, Samarkand Silk) are clearly the squarest, reinforcing the idea that higher-quality and tightly-controlled standardized work tends to be squarer. This idea is strengthened by the **Production Setting** plots, which describe the scale of labor control. Here again, the professional workshops produce the most square knots, followed by semi-professional collectives, and finally domestic weavers producing distinctly rectangular knots. Both of these variables are supported by a significant Levene's test ($p < 0.001$).

When comparing these two variables, note that the professional 'workshop' group, while it trends distinctly square, also has a not insubstantial rectangular segment. This is because the 'workshop' group contains the distinctly square Khiva Silk and Samarkand Silk communities, but also the professional art studio Altyn Orda. Despite their professional status, the artisans at Altyn Orda (Shymkent, Kazakhstan) do not make knotted carpets often. Their textile products are

primarily felted, not woven. It is interesting to see how despite their tightly-controlled setting and high consumer pressure, their knots still trend rectangular. This suggests that while professional status and intensive work do encourage the production of square knots, other radiating factors such as experience, attention, priority, or design complexity may actually be the bigger driving factor in these distributions.

Country, City, & Village

The geographic locations and national-regional identities of the weavers are represented in the **Country**, **City**, and **Village** variables. These, like some of the other variables discussed, are not expected to have a direct impact on the knot shapes. Instead, I would interpret any visible patterns as a result of some unifying characteristic shared by weavers in that location, and not a result of the location itself. These variables, as well as the **Community** and **Weaver**, were included specifically to catch explanatory information that isn't captured in the named technological and social variables described already. All three locational variables have significant Levene's test results, indicating that they are all statistically meaningful ways to divide the data.

Weavers working in Kazakhstan are the most rectangular of the group. This is not surprising, as Kazakhstan includes the only truly domestic/hobbyist weaver surveyed. It is also somewhat expected because Kazakhstan has by far the least robust knotted carpet industry of the three countries studied. The south-Kazakhstan cities included (Shauldir, Shymkent) sit at the northern edge of the Central Asian Southern Desert, against the Northern Desert and the wider north Eurasian steppe. This area gets progressively colder, and historical textile traditions of the

steppe nomads tend to favor the denser, cheaper, faster, and less resource-intense felt over wovens like carpets. This is part of the reason that the Pazyryk carpet is generally assumed to not be local to the Altai (eastern Kazakhstan, at elevation), and instead is usually attributed to the edge of the Achaemenid empire in southern Kazakhstan or lowland Kyrgyzstan. The reduced variation in knot shape and the more rectangular knots documented here support this historical-cultural preference for felt through most of Kazakhstan.

Of the three countries studied, Turkmenistan has the widest ranging and most modern intensive carpet industry. That intensity seems like it should lead to the squarest knots, but it doesn't. Although Turkmen weavers make up a larger economic sector than in Uzbekistan or Kazakhstan, they are also tightly regimented. The techniques and tools used there are less diverse, despite the large number of weavers. This is due to government oversight, centralized workshops and training schemes, and consumer preference for certain styles and outcomes. Most modern Turkmen weavers, including all five in this study, are following Teke weaving traditions. It therefore may be that despite the high skill and intense production of Turkmen weavers, their standardized techniques and systems generally preclude the type of intentional variation and concerted effort necessary for creating square knots.

The Uzbek weavers in this study range from ad-hoc cottage industrialists to full-time professional weavers of luxury goods, and are therefore the most diverse nationality represented. Their work includes more techniques, variations, tool types, materials, and weaver demographics than the other countries, as well as a wider range of social and economic pressures. The shape data support this, with the largest distribution of knot shapes.

When subdivided into **CITIES**, the geographic shape data refine even further. The Kazakh weavers (Shauldir, Shymkent) show a stronger drive towards rectangular knots in Shauldir, a small town in a rural area where the weavers are not professionally employed at any scale. The professional weavers in Shymkent show a wider and more consistent range of knot shapes, although their steppe nomad cultural history still disincentivizes the production of more laborious square knots.

The Uzbek data (Khiva, Samarkand) follow the established pattern of more professional groups having more square knots, while less professional or mixed-intensity groups have a wider range of shapes. The Samarkand group are exclusively luxury silk workshop weavers, while the Khivan include both silk workshop weavers and home collective weavers.

Weaver (Pseudonym)

Perhaps the most interesting way to divide both the shape and size data are by **Weaver / Pseudonym**. Each weaver's plot represents her specific combination of technology, tools, materials, social-cultural and economic pressures, and personal idiosyncrasies. These plots could be conceptualized as a "signature" for each weaver's work, and they are certainly distinct! Of all the variables discussed, dividing the data by weaver produces by far the most nuanced division of data. While most variables produce very square, very rectangular, and a generalized "everything" distribution, the **Weaver** divisions create more incremental and small-scale patterns.

It is interesting that even within these data, it is still possible to pick out the weavers who are part of the same communities of practice. The five Turkmen weavers are the best example (Anonymous A-E), with each producing a slightly rectangular-leaning knots in a relatively wide range of shapes. A few other weavers have interesting patterns too, including Bashorat (Kathleen) and Durdiposhsha (Ginny), who both have very tightly packed data indicating a lower overall rate of variation in their knots.

Many of the weavers also contributed more than one carpet: I was curious if their work remained relatively consistent between pieces, or if each carpet would have a distinct pattern. To test this, I re-plotted the PCAs of Sholpan (Kate) (Fig. 8.11) and Anonymous A (Anna) (Fig. 8.12), both of whom contributed three carpets to the project. The plots are color-coded by carpet, allowing me to see how the knot shapes change between projects. Sholpan's show an interesting pattern: two carpets (KZ-OT-1, 2) are very similar, and the third carpet (KZ-OT-3) is less so. All three carpets were made of the same materials, they are all the same general size and style of design, they were all made in Sholpan's home on the same loom with the same tools. They all have the same structural characteristics, and were all woven in the same timeframe. The only obvious difference between them is that carpet KZ-OT-1 and KZ-OT-2 were commissioned and ultimately sold to me for this project, while KZ-OT-3 was another carpet Sholpan had woven for personal use. It may be that Sholpan put a different standard of attention or care into my carpets than hers, or that she sourced slightly different yarns for a sale carpet vs. a personal one. It is interesting that the sale carpet knots are more rectangular while the personal carpet knots are more square: this is the opposite of the pattern seen elsewhere, where consumer pressure

seems to encourage square knots. I cannot say the exact reason for this, but several possible explanations present themselves. Perhaps Sholpan did not expect that I would look that closely, or that I would be able to tell any difference in the carpets. Maybe she was experimenting with a new system in her personal carpet and was not wiling to risk using sale carpets as guinea pigs. Or perhaps this is an artifact of the designs, wherein the personal carpet's design slightly shifted her weaving process due to the level of complexity or social-cultural value. I cannot know for sure, and I would not be surprised to learn that Sholpan also doesn't realize that she did anything different.

Turkmen weaver Anonymous A (Anna) shows less division between her different carpets. All three (TK-MA-2, 5, 6) show similar distributions and are centered on the same general point. This plus Sholpan's two sale carpets suggest that weavers are generally pretty consistent within their own work. However, the notable difference of Sholpan's KZ-OT-3 implies that even a well-practiced artisan with firmly-established techniques and gestures can produce distinct outcomes in the right situations.

Summary

The size and shape analyses show a mixed result of statistically-distinct, patterned data, and data that seem to be random. This is not surprising in itself, as I did not expect every production characteristic to have an effect on the knot sizes or shapes. However, the results do speak to a few notable themes: 1) the importance of specificity and diversity in description and analysis, 2) the ability to measure lived experience from physical material remains, 3) the

pervasive understanding of carpets through a lens of lore, and 4) the strength of community and technological tradition in modern carpet manufacture.

The results of the size and shape analysis provide salient examples of why discrete, detailed, and specific description of carpet technology is critical for work like this. The new typology system described in Chapter 6 may seem over-complicated at first glance, but that specificity creates interesting results. For instance, my system separates tension rods used at the top of the loom from those used at the bottom. These could more succinctly have been treated together. However, the analysis shows that the position of the rod, and not just its presence, has an effect on knot-size. While of course I did my best to be as specific and detailed as possible in my classificatory system, this result highlights both the importance of that step, and the value in continuing to refine descriptions and divisions into narrower sets. Similarly, using non-binary halfway points in several trait categories (such as the **Knotting Order** and **Oversight**) also seems to reinforce progressive ordinal patterns, strengthening conclusions and explanations about those characteristics.

These refined classification systems are clearly useful in teasing out small-scale differences and influences, but they also open the door for correlative problems. Several of the analyses are confused by non-separating data, where several characteristics all divide the data in the same way. These cases make it difficult to explain which (if any) of the traits are contributing to the visible pattern. The knot-sizes in the **Knot-Weft Pattern** where pattern C is wholly duplicated to weaver Kulyash//Teri, and the knot-shapes in the **Knotting Order** where the motif-driven order is more than half the work of weaver Bashorat/Kathleen. In both these cases, it is impossible to say

whether the distinct patterns shown in the technological data are actually the result of the techniques, or are better described as personal idiosyncrasies of the named weavers.

The value of treating the size and shape data separately is also evidenced in this analysis. The **Knot-Weft Pattern** is a good example of this: despite being a grouped/symmetric classification system, the knot-sizes do not follow a grouped/symmetric pattern. This suggests that the knot-sizes may not be especially meaningful here. The knot-shape data, on the other hand, do follow a grouped/symmetric pattern, where the conceptually and structurally paired patterns seem to create correlated changes in knot-shape. If the size and shape had been studied in a single analysis, it is possible that this useful result might have been clouded or even invisible, or that the trait might be mistakenly linked to changes in size when it seems to have more impact on shape. These several examples of specificity, diversity, and separation in the data reinforce the logic and statistical value of the analyses used.

These analyses provide several intriguing examples of how the ephemeral lived experience of carpet-weaving can leave a trace on and be measured empirically from the physical textile. To the best of my knowledge, my own work was the first to suggest that this might be possible (V. Sluka 2017, 2018), and this dissertation is the first to show it in a controlled setting. The **Knotting Order** (size & shape), **Cartoon Use** (size), **Oversight** (shape), **Weaver/Pseudonym** (size & shape), and geographic variables (size & shape) are all examples of information that would normally be completely unknowable and lost in the archaeological and historic record being recorded in the material culture. The **Knotting Order**, with apparent effects on both knot-size and knot-shape, is the best example. With no technological impetus, no visible (to the naked eye)

effect on structure or aesthetics, no universal impact on efficiency or material usage, the order in which the weaver chooses to tie the differently colored knots is purely personal, and entirely ephemeral. And yet, these data suggest that the order chosen by the weaver leaves a measurable and consistent trace in both the knot-size and knot-shape of her work.

These lived experiences go beyond multi-person patterns like the **Knotting Order** and **Cartoon Use**, but also suggest new insight into more individual traits. The weaver Durdiposhsha/Ginny's work shows a distinct change in knot-size after weaving approximately two-thirds of the carpet. I suggest that this is the point at which she wound the warp, bringing the weaving zone back into a comfortable range. As her loom was too large to work a carpet without winding the warp but small enough that a significant portion of the carpet *could* be woven without winding, her work is an excellent opportunity to look at individual biomechanics in weaving. Her work, as well as a similar pattern displayed by Mehribon/Monica, both document the physical limits of the weaver's personal size, mobility, and comfort, in direct relationship to the form of her loom. Although this specific project could not take this further, a similar study might be able to identify children in the woven record through their distinctly reduced arm spans.

Mehribon/Monica's changing knot-sizes, which align well with the chunky border style her designs use, also suggest a differential technical comfort driven entirely by the non-structural design. Although several other characteristics suggest that comfort with or memorization of the pattern might affect knots on the whole-carpet scale, Mehribon's work is a unique insight into variation at the smaller scale, showing differential ability in specific motifs/sections. Improved resolution at this smaller scale might be a new way to evaluate changing styles and personal

creativity, by measuring knot variation between different sections and designs within a single carpet. Although the designs and aesthetics were not of direct interest in this dissertation, there does seem to be some significant overlap between the fashions and motifs of carpet-weaving, and the weaving itself.

Carpet designs have been used as the primary classificatory structure among scholars, artists, and merchants over the last century, and have contributed to the wider carpet lore ubiquitous today. This lore, repeated in both artistic, scholary, and popular works and by weavers themselves, include ideas such that double-warping results in higher-quality work, or that asymmetric knots are more square and therefore have higher design fidelity. This latter piece of technical lore even contributes to the trend of referring to Renaissance Cairene weavers as "masters", for their unusually square asymmetric knots. But just as the knot-size and knot-shape analyses seem capable of commenting on design attributes, they also seem to comment on these other aspects of carpet lore. The **Knot-Warp Pattern** knot-size results suggest that double-warping, or off-setting alternate warps slightly behind the weaving plane, does not reliably improve consistency in knot-size, nor does it create consistently squarer knots. As both of these features are common measures of quality, the lack of empirical evidence is intriguing. Despite a widespread belief between both researchers, buyers, and makers, this lore does not appear to have a factual grounding. This reminds me of the mythological and non-explanatory explanations sometimes recorded in ethnographic study of technologies, where beliefs are repeated until they are accepted as fact regardless of physical evidence. Or alternatively, this mismatch between the measured data and the lore might suggest a more recent change in carpet-weaving practices:

perhaps double-warping *used* to be a reliable marker of quality which has since been superseded or counteracted by other factors.

While the beliefs about double-warping are not supported by this project's results, the common lore that asymmetric knots are higher quality does seem to be supported. I showed that asymmetric knots have a lower range of variation than symmetric ones, resulting in a more even and consistent weave. It is interesting that this piece of lore seems to be accurate, but not for the reason usually given: the higher-quality of asymmetric knots is usually explained by them being squarer. Based on these results, they are not squarer – they are just more consistent in size. This again reinforces the value of analyzing the knot-size and knot-shape data separately.

Finally, separate from an ability to explain changes in knot size/shape based on production characteristics, these results are promising examples of how this technique can be used to organize and differentiate technological traditions, communities-of-practice, and even individual weavers. In both the knot-size and knot-shape analyses, the **Weaver** and **Community** results show strong signatures between groups/people, and statistically-significant divisions in their work. This supports the foundational theory of this dissertation, that weavers or groups of weavers have distinct patterns of work that could be used to differentiate them in the archaeological record. Even if we cannot exactly explain what facets of their technology, setting, or culture are causing these differences, the strong clustering of different communities is a promising result.

Despite this strong support for a community-of-practice approach, these analyses also produced some notable contradictions to general guidelines used in studies of communities, technological evolution, standardization, and specialization. Generally, reduced levels of variation

are used to indicate higher levels of standardization and therefore, usually, specialization. That pattern is not strictly followed here. There are a few examples of more-specialized and more tightly-regimented work being less standardized. For example, the very regimented and low-diversity Turkmen weavers producing less consistently-shaped knots that the more ad-hoc and unsupervised Khivan collective. I can't say for sure why this is the case, but it may be a fundamental limitation of the techniques used by the Turkmen weavers. This is an example of why it is so important to evaluate standardization & specialization separately for different technologies and contexts.

In a similar vein, the idea of a "techno-gesture", or a movement learned by muscle-memory and difficult to change, is usually believed to be an extremely conservative aspect of technological practice, requiring concerted long-term effort to change. While certainly the weavers represented here seemed to have generally high internal consistency in their knot-tying gestures, this was not a universal result. The Kazakh weaver Sholpan/Kate produced knots with two distinct forms in her three carpets, with the two carpets sold to me having one form, and the carpet she kept for herself having another. This suggests that there is some ability of the weaver to change their techno-gesture, whether intentionally or unintentionally. Knot-tying might therefore not be a good example of a techno-gesture in carpet-weaving, despite what I would have guessed.

Figures: Chapter 8

	PC 1	PC 2	PC 3	PC 4	PC 5
Top Left X	-0.34763	0.39564	0.47554	-0.15396	0.36117
Top Right X	0.34805	0.39136	-0.47477	0.16148	-0.35533
Bottom Left X	-0.34804	-0.3942	-0.4729	0.15326	0.35681
Bottom Right X	0.34798	-0.39127	0.47483	-0.16167	-0.363
Top Left Y	-0.35893	-0.31366	0.15715	0.47168	-0.34342
Top Right Y	-0.35888	0.31403	-0.15783	-0.47046	-0.35202
Bottom Left Y	0.35934	-0.3034	-0.15699	-0.47736	0.35268
Bottom Right Y	0.35923	0.30459	0.15844	0.47845	0.34349

	Eigenvalue	Percent	Cumulative %
PC 1	6.652313	83.154	83.154
PC 2	0.622444	7.781	90.934
PC 3	0.369982	4.625	95.559
PC 4	0.29372	3.672	99.231
PC 5	0.061541	0.769	100
PC 6	6.652313	83.154	83.154
PC 7	0.622444	7.781	90.934

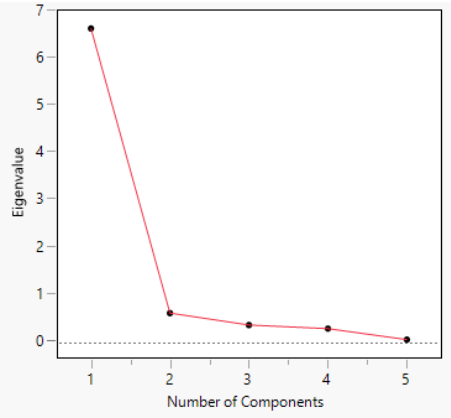

Figure 8.6: PCA – Knot Shapes

Results of PCA on the eight values that make up the knot shapes, plus the knots' X-Y position in the carpet. Figures by author.

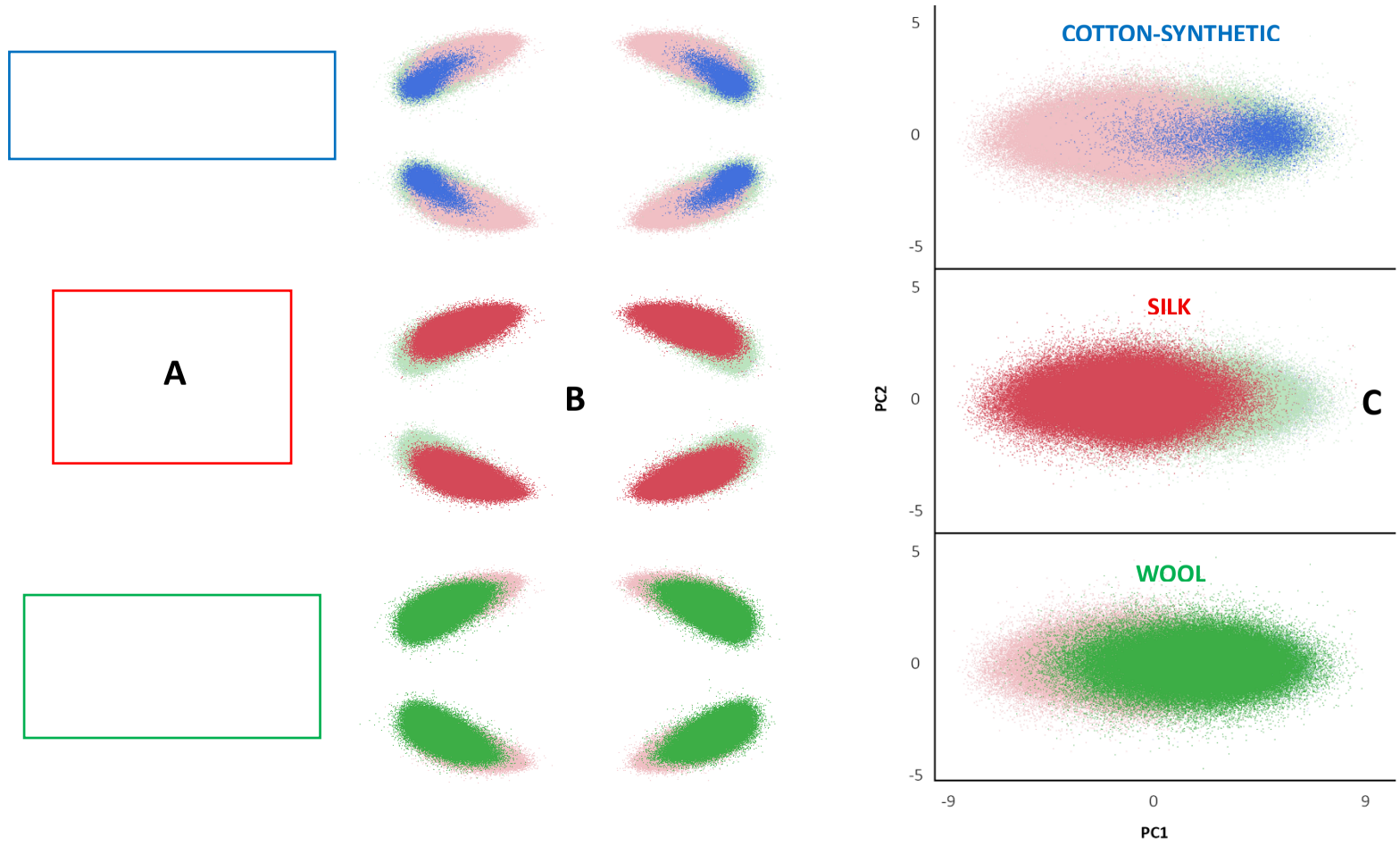

Figure 8.7: Original Shape → GPA Reprojection → PCA Condensation

A comparison of the original shape of the knots in the carpet (A) to how they are reprojected by the GPA (B), and how the PCA reduces dimensionality (C). A knot that falls at the left side of the PCA cloud is more square than a knot that falls at the right side. Weft Material data shown. Figure by author.

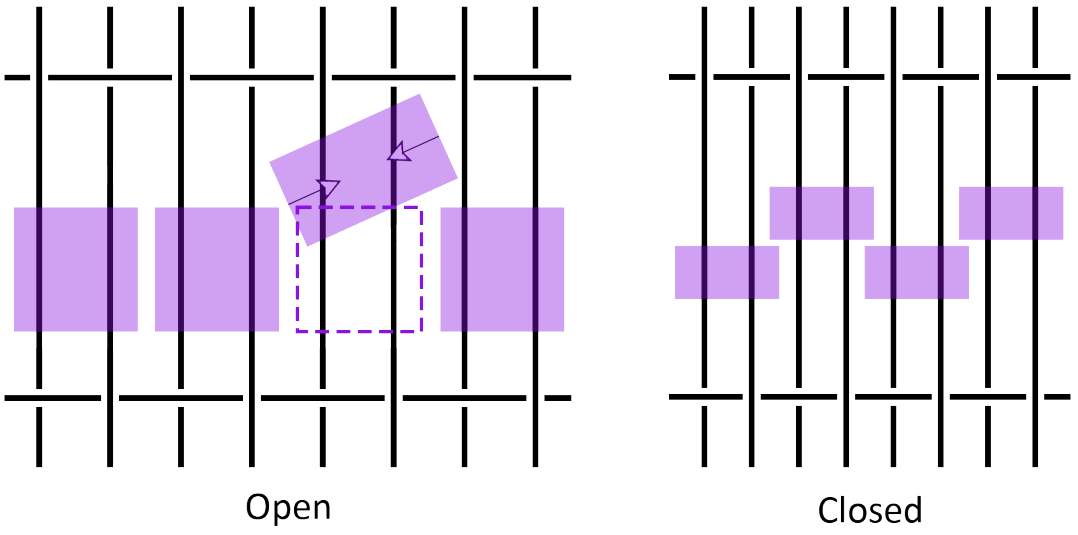

Figure 8.9: Condensing to Square Knots in Open Sheds

When the warps are spaced wider in an open shed (left), there is more space to maneuver and squish a rectangular knot between its neighbors, creating squares. When the warps are spaced narrower in a closed shed (right), there is not enough space to maneuver, and rectangular knots end up stacking rather than compressing to sit side-by-side. Figure by author.

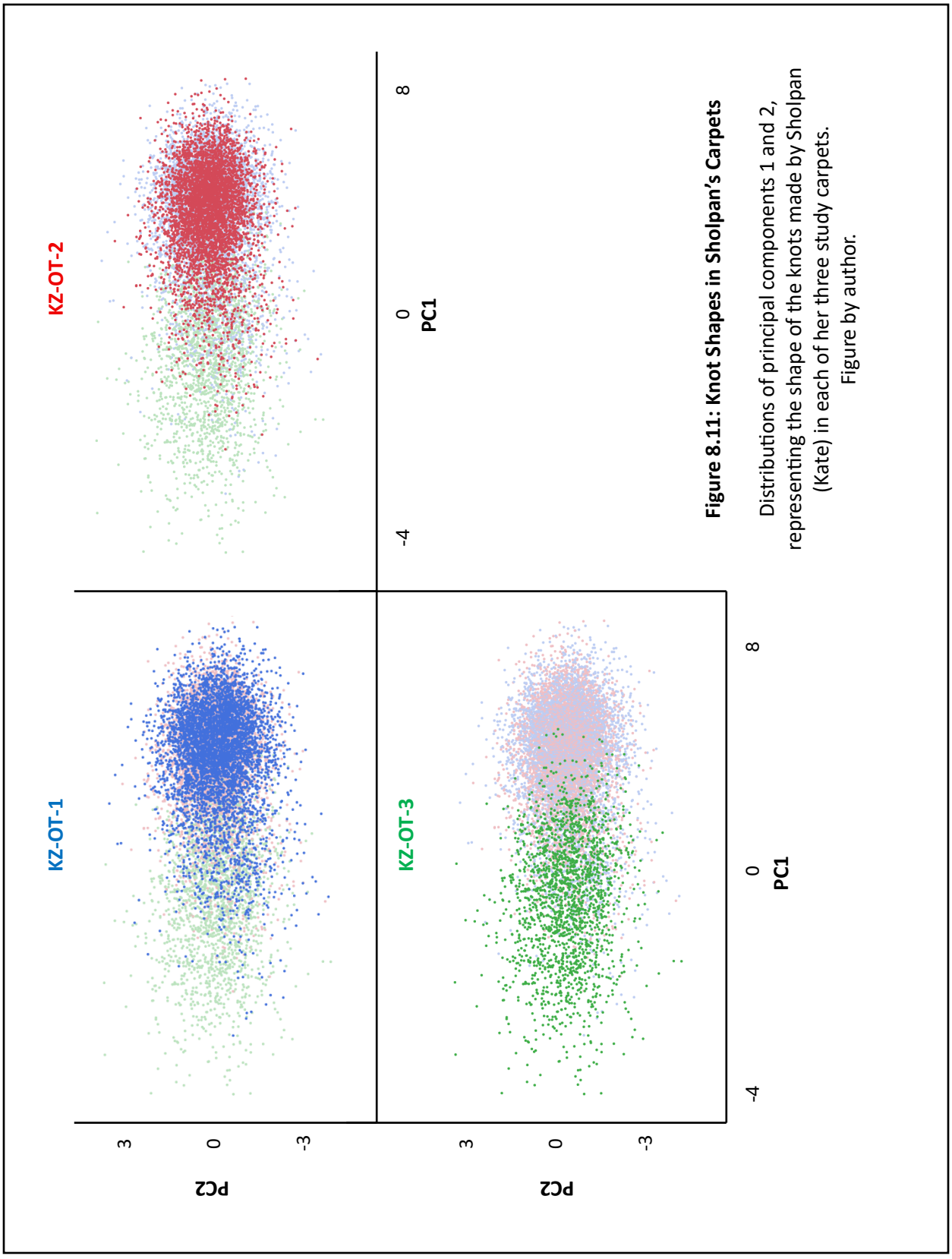

Figure 8.11: Knot Shapes in Sholpan's Carpets

Distributions of principal components 1 and 2, representing the shape of the knots made by Sholpan (Kate) in each of her three study carpets.
Figure by author.

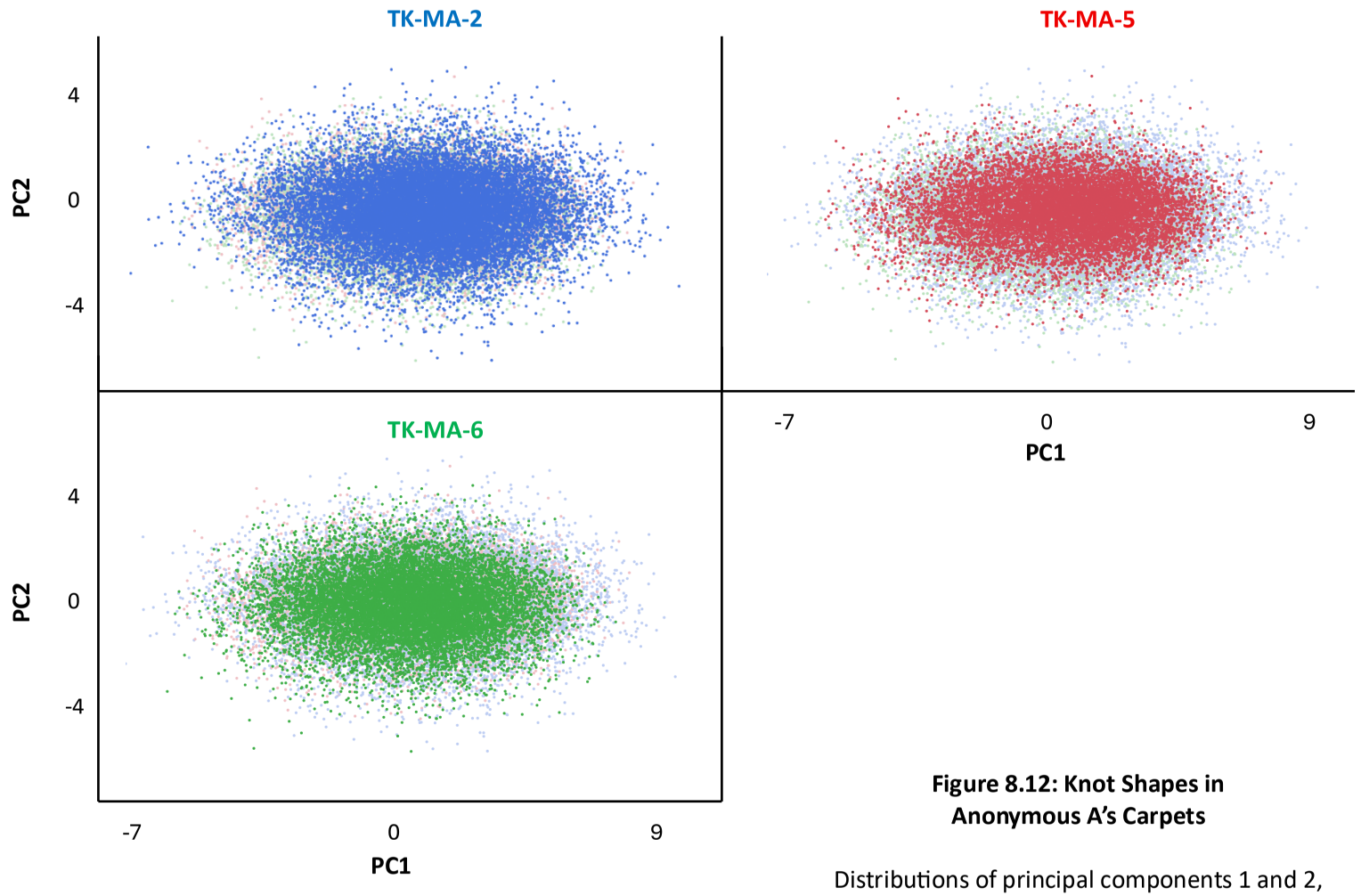

Figure 8.12: Knot Shapes in Anonymous A's Carpets

Distributions of principal components 1 and 2, representing the shape of the knots made by Anonymous A (Anna) in each of her three study carpets. Figure by author.

Tables: Chapter 8

Carpet	Mean	SD	Minimum	Maximum	CV (%)
KZ-OT-1	0.108	0.019	0.05	0.203	17.445
KZ-OT-2	0.122	0.02	0.052	0.221	16.047
KZ-OT-3	0.086	0.015	0.04	0.168	17.809
KZ-SH-1	0.057	0.014	0.015	0.119	24.229
KZ-SH-2	0.038	0.008	0.017	0.07	20.623
TK-MA-1	0.035	0.009	0.01	0.103	25.363
TK-MA-2	0.032	0.008	0.007	0.071	24.186
TK-MA-3	0.034	0.008	0.012	0.079	23.852
TK-MA-4	0.037	0.008	0.014	0.088	21.577
TK-MA-5	0.036	0.009	0.013	0.073	26.123
TK-MA-6	0.036	0.008	0.013	0.081	23.148
TK-MA-7	0.036	0.01	0.011	0.102	27.221
TK-MA-8	0.034	0.008	0.012	0.075	25.122
TK-MA-9	0.038	0.008	0.011	0.077	22.172
UZ-KH-1	0.129	0.023	0.051	0.222	18.151
UZ-KH-2	0.123	0.023	0.057	0.291	18.585
UZ-KH-3	0.132	0.027	0.043	0.262	20.443
UZ-KH-4	0.122	0.026	0.036	0.234	21.048
UZ-KH-5	0.111	0.03	0.041	0.244	26.692
UZ-KH-6	0.11	0.02	0.044	0.212	18.323
UZ-KH-7	0.112	0.022	0.046	0.229	19.922
UZ-KH-8	0.11	0.022	0.041	0.223	19.998
UZ-KH-9	0.03	0.006	0.012	0.064	20.287
UZ-KH-10	0.035	0.008	0.011	0.081	22.69
UZ-KH-11	0.019	0.004	0.007	0.04	19.975
UZ-KH-12	0.025	0.005	0.011	0.048	20.402
UZ-KH-13	0.033	0.006	0.012	0.073	18.59
UZ-SK-1	0.034	0.007	0.016	0.071	20.129
UZ-SK-2	0.017	0.004	0.006	0.041	23.356
UZ-SK-3	0.033	0.006	0.013	0.068	17.561

Table 8.1: Summary Statistics for Ethnographic Carpet Knot Size
Values in unstandardized cm^2. Table by author.

9. Estimating Traits in Historic Carpets

The first immediate goal of this dissertation was to determine if any of the documented production characteristics create consistent, patterned division in knot size and/or shape. These patterns, where they exist, were identified and described in the previous chapter. While not every characteristic seems to produce a pattern, many others do, with conceptually logical explanations. This is a promising outcome, which I suspect could become even more nuanced and useful with dedicated testing of the individual characteristics.

The second immediate goal of the dissertation was to evaluate the applicability of the modern knot size and shape trends in estimating production characteristics of historic carpets. If the guidelines provided by the ethnographic data can be shown to give accurate insight into historic weaving, that would allow for several radiating outcomes. First, it could highlight where carpets that are already attributed to a specific group are similar or different. Similarities could be used to strengthen the attribution through shared community techniques and consistency of small-scale gestures, while dissimilarity could suggest an inaccuracy or oversimplification in the attribution. Where carpets do not currently have a well-accepted attribution, matching detailed evidence in their structure to attributed carpets could increase the number and quality of attributions available. This might come in the form of showing that some carpets are linked, or in showing that they are particularly dissimilar. A better network of attributions and more detail

about production technologies and settings could then provide effective grounding for more nuanced studies of carpet evolution, to understand how techniques likely travelled and were innovated in the Bronze and Iron Ages. Finally, a better resolution in describing carpet technologies and settings provides new insight into tools, social structures, trade relationships, migration patterns, and resource acquisition among ancient and historic weavers and their wider communities.

For each of the 52 historic carpets and fragments, a comparison was made between the carpet's knot measurements and the patterns identified in the previous chapter in the knot size and shape data. The historic data are transformed and standardized the same way as the ethnographic data: knot sizes are normalized within each carpet using the min/max method, setting all ranges between 0 and 1 and all means as 0.5. The historic shape data were spatially standardized along with the modern data using the generalized Procrustes analysis, and were then compressed into two principal components using the same eigenvectors as were used on the ethnographic data. These eigenvectors were generated only to best-fit the ethnographic data: the historic data were not included in the original principal components calculation. The eigenvectors applied to the historic data should be considered a standardization or scaling factor to reposition the historic data in the same area as the ethnographic data, and not as a separate PCA.

These transformed historic data were plotted over the modern data to compare distributions in the size and shape. An estimate was given for which trait the historic carpet's data matched best. Because a true regression analysis was not possible with this poorly-

diversified sample, the historic estimations were based on a simple pattern-match of distributions. As this is inherently subjective, I also gave a second estimate representing the second-best distribution fit. This helps to minimize personal bias and provides some insight into how accurate or inaccurate a particular distribution is in estimating production traits. However, it is important to remember that some of the traits are binary (for instance, either a **HOOK** is used or it's not). This means that by providing two estimates, the 'correct' answer will always be captured. A correct estimate occurring in the secondary position in a binary trait should therefore be considered non-meaningful.

Because the knot-size data were analyzed on two axes (along the length and width of the carpet), the size-based estimates given represent the best fit available from either axis. Some historic carpets and some traits draw their best-fits from the same axis, while others are drawn from both axes.

There are 34 production characteristics estimated up to four times each: a best- and second-best fit based on knot size, and a best- and second-best fit based on knot shape. This means that there are up to 136 estimates per historic carpet. With 52 historic carpets and fragment groups, there are more than 7,000 individual estimations possible. Each estimate is based on a carpet vs. trait distribution plot, of which there are 5,304 (for each carpet, for each production characteristic [1,768]: a shape plot, an x-axis size plot, and a y-axis size plot [x3]). These high numbers mean that it is not realistic to discuss each estimate individually, or to include every comparative plot. A subset of representative samples is discussed instead. Although not all discussed individually in the text, all the estimates are included in Appendix E.

Some of the production characteristics are visible, meaning they can be studied, described, and classified by observing only the carpet. They do not require access to the weaver, observation of the weaving process, knowledge of tools or geographic location, etc. These are the traits that are normally accessible in archaeological settings. Because I have recorded these traits for the historic carpets, I was able to directly check the historic estimates for accuracy. By evaluating these relationships first, I gauged how successful this method of ancient trait estimation is.

Visible Variables

Ten of the thirty-four variables included in the detailed analysis are visible variables. In general, these variables were measurable in all carpets. However, degradation and damage to carpets, particularly along the edges where considerable diagnostic information is stored, caused some normally visible variables to become invisible in certain carpets/fragments. When this occurs, the accuracy of estimates could not be checked. Similarly, some characteristics that would normally be visible were not accessible here due to restrictions of use and access. For instance, the pieces in this study that were on consignment to Christie's and Sotheby's are all whole carpets (MU-CH-1:7, MU-SO-1:4). While they were somewhat threadbare, it was not always clear just from inspection what type of knots were used (particularly in denser pieces). Evaluating the knot shape would have required either a section of damage where the knots could be viewed in cross-section, or permission to remove a few knots to see how they were tied. As the auction houses could not approve this type of damage to items on consignment and the

carpets were complete and without access to a cross-section, some traits could not be documented. Some normally-visible characteristics are also missing from the de Young Museum carpets (MU-DY), because these pieces were included via professional photographs provided by the museum and I was not able to study them in-person. Some subtler traits are not clearly visible in photographs, so they are left out. This cuts the total number of checkable estimates to 430 out of a possible 520 (52 carpets, maximum of 10 visible traits each).

In addition to the minority of traits that could not be documented for the historic sample, there are also traits present that were documented, but which are not reflected in the ethnographic sample. For instance, the ethnographic sample includes five observation types for the **Knot-Weft Pattern**: A, C, D, A/D, and C/D. The historic sample includes these five observations, but also several more: B, G/H, and Q/R/L/J. Since these options are not represented in the ethnographic data at all, it is not reasonable to think that they could be estimated through comparison to the ethnographic sample alone. Of the 430 checkable estimates, 65 are for un-represented data. This leaves 365 estimates that could be directly confirmed or refuted. Every historic carpet included had at least 2 confirmable characteristics, and many have up to 9. None has all 10.

A final complexity is added to the evaluation of visible traits. Because some of the historic carpets are small fragments without good information on which part of the original carpet they came from, their clusters numbers and the associated X-Y coordinates are somewhat arbitrary: they do not represent distance from the edges in the same way that the cluster numbers do in a complete carpet. Similarly, I do not know what proportion of the original carpet is represented

by the fragment: the fragment may be only a few percent of the total area, or a substantial portion. Since the knot-size data are organized by position & scale in the carpet, this means that a direct comparison between complete carpets and fragments is not advisable. It is not possible to place the fragment data correctly "in the plot" (Fig. 9.1), and therefore I cannot say if it does/doesn't match a particular distribution. Fragmentary pieces were therefore not given trait estimates based on knot size. They were still given estimates based on shape, as the knot shape data are not a spatial distribution. While there were 365 traits eligible for a checkable and ethnographically-represented shape-based estimate, only 100 are eligible for a size-based estimate. These 100 traits are distributed across 19 carpets.

Knot Size

Overall, the knot-size distributions were very difficult to match to the historic carpet data. The vast majority of the distributions had only vague similarities, if any at all (Fig. 9.2). This was a potential outcome I had not considered until I saw the plots. Because the ethnographic data are based on thousands, even tens of thousands of knots spread across many carpets, harsher variations tend to be smoothed out by the enormous sample size. While this provides robust statistical support for any resulting trends, it also makes comparison to historic data much harder. The historic carpets must necessarily be compared as individuals, meaning that random noise and meaningless variation does not get "smoothed out" by enormous sample sizes in the historic data. This is evident in Figure 9.2.

Potentially, this problem could be corrected by expanding the sampling scheme in historic carpets. By including more knots in the measurement stage, it is possible that a single carpet

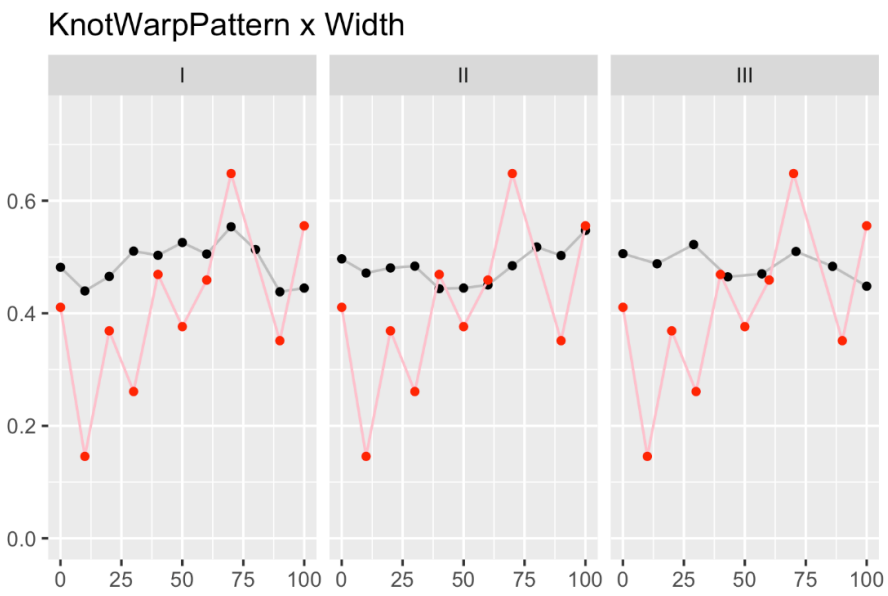

Figure 9.2: Comparison of Distributions for Knot-Size

The ethnographically-calculated average knot sizes (black), plotted as distance from the left-hand edge of the carpet. Grouped by the **Knot-Warp Pattern**. The average knot sizes for historic carpet MU-AS-10 (red) do not follow a distribution particularly close to any of the ethnographic options. Figure by author.

could approximate or at least approach the large-sample benefits of many carpets sampled at a lower rate. However, this would substantially limit the applicability of the technique, as many historic carpets are fragmentary, threadbare, or otherwise damaged and may not have that many measurable knots left. Still, an expanded sample might be an effective way to skirt around this problem in some cases. The systematic samples here range from only 12-25%, so there is certainly room for expansion.

As the highly-variable historic data shown in Figure 9.2 do not obviously match any of the ethnographic distributions, I base the estimate on generalizations. The historic data have a wide

range of values and significant variation between neighboring sections, but a generally positive trend towards the right side of the carpet. I therefore select **Knot-Warp Pattern** I as the best-fit, because that distribution also has a large range of values and significant variation between neighboring knots. Pattern II is selected as the second-best fit, because it has a generally positive trend towards the right of the carpet and a high(-ish) total range of values. Pattern III, while it does have notable variation in size between neighboring sections, does not have a high overall range, nor does it have a positive change in knot size towards the right side of the carpet. Pattern I is, in fact, the type used in MU-AS-10.

While the majority of the knot-size distributions are similarly bad fits, there are some with remarkable similarity. Carpet MU-CH-6's data fit very well over the **Knot-Weft Pattern** C/D (Fig. 9.3). Both distributions have a similar total range, both have similar differences between neighboring regions, and both groups see their knot sizes increase/decrease at about the same points, by about the same amounts. Despite the close distribution match however, MU-CH-6 was not made with a C/D pattern: it was made with a C pattern. The match for distributions C is probably the worst of the five!

Of the 100 size-based traits which are checkable, 44 were estimated correctly at the first level (44%). This is a surprisingly good number, considering how difficult it is to match the historic distributions to the ethnographic ones. This figure is joined by 40 more correct second-level estimates, although 18 of those are binary traits where the correct option would always have occurred in two estimates. Excluding those binary results, 66% of the traits are estimated correctly in two best estimates derived from the size data. However, because the visible traits

have between 2 and 5 options each with an average of 3 options, these results are likely random chance rather than proof of predictive power. A 66% success rate in 2 guesses is exactly what would be expected if 3 options were selected from randomly.

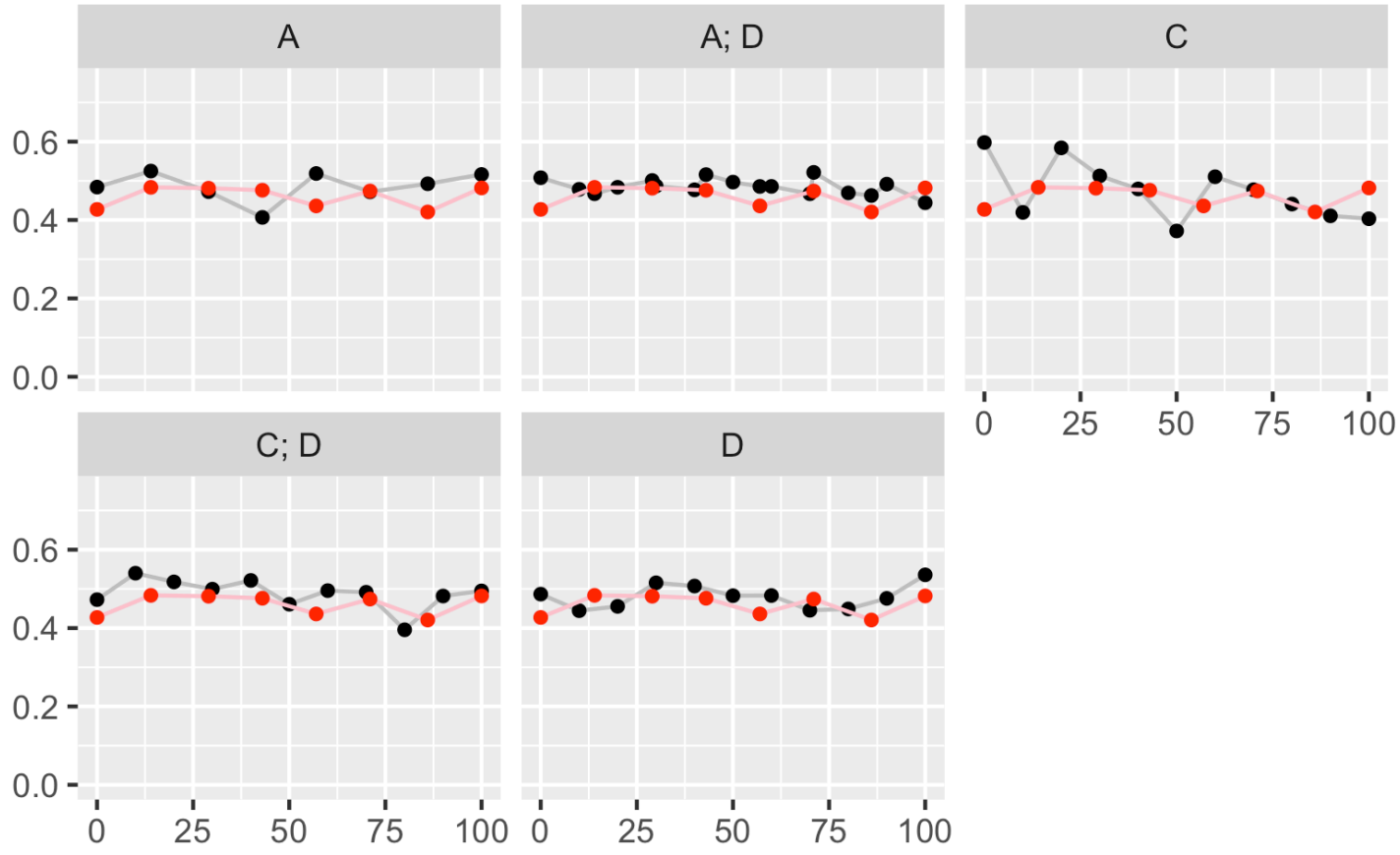

Figure 9.3: Matching Historic Carpet to Ethnographic Data

The ethnographically-calculated average knot sizes (black), plotted as distance from the left-hand edge of the carpet. Grouped by the **Knot-Weft Pattern**. The average knot sizes for historic carpet MU-CH-6 (red) match reasonably well in size and relative change to the distribution for pattern C/D. Figure by author.

Knot Shape

The knot-shape data were much easier to draw estimates from, as the point clouds create more obvious visual clusters. Some of the historic data are remarkably well-matched to the distributions of the ethnographic data and results in an accurate estimate (Fig. 9.4). Carpet MU-AS-8's shape data fit quite well over the distribution for **Knot-Weft Pattern** D. While the fit over some of the other patterns isn't terrible, the fit for pattern D is clearly the best, and indeed MU-AS-8 is woven with a D pattern.

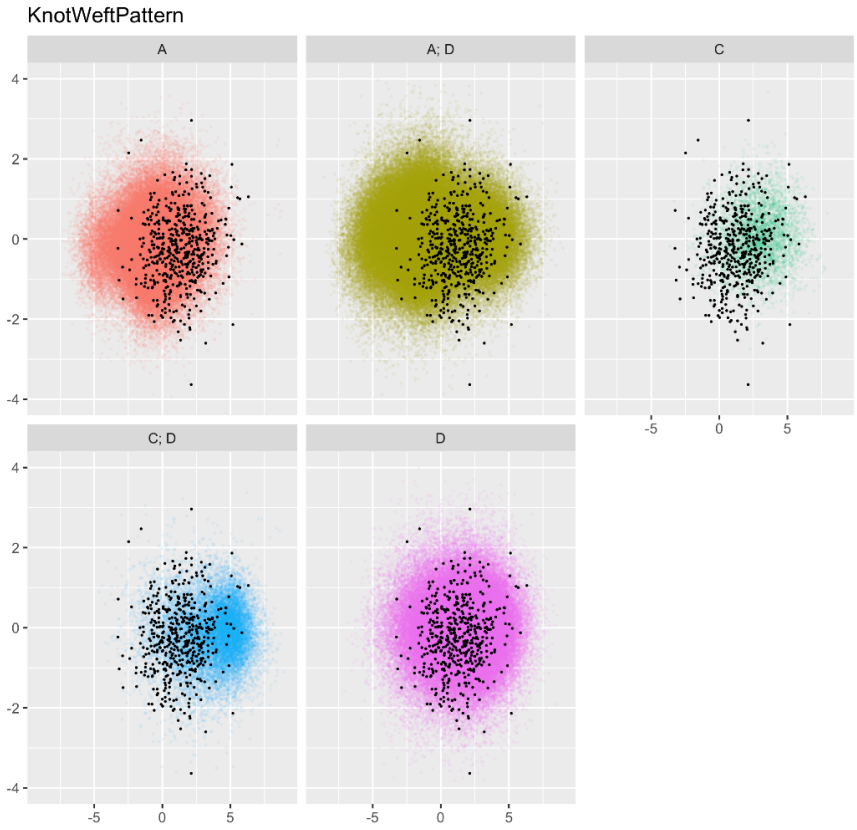

Figure 9.4: Estimate Plots for Knot-Weft Pattern, MU-AS-8

Principal component compression of the knot-shapes for the five ethnographically-observed **Knot-Weft Patterns**. Ethnographic data plotted in color.
The shape data for historic carpet MU-AS-8 are plotted over each group in black. Figure by author.

Other carpets have distributions that appear well-fit, but do not result in an accurate estimate (Fig. 9.5). Carpet MU-CH-5's shape data fit very well over the distribution for **Knot-Warp Pattern-III**. However, the carpet was actually woven with pattern I, which is the worst-fit distribution of the three options.

For some characteristics in some carpets, the distributions do not fit any of the ethnographic patterns especially well, making it difficult to assess which is the best estimate (Fig. 9.6). Fragment MU-DY-1a's shape data do not align with any of the **Pile Materials**, and so even the best estimate (Synthetic) is a poor fit, and an inaccurate one.

The opposite is also true: some historic distributions fit several of the ethnographic patterns very well, making it difficult to select which is the best representation (Fig. 9.7)! Fragment MU-VA-2, one of the oldest in the sample, has a strong pattern match for two different **Strands per Knot**, meaning that selection of which is the better fit is somewhat subjective. Unfortunately, without a regression analysis, selecting the estimated traits is inherently subjective. This is why I chose to give the best two guesses, as it acknowledges some amount of subjective error.

The non-alignment (as in Fig. 9.6) and the multiple-alignments (as in Fig. 9.7) both reinforce the importance of using a large, non-overlapping, and technologically diverse sample. It may be that the distributions shown by historic carpets MU-DY-1a and MU-VA-2 are both normal for their traits, but that the ethnographic sample was not sufficiently diverse to capture the full range of outcomes, or to fully differentiate similar but distinct ones.

There are several cases where the trait observed in the historic piece was not included in the ethnographic tests, but where the best-fit estimate still approximates the missing value (Fig. 9.8). I find this to be an exciting and intriguing result. Carpet MU-AS-9c was made with 3 strands of yarn per knot. The ethnographic sample did not include any 3-strand carpets, but does include 2-, 2.5-, and 4-strand ones. When plotted, MU-AS-9c's data fit almost equally well with the 2- and 4-strand distributions. We could therefore interpret this result to mean that the true **Strands per Knot** value for this carpet is somewhere between 2 and 4, which we know to be the case. This suggests that in some cases, using the estimates as an approximation is reasonable, if not exact.

There are other cases where an unrepresented trait does not follow what would be the most conceptually reasonable approximation (Fig. 9.9). Carpet MU-CH-3, for example, was made with **Knot-Weft Pattern**-B. Pattern B is a correlate to pattern A: both represent a knot which is bounded on top and bottom by wefts sitting in the same shed. The two patterns are mirror-images of each other, but make up a conceptual unit. Other patterns make other units, including but not limited to C & D, E & F, and G & H. If the estimation technique was providing the best approximation from the available options, as was seen in the MU-AS-9c (Fig. 9.8) example, I would expect the shape data to link the B-pattern MU-CH-3 to its closest represented correlate, pattern A. This is not the case. The shape data best fit pattern C, which is not a conceptual or geometric pair to pattern A. The relationship between some traits and their resulting distributions is therefore likely more complicated than the available data can capture.

Of the 365 shape-based estimates which are checkable, 133 were estimated correctly at the first level (36%). This figure is joined by 153 more correct second-level estimates, although 53

of those are binary traits where the correct option would always have occurred in two estimates. Excluding those binary results, 64% of the traits are estimated correctly in two best estimates derived from the size data. As with the size estimates, because the visible traits have between 2 and 5 options each with an average of 3 options, these results are likely random chance, and not proof of predictive power of the technique.

Of the 100 traits where both a size-based and a shape-based estimate was possible and checkable, only 25 had agreement across both size and shape in the first-level estimate. This suggests that in general, the two methods of comparison do not agree with each other and are not picking up on the same data variation. The two methods both have a similar success rate though, with the size-based comparisons getting 44% of estimates correct at the first level, and the shape-based estimates getting 36% right at the first level. As the random success rate for the visible variables is about 33%, both methods do slightly better than random. However, the improvement on random is only very slight.

I next broke down the traits' individual success rates to see if they are all performing at random chance, or if some are performing better/worse. Of the ten visible traits, four perform better than random chance when looking at both the size and shape estimates (Table 9.1). When calculated individually, six traits perform better than random in the size-based estimates, while four perform better than random in the shape-based estimates. It is therefore reasonable to conclude that the size-based estimates are slightly more reliable, despite being harder to read in my opinion. However, no success rate was ever higher than 50%, which is not overwhelming evidence even for traits with a 33% randomness level. Of the four traits that are estimated at

better-than-random rates, three relate to the materials used, suggesting that material factors (tensile strength, stretch, friction, etc.) may have more impact on knot size and shape than anything else.

It should be noted however that many of the outcomes are well *below* the expected success rate for a random selection. If these results were truly random, we would expect most of the per-trait rates shown in Table 9.1 to be at or near their expected random rate, but many are considerably below. This may imply that there *is* a systematic link between the various traits and the knot size/shape, but that this particular dataset has not defined it correctly. There may also be biasing factors at play, like the degradation of the historic carpets or the low historic sample size.

Production Characteristic	Random Rate (%)	Estimates by Knot Size			Estimates by Knot Shape			All Estimates		
		n	Correct	Success Rate	n	Correct	Success Rate	n	Correct	Success Rate
Knot Direction	50	3	0	0%	27	8	30%	30	8	27%
Knot Type	50	10	2	20%	51	18	35%	61	20	33%
Knot-Warp Pattern	33	37	15	41%	104	26	25%	141	41	29%
Knot-Weft Pattern	20	28	6	21%	86	21	24%	114	27	24%
Pile Material	33	16	7	44%	82	39	48%	98	46	47%
Strands per Knot	25	0	0	NA	24	5	21%	24	5	21%
Warp Material	33	16	8	50%	82	41	50%	98	49	50%
Weft Material	33	14	6	43%	78	38	49%	92	44	48%
Weft Offset Pattern	50	30	11	37%	69	18	26%	99	29	29%
Weft Shot Pick Count	33	28	11	39%	72	18	25%	100	29	29%

Table 9.1: Success Rates for Estimating Visible Traits

Estimates that performed better than random shaded in green. Table by author.

Invisible Variables & Other Tests

Overall, the size and shape distributions seem to be mostly non-predictive when applied to visible traits. This same rate presumably would carry over to the invisible traits, but this assumption cannot be directly checked in this experiment. For completeness, estimates were produced for all the invisible traits anyway, available in Appendix E. Like the visible traits, the distributions for the invisible traits range from very similar to very dissimilar to the ethnographic data.

Although the distributions are not especially predictive, there may be other useful applications of these data. One of the long-term goals of this methodology is to be able to identify when carpets are more similar/dissimilar than they seem at the macro-scale. There are several sets of fragments in this study which are presumed to be from the same carpets based on similarity of material, structure, design, and recovery location, but which are not actually connected by any surviving fiber and which were analyzed separately here. These groups are MU-AS-2a/b, MU-AS-4a-c, MU-AS-9a-d, MU-AS-17e-g, MU-DY-1a-d, and MU-DY-2a-c. There are also several fragment groups (MU-AS-8:10) where connective fibers or diagnostic edges remain, and the fragments were analyzed as a cohesive unit. Because their measurements were catalogued as a single set in data collection, separating the fragments out now is not simple.

By comparing the results of the visible-trait estimates in the unconnected fragment groups, I evaluated the internal consistency of the method and its ability to differentiate carpets that seem identical, on the surface. If these pieces were actually from the same original carpet(s), I would expect their estimated traits to be mostly if not entirely the same between fragments,

because the underlying knots would presumably have been tied under the same conditions. MU-AS-2a/b follows this expected pattern: of the 20 available estimates (based on shape; 10 first-level, 10 second-level), 17 are identical between fragment A and fragment B. Of the three that are mismatched, two are the same two traits but given in opposite orders. Only one of the 20 estimates for these two fragments truly differs (second-level estimate for **Weft Shot Pick Count**). The fragments of MU-AS-9 are similarly consistent, although with four fragments in the group (a-d) instead of two, there is a little more inter-fragment variation. The majority of that variation is just in first- and second-level inversions. The same pattern holds true for MU-DY-1. The consistency of the knot shapes can be visualized with a PCA plot (Fig. 9.10).

Three of the assumed fragment groups (MU-AS-4a-c, MU-AS-17e-g, and MU-DY-2a-c) do not have such consistent outcomes. Each group has significant variation, with many traits having no overlapping estimates. MU-AS-4a-c and MU-AS-17e-g have only two estimates each that match across the whole group, and MU-DY-2a-c doesn't have any! All three of these groups have some fragments that are more similar to each other than others. In MU-AS-4, fragments A and C are quite similar, with ten identical estimates and six more inverted ones. Fragment B is the odd one out. In MU-DY-2, fragments A and B are very similar, with twelve identical estimates and six more inverted ones. Fragment C is left out, considerably different from the other two. MU-AS-17e-g is a little different, as fragments E and F are confirmed to be from the same original piece already due to a surviving thread between them, but they are not that similar to fragment G with only two identical estimates in twenty. The inconsistency of the knot shapes can be visualized with a PCA plot (Fig. 9.11).

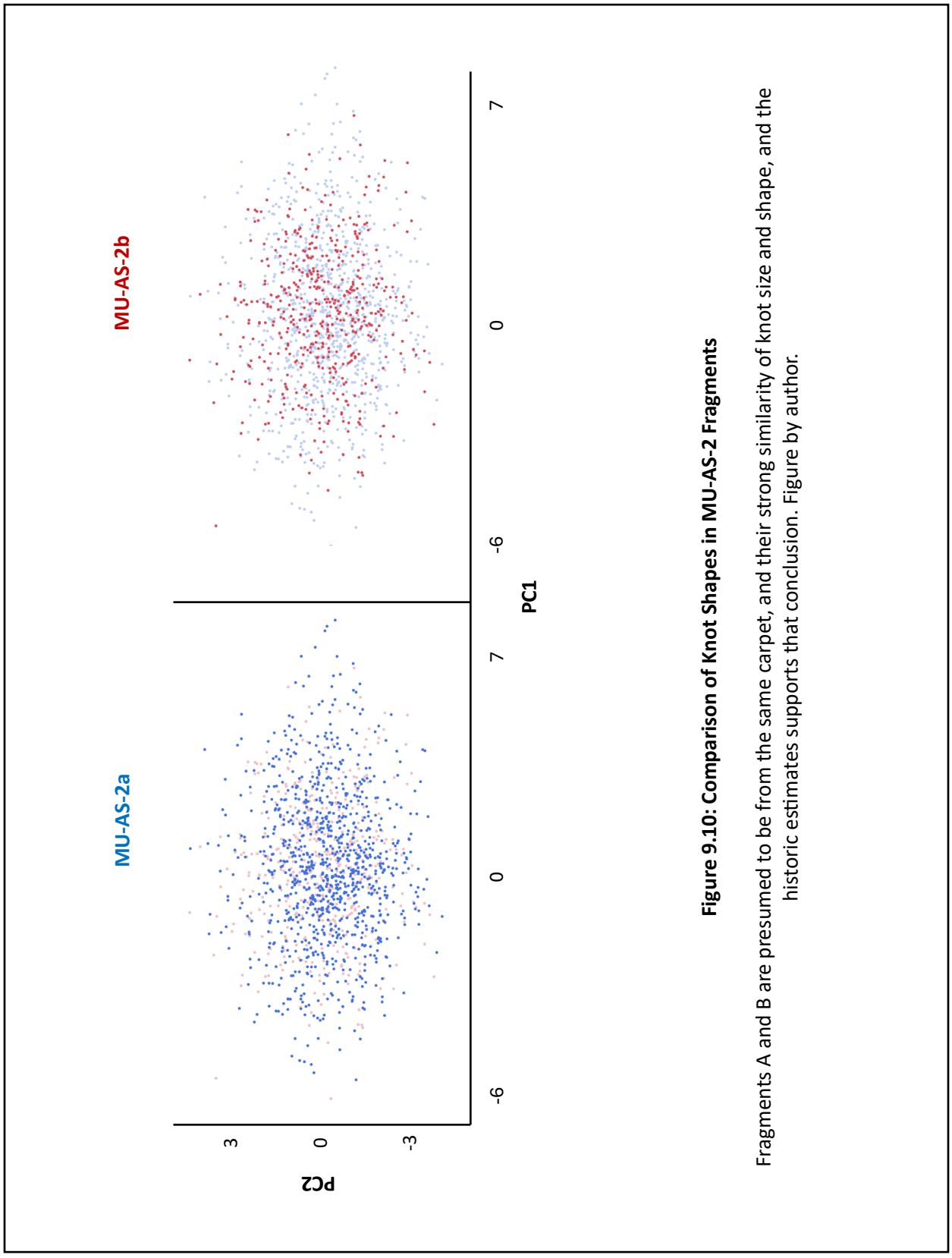

Figure 9.10: Comparison of Knot Shapes in MU-AS-2 Fragments

Fragments A and B are presumed to be from the same carpet, and their strong similarity of knot size and shape, and the historic estimates supports that conclusion. Figure by author.

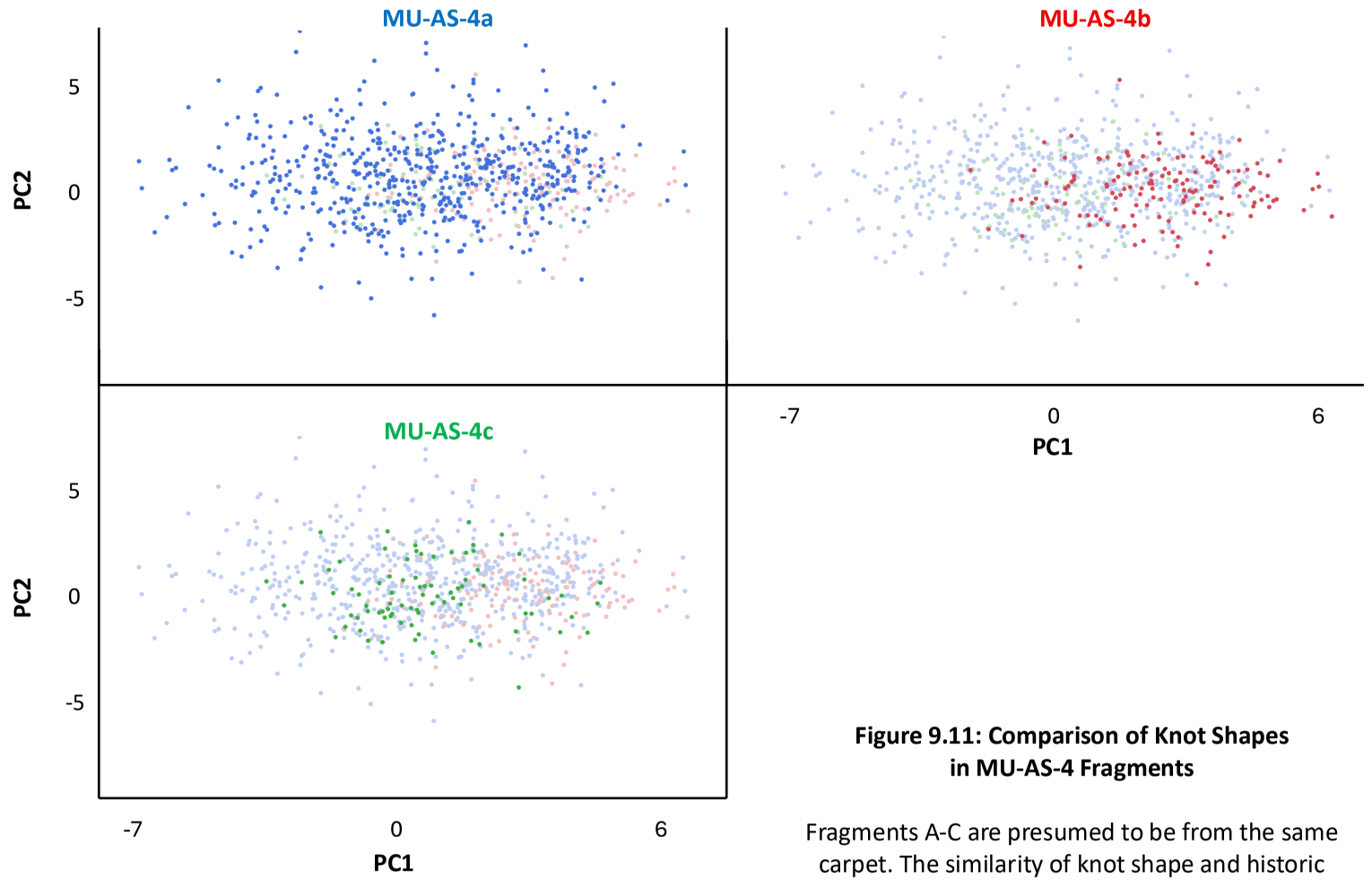

Figure 9.11: Comparison of Knot Shapes in MU-AS-4 Fragments

Fragments A-C are presumed to be from the same carpet. The similarity of knot shape and historic estimates between fragments A and C supports a shared origin, but the dissimilarity of B suggests it may not belong to this group. Figure by author.

There are several possible explanations for these mismatches. First, it could be that the odd pieces are not from the same original carpet as the rest of their group. That is the simplest reason I can imagine. While the groups are all reported to have been found together, that does not necessarily indicate that they are a single original carpet. Their structural and design similarity may be due to a strong community design language that generates visually similar carpets or a limited resource pool that results in high consistency between products, rather than being indicative of a single original artifact. A second possible explanation is that the difference in estimated traits is due to age, degradation, or deformation of these 1,000+ year old pieces. Perhaps one fragment was crushed, rolled, or subjected to extensive water damage that distorted the knots over time, making them appear more different than they originally were.

These knot differences could also be explained by the original carpet having had more than one weaver: the weaver shape data show that different individuals have slightly different "signatures", even when working within the constraints of the same community-of-practice (Fig. 9.12). The differences in the ancient fragments could therefore indicate that multiple people worked on the same original carpet, producing sections of slight individuality which were picked up by this analysis over a millennium later. This, I think, is a particularly exciting possibility. The difference in knot shapes need not indicate multiple weavers at time of manufacture, but could also indicate that sections of the carpet were reworked or repaired later. Sections of repair may not otherwise be readily apparent, if the diagnostic boundaries are lost.

You will remember that there was an example of a multi-person carpet included in the ethnographic sample (UZ-KH-11), and the shape-analysis methods were unable to clearly

differentiate the two weavers in that case (see Chapter 8, pg. 526). That might seem to indicate that the possible interpretation of multiple weavers in the historic fragments is unlikely, but I argue the opposite. True, the ethnographic carpet did not show an unambiguous distinction between the weavers, but it had several confounding factors that don't appear in most ancient and historic carpets. First, that piece was entirely silk. While certainly some silk carpets are known from the Renaissance, particularly among the Mughals, they were as rare then as they are now. The obfuscation of Maloxat's and Nazokat's contributions to UZ-KH-11 may be due to a smoothing or generalizing effect of the silk rather than a true lack of distinction between their work. Weavers working in coarser wool, the medium of the vast majority of history's carpets, may be more distinguishable. Second, Maloxat and Nazokat are professionals working in a highly-standardized and tightly-controlled setting. It would not surprise me to learn that they are more capable of and incentivized to match each other's work than most weavers are, and a more casual weaving pair might be more easily distinguished. Finally, and most simply, UZ-KH-11 was brand new. It had not even left the workshop yet, much less been subjected to years on the floor of a family home or millennia rolled up in the back of a cave or sealed in a tomb. Perhaps one weaver's knots are tied less tightly and will loosen over time, making them more distinguishable than they were on the day of photography. Of course the opposite is also potentially true, that their knots were at their most distinguishable when new and will become less distinguishable with wear. Either way, I do not think the inability to separate Maloxat's and Nazokat's work in UZ-KH-11 is evidence that multiple makers couldn't have contributed to the fragment groups with mismatched knots.

Finally, the difference between the fragments could be due to an error by me in photography or measurement. The differences measured this study are extremely fine (mostly less than a millimeter), but there are also almost a million of them. While the tiny measurement scale might be expected to magnify human error, the large sample size should smooth it out, particularly as overestimating and underestimating the measurements were equally possible here. It is hard to understand why some fragments measure as well-matched while just one is so different. If all the fragments in all the fragment groups were badly-matched, I would probably agree that this was some error introduced by me. But the well-matched estimates for most of the supposedly-linked fragments imply that both my work and the sampling/measuring methods are robust enough to resist low-level, systematic, researcher-introduced variation and error. So, either I made a particularly big error when photographing & sampling just that one fragment, or there is a true underlying difference in the fragments. While I certainly don't outright reject the possibility of this being my own error, I am surprised that it affects only a few fragments, and not all of them.

To quantify my level of accuracy and error, I performed a calibration test. I created a digitally-generated grid where the size of each box was set and known. I then followed the same procedure to add dot-measurements to the grid in QGIS as was used for the real carpets. Except that I used a drawn grid rather than a carpet photo, all steps were the same: I used the same QGIS settings, the same screen and stylus, the same method for marking the embedded scale bars and exporting the data. The data were processed as if they were real knots, following the same grid-alignment, measurement, and area calculation procedures. There is even a knot-plot

for the calibration data (Fig. 9.13)! Once I had the experimentally-calculated "knot" areas for the artificial grid, I compared them to the known box sizes. This test was performed twice, once on a full grid and once on a grid with visible "weft rows" where alternate rows are deleted/not counted. On average, my measured boxes were about 18% smaller than the actual grid. This seems concerning, but it is not. If the rate and direction of my introduced error are consistent, it does not matter what they are. Remember, all the knot data are standardized within each carpet. As long as I measured all the knots in the carpet consistently around 18% small, then they would be standardized to the same values as if they were measured exactly accurately. In fact, the most likely explanation for this apparently significant error rate is not that I consistently under-measured the knots, but rather that I undermeasured the scale reference. As the scale reference is used to convert the measured data into real-world square centimeters, a -18% error in marking the scale would result in a -18% average error in all the knot sizes, even if those were measured accurately. I think this is more likely than me having consistently marked thousands of boxes 18% small.

But again, the absolute error rate is not especially important, as it is corrected/removed by the standardization process. As long as the error rate is consistent across the whole "carpet", it does not matter what it is. To check that my measurements were consistent, I calculated a coefficient of variation (CV) for this artificial data. It is only 3.46%, right at the physiological limit for length estimation (usually given as a CV of 2-5%), and about as good as could reasonably be expected in hand-measured data. The volunteer who assisted with some of the dot-drawing took the same calibration test: she had a more significant average absolute error of -30%, but her CV

is comparable to mine at 2.98%, and still right at the limit of what could be hoped for hand-measured data.

This indicates that it is probably not a systematic human error that separates some of the fragments from the rest. Error in standardization and other calculations are also unlikely, as the data were all processed as a group by the same R codes, in the same sitting. Any error introduced in that process would be systematic, not a one-off mistake applicable to only a few random fragments. The remaining human-error explanation would have to be in the photography, which seems unlikely as photos of grouped fragments were all taken with the same procedure, the same equipment, the same lighting, and usually only a few minutes apart – some very small fragments even appear in the same single photo. One set of photos (MU-DY-2a-c) was not taken by me at all, but by the professional staff photographer at the de Young Museum in San Francisco. If not a human measurement, analysis, or photography error, the remaining explanation is a fundamental difference in the fragments themselves.

That difference could be from degradation, or because ancient weaving had less internal consistency than modern weaving does, or because the fragments are from different original carpets or were woven by different individual people, or because certain fragments were subjected to unique taphonomies. Although more testing would certainly be needed, it is very interesting that while most of the attributed groups seem to have strong underlying consistency, there are a few grouped fragments that differ quite notably. If tested more robustly, this may be a very useful way to refine attributions and assumptions. I think that this outcome is the most exciting result of this project, and indicates that this method may have useful applications even

if the exact causes of shape/size differences cannot be explained or correlated to individual production characteristics.

Summary

Overall, this comparison to the historic fragments was an important test of the methodology. One of the goals of this dissertation is to be able to reverse-engineer production characteristics of historic carpets, based on similarities in knot size/shape to modern carpets. Although it would be easy to draw these predictions and take them at face value, performing this direct confirmation/refutation of the "visible" traits provides several insights and a concrete evaluation of the applicability of the methodological theory.

First, the overall success rate is low. This is not wholly surprising based on the relatively small and poorly diversified sample, but it is important to note nonetheless. This suggests that, most likely, many of the measured traits do not have any impact on the knot shape/size. Or if they do have an effect, it is non-directional/random, and therefore not a useful metric for inter-object comparison. Rather than following each trait through the whole analytical process as was done here, a more fruitful avenue going forward might be to focus on exploring how to differentiate diagnostic traits from non-diagnostic traits. This would speed the work and reduce complexity in the analysis, and would also help to minimize natural diversification and sampling problems present in ethnographic work.

Despite their low number, the characteristics that predicted historic traits at better-than-random in either or both knot shape and size (**Weft Material**, **Pile Material**, **Warp Material**, **Knot-**

Warp Pattern, **Weft Shot Pick Count**, and **Knot-Weft Pattern**) do have some similarities. Although a social-technological link is not immediately obvious, some statistical similarities do appear between these characteristics. All six traits have at least one statistically-significant test, either for variance in size or variance in shape (or, in several cases, both). This suggests that high levels of knot variation are more diagnostic of predictive success than more uniform distributions. This may be a way to streamline this process, by focusing only on traits that return a statistically significant difference in variation between trait groups.

Size estimates were slightly more accurate in predicting historic values (see Table 9.1). Six traits were predicted at better-than-random levels using comparison in knot size, while only four were predicted at better-than-random levels using comparison in knot shape. This suggests that size is a more robust tool than shape in reverse-engineering production traits from historic carpets. This is a little surprising to me, as the shape data look so much more visually distinct than the ambiguous size data. It may be that this success despite the ambiguity is a clue that the size data have even higher potential, if a systematic way to interpret the ambiguous results could be identified.

All four of the traits that were successfully predicted from the shape data were also successfully predicted from the size data. This is excellent evidence that a consistent and measurable change is occurring in the underlying knots in those four production characteristics (**Knot-Weft Pattern**, **Weft Material**, **Pile Material**, **Warp Material**). The presence of all three of the material variables in this list is notable: the quality of the materials may have a bigger effect on knot size/shape, or at least a more consistent one, than any of the techno-social characteristics

measured. This is surprising to me, as I would have expected a competent weaver to be minimally affected by the fiber content assuming all other characteristics are equal. This does not seem to be the case though, and this merits further testing. Fortunately, purely material trials are relatively easy to perform in a controlled experiment.

Although these results were not a slam dunk, the successful prediction of some traits in the historic carpets is a promising start in detailing ancient weaving practices. The results show that the underlying logic of this project is sound: some production characteristics do have a consistent and measurable effect on knot size/shape between weavers and settings, and those effects can be used to accurately reverse-engineer production characteristics from historic carpets and fragments. This, if taken further, should be able to give us new insights into carpet production in different times and places, and to expand our technological understanding of the craft.

The results also indicate a possibility I had not considered before working through the data: that differences in knot size/shape can be useful without explanation for how they came about. As discussed above, several fragment groups have distinct difference in their knot shapes, suggesting some pieces may not belong in the unit. This clear result is useful in refining carpet attributions and understandings, even if we cannot articulate what is causing the difference. While understanding the causes of the differentiation would probably be helpful and certainly interesting in the long run, this quick comparison is a useful metric for attribution studies, as it provides a concrete, external validity check of more paradigmatic social-historic explanations, assumptions, and biases.

Figures: Chapter 9

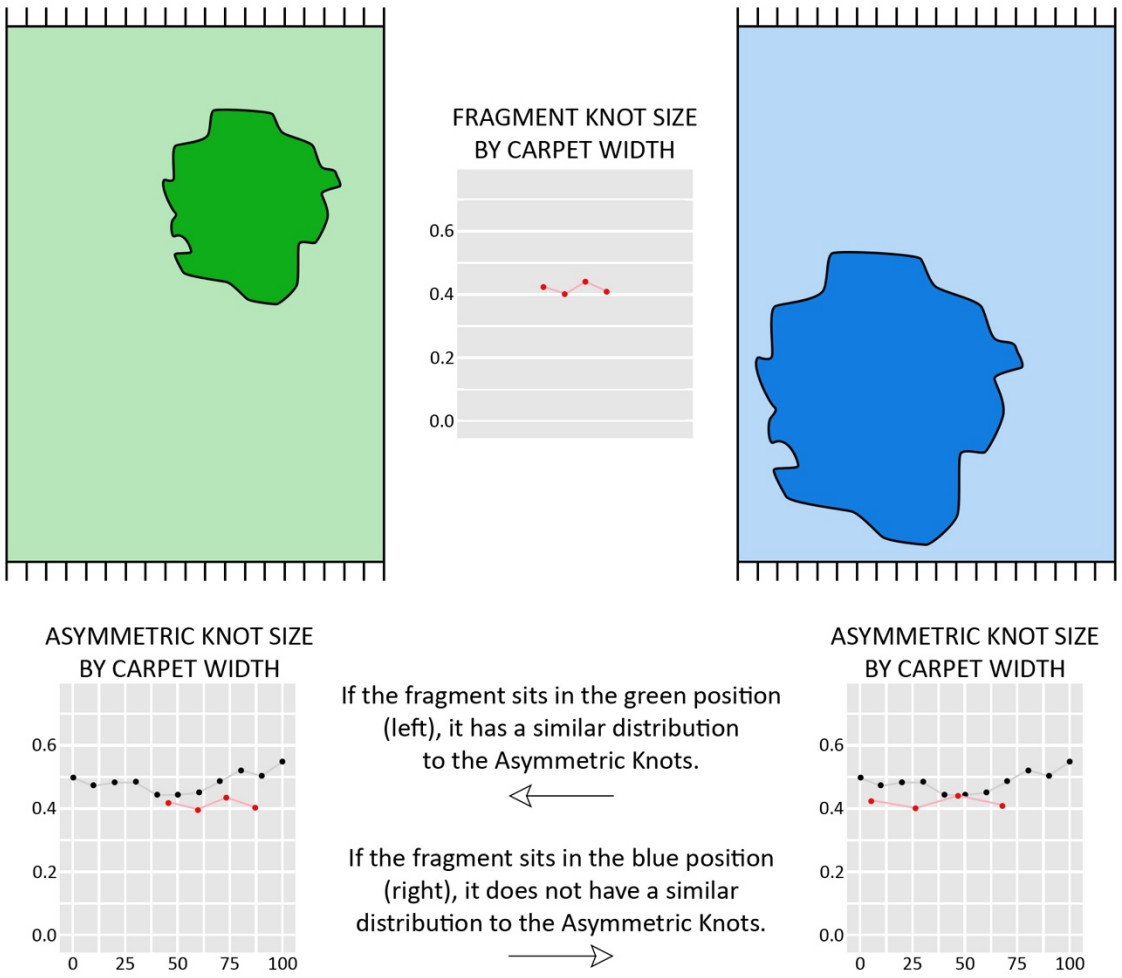

Figure 9.1: Positioning Fragments in Ethnographic Distributions

Depending on how the fragment is scaled and positioned relative to its original complete carpet, the distribution match changes. A similar distortion/displacement would occur in the carpet's Y-axis as well. This means that fragmentary historic carpets cannot be directly compared to the knot-size distributions built off the complete ethnographic carpets. Figure by author.

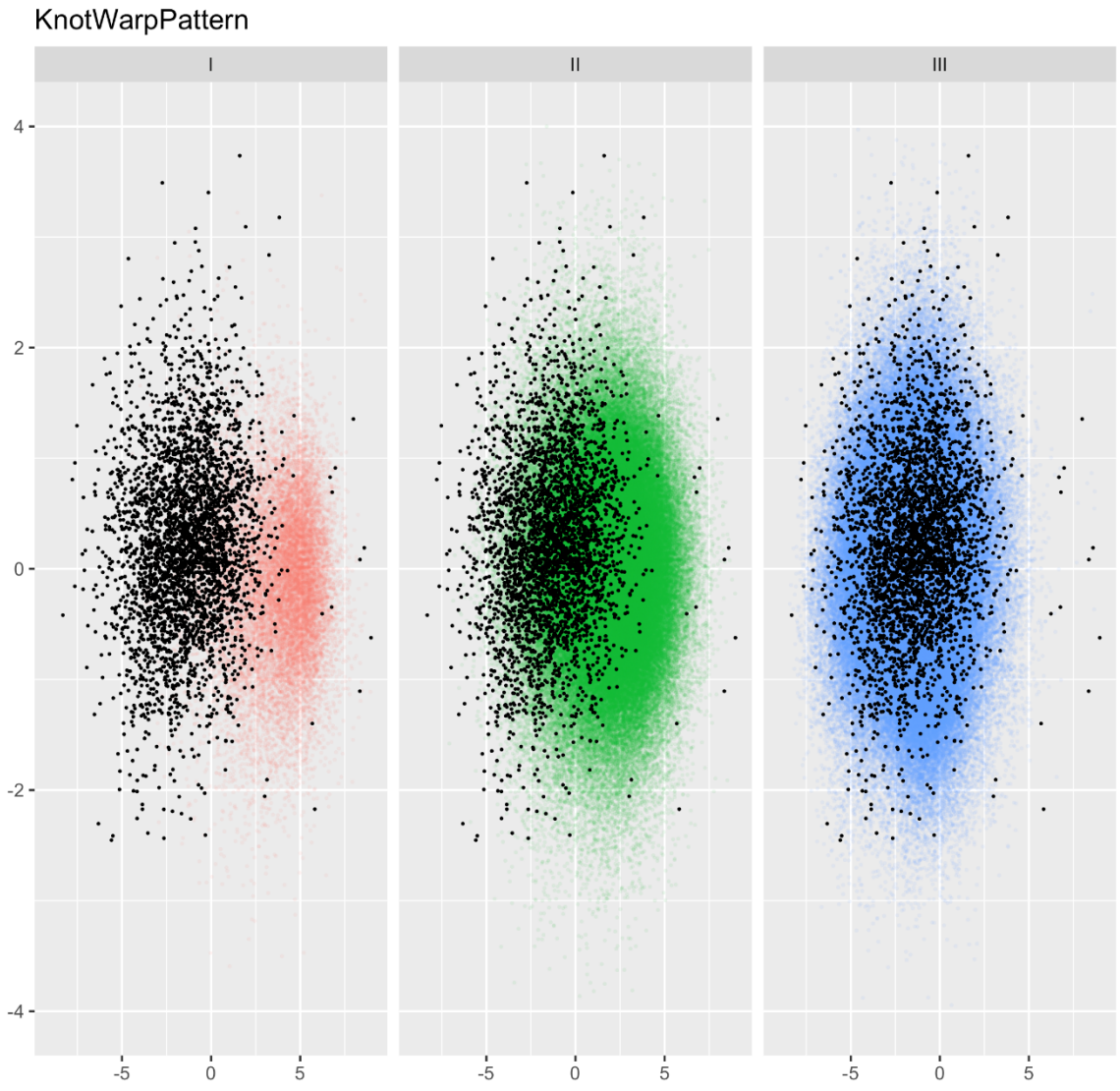

Figure 9.5: Estimate Plots for Knot-Warp Pattern, MU-CH-5

Distributions of principal components 1 (X-axis) and 2 (Y-axis), representing the shape of the knots made on each of the three ethnographically-observed **Knot-Warp Patterns**. Ethnographic data for MU-CH-5 plotted in color. Despite how well the MU-CH-5 data seem to fit with pattern III, this carpet was actually made with pattern I.
Figure by author.

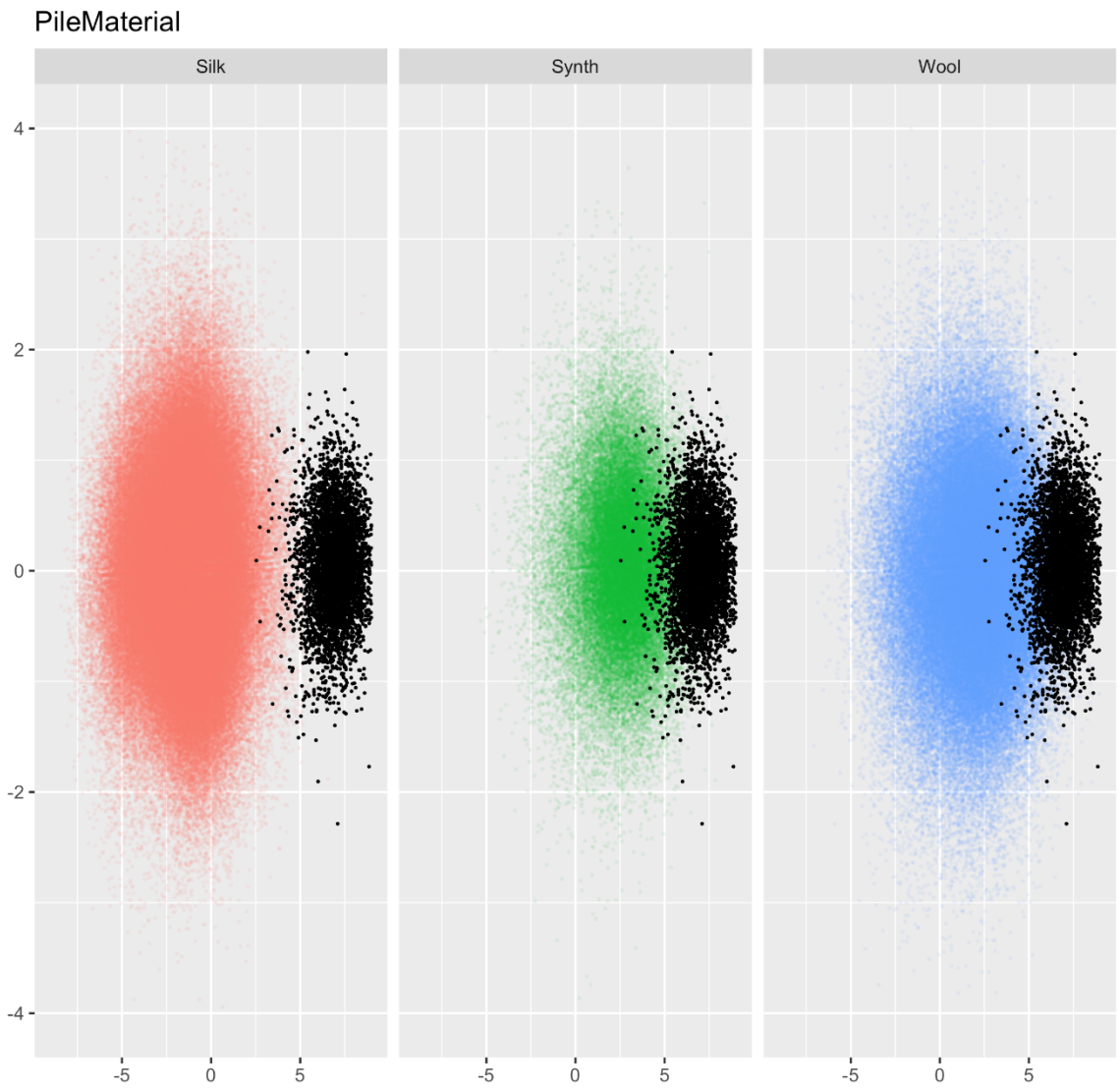

Figure 9.6: Estimate Plots for Pile Material, MU-DY-1a

Distributions of principal components 1 (X-axis) and 2 (Y-axis), representing the shape of the knots made on each of the three ethnographically-observed **Pile Material**. Ethnographic data for MU-DY-1a plotted in color: it does not seem to match any of the material distributions well. Figure by author.

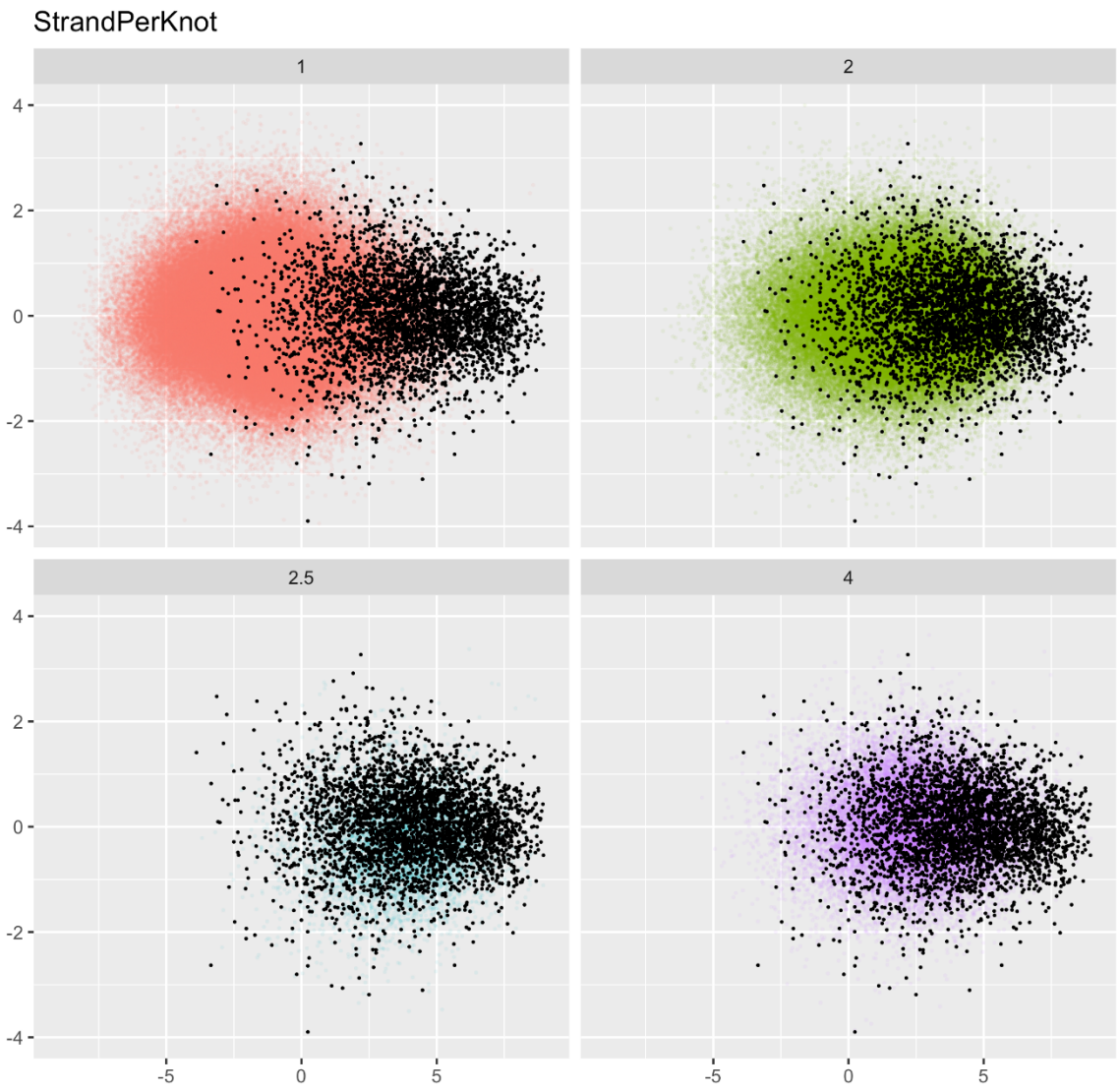

Figure 9.7: Estimate Plots for Strands Per Knot, MU-VA-2

Distributions of principal components 1 (X-axis) and 2 (Y-axis), representing the shape of the knots made on each of the three ethnographically-observed **Strands per Knot**. Ethnographic data for MU-VA-2 plotted in color. The MU-VA-2 data matches distributions 2.5 and 4 quite well. Figure by author.

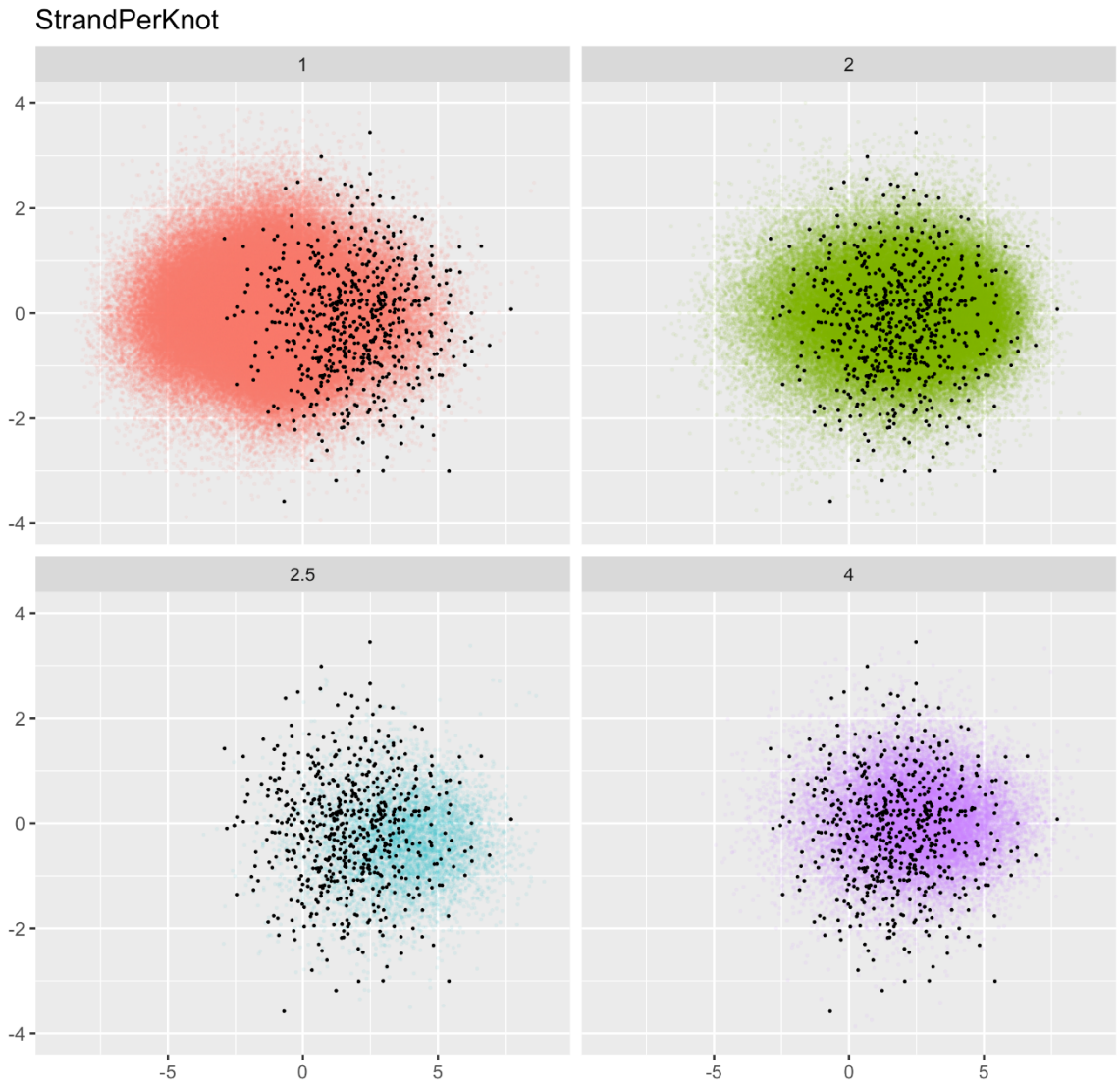

Figure 9.8: Estimate Plots for Strands per Knot & MU-AS-9c

Distributions of principal components 1 (X-axis) and 2 (Y-axis), representing the shape of the knots made on each of the three ethnographically-observed **Strands per Knot**. Ethnographic data plotted in color. The shape data for historic carpet MU-AS-9c are plotted over each group in black. The MU-AS-9c data fit both 2 and 4 strands equally well: it was actually made with 3 strands per knot, which was not represented in the ethnographic sample. Figure by author.

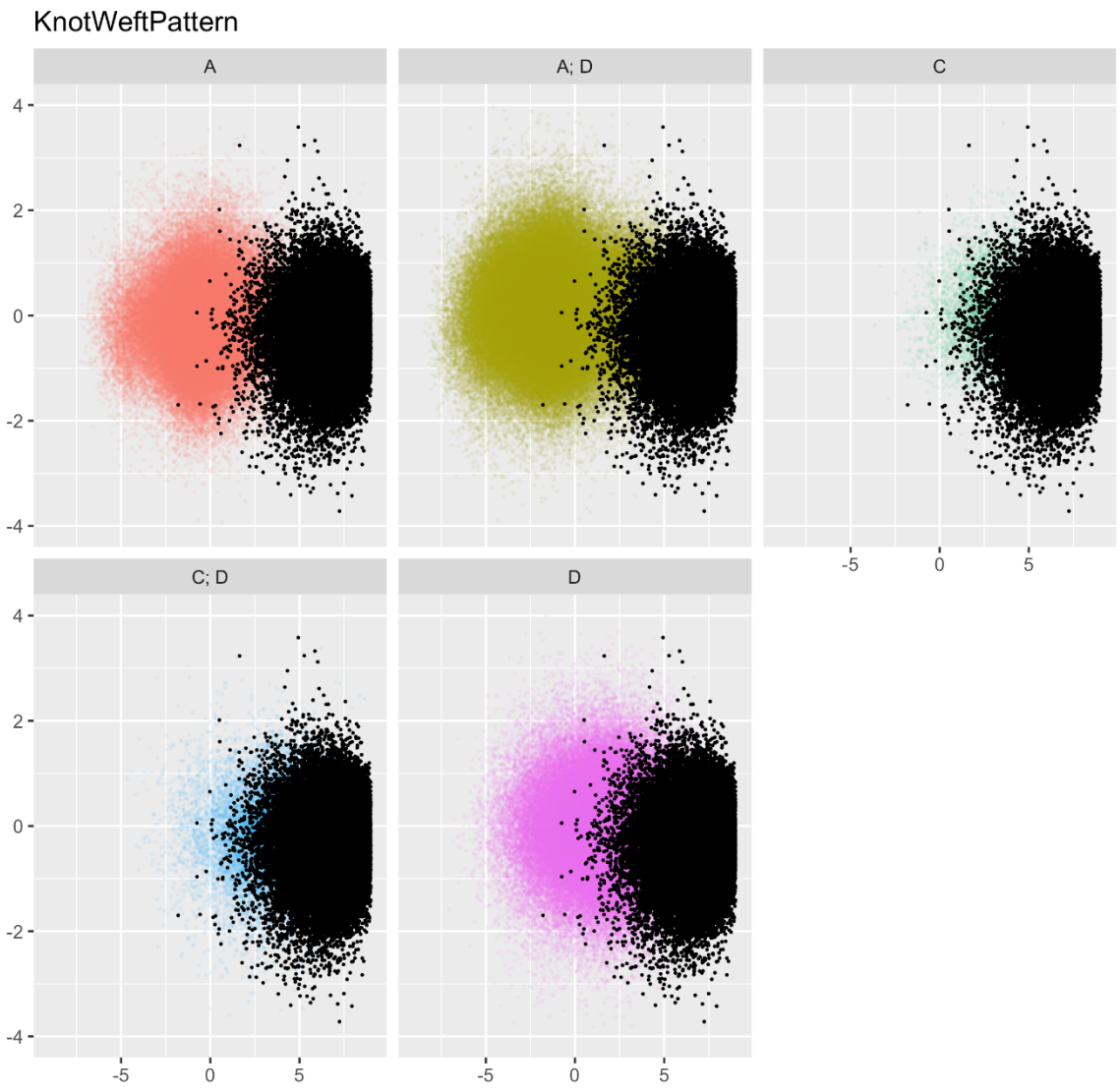

Figure 9.9: Estimate Plots for Knot-Weft Pattern, MU-CH-5

Distributions of principal components 1 (X-axis) and 2 (Y-axis), representing the shape of the knots made on each of the three ethnographically-observed **Knot-Weft Pattern**. Ethnographic data plotted in color. The shape data for historic carpet MU-CH-3 are plotted over each group in black. The MU-CH-3 data match pattern C quite well but was actually made with pattern B. The closest analogue to pattern B in the ethnographic sample is pattern A. Figure by author.

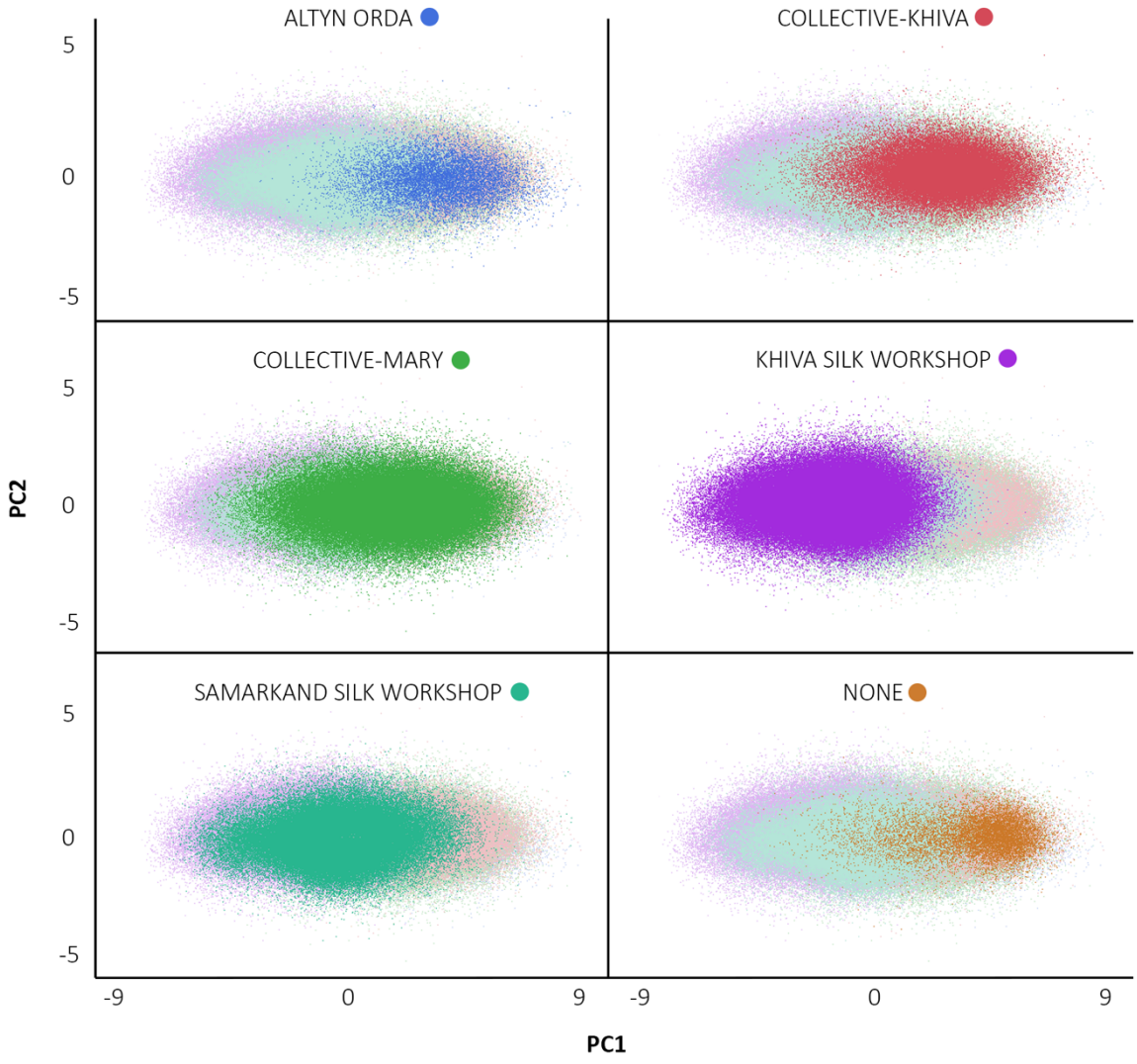

Figure 9.12: "Signatures" of Ethnographic Weaving Communities

Distributions of principal components 1 (X-axis) and 2 (Y-axis), representing the shape of the knots made by each of the five weaving communities (and one weaver without a community). Notice the distinct quality of knots, even when multiple people's work is represented. Figure by author.

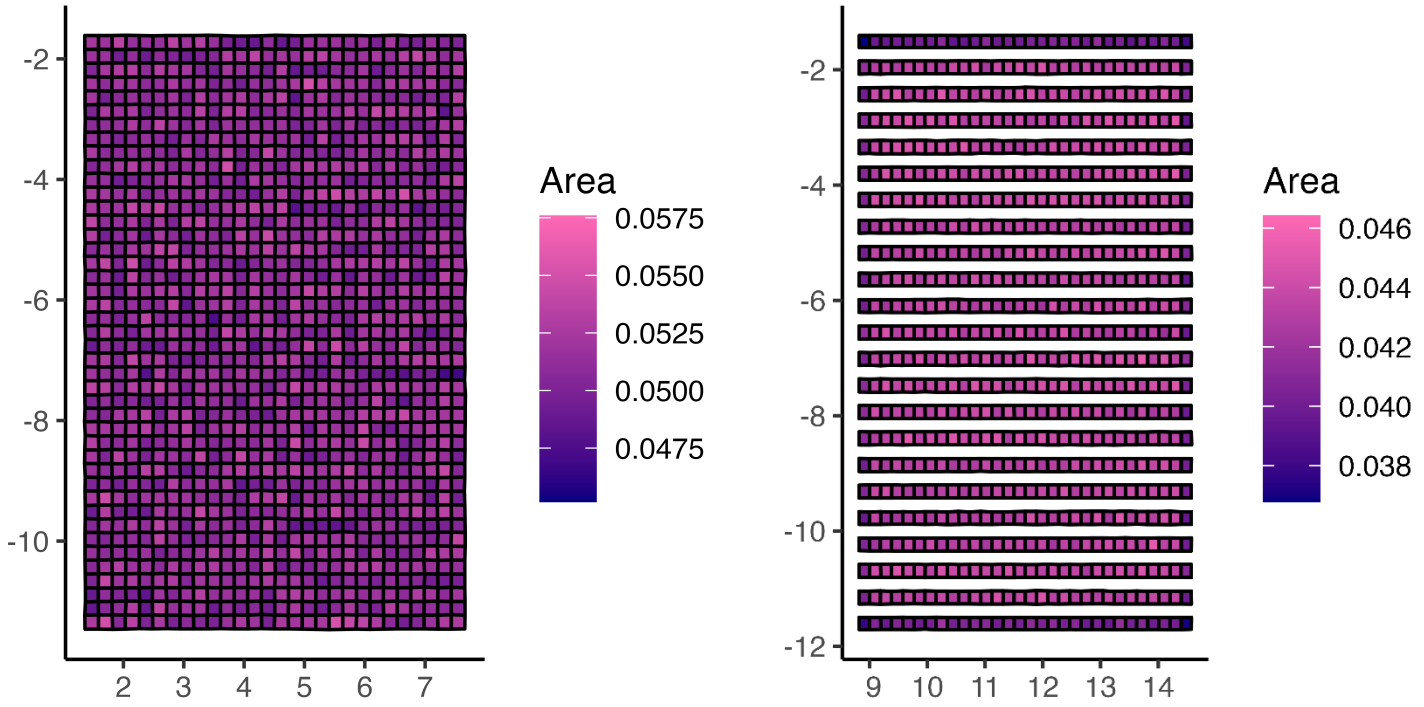

Figure 9.13: Researcher Calibration Tests

Visualizations of the knot sizes & shapes generated in the calibration tests by V. Sluka and the volunteer who assisted with data collection ("G"). Both people performed a test on an all-knot grid (like left, by V. Sluka), and on a grid with visible weft rows that had to be excluded (like right, by G). The area shading is in cm^2. Compare to a real-carpet knot plot in Fig. 7.12. Figure by author.

10. Discussion & Conclusion

The evidence presented suggests that some production characteristics, including technological, social-cultural, and idiosyncratic ones, leave a measurable and consistent distortion in knotted pile carpets. These patterns were then shown to reverse-engineer the production characteristics of historic carpets and fragments, in a limited and controlled setting. This restrained success is not a surprising result, but it is a promising one: an exploration of a method like this at this scale was unlikely to yield immediately actionable results or a "smoking gun". Instead, the contributions of this work are in smaller-scale improvements and advancements in many areas.

Predictive Value of Statistical Tests

In the knot-size analyses, Levene's tests for unequal variances and Wald-Wolfowitz tests for non-random sequences both frequently yielded statistically-significant p-values, indicating that there was some underlying patterning in the knot-size data when organized by production characteristics. The Levene's tests quantify the likelihood that two (or more) samples were drawn from the same population, based on a comparison of their breadth and rate of variation. Although commonly used as a prerequisite test for t-tests for equal means, a variance test can provide similar insight into an underlying difference in two populations. Thirteen of the thirty-four tested

characteristics resulted in statistically-significant p-values at a confidence level of $\alpha = 0.05$ (see Appendix D). This shows that there is a consistent and measurable difference in the different trait groups for those variables, and that they do not represent random groupings of a single source population. Although I had hoped that this variation might occur in distinct spatial patterns across the width and/or length of the carpets, the busy and difficult-to-interpret spatial plots suggest that universally patterned distribution is rare. That does not discount the meaningful variance results, however, which show an underlying division in the data whether it creates a visible pattern or not.

Only four of those thirteen significant results are for visible traits (**Weft Material**, **Strands Per Knot**, **Weft Shot Pick Count**, and **Knot-Weft Pattern**): these four can be commented on in a more meaningful way, because they can be traced through the reverse-engineering stage of the experiment. Three of those traits produced better-than-random historic estimates in the knot-size distributions (**Weft Material**, **Weft Shot Pick Count**, and **Knot-Weft Pattern**). This reinforces the idea that an underlying difference in knot size exists between knots made with these different techniques.

The fact that the characteristics with significant Levene's test are also those that resulted in better-than-random historic estimations further implies that this methodology may have underlying merit, even if it was not fully realized in this experiment. Although they cannot be directly confirmed, I suggest that the historic estimates resulting from invisible traits with significant Levene's p-values may be more accurate than those without. This could mean that up to 9 new pieces of information could be reasonably estimated from the historic carpets, including

intriguing points the **Production Setting**, use of **Tension Rods,** and the **Weft Addition Rate**, none of which can currently be commented on at all.

As an example, let's look at one of those 9 characteristics that produced a statistically-significant Levene's test for an invisible trait, based on knot size: **Knotting Order.** This variable captures the idiosyncratic order in which the weavers tie knots in a single row. Before starting this project, I assumed that most literate people would weave in the same order that their native language is written/read (e.g., left-to-right for English, Kazakh, Turkmen, and Uzbek speakers, but right-to-left for Arabic, Azeri, and Farsi speakers). This turned out not to be the case among the ethnographic weavers interviewed. Those that wove in a consistent direction at all, which was not universal, all reported weaving right-to-left, opposite of their native languages. Instead, the order of knotting seemed to be loosely tied to the weavers' memorization of the pattern, where more complicated patterns that she didn't have memorized were tied in a design-centric way (either by motif or by color), while simpler patterns that were easily memorized were knotted in consecutive order (always right-to-left among this group).

The carpets from the Indianapolis Museum of Art at Newfields (MU-IN-1:7) are the most cohesive set of the historic sample: all are dated to the second half of the 19th century, and all are attributed to the Baluchi people of the Khorasan Province of eastern Iran. Of these seven carpets, six were estimated to have been woven with a "patterned" knotting order, meaning that all the knots of individual motifs were tied as a group, before moving to another motif, and finally filling in the background. This seems to fit with the modern trend of using pattern-centric systems for

more complicated designs, as all these carpets are relatively complex, with tightly-gridded repeating motifs.

If the historic estimate is correct, I would suggest that this indicates that these Baluchi weavers did not have their designs fully memorized. That would be an interesting insight, considering many carpet historians believe the majority of weavers in history A) learned a set of traditional patterns from their mothers or other female relatives, and B) practiced those patterns in childhood so they were memorized by adulthood (Bier 1996:70; Tsareva 1984:9-10. If these Baluchi carpets were not memorized, that paradigm of conservative household motif replication is put in question. Perhaps this is direct evidence that the European carpet fads tended to kill off more local, traditional designs and replace them with ones successful in Europe and North America (Erdmann 1970:27), and that the Baluchi weavers were transitioning to new, unmemorized patterns during the Victoria carpet boom when these sample carpets were woven.

This is an interesting thought experiment and highlights the potential that these methods could have on our wider understanding of carpet history and processes, and particularly in challenging old narratives. The relatively higher predictive success rate of knot-size characteristics with a significant Levene's test could well carry over into the invisible traits and make these conclusions robust and empirically supported. Levene's test and similar quantifications of inter-population variation may therefore be a way to quickly estimate the potential predictive power of any individual production characteristic.

The results found in this study show that Levene's test may not be the only useful indicator in the knot size data. A second statistical test was conducted on the knot-size data to evaluate the

presence of spatial patterns: the Wald-Wolfowitz tests. This test looks only at sequences and patterns, and not the underlying difference in mean size or variance. Two groups can match or differ in the Levene's and Wald-Wolfowitz tests without impacting the other result. For instance, two traits may have the same overall average knot size and same overall variance, but that variance could be differentially distributed on the edges or in the center of the carpet. And inversely, two traits may have different overall average knot size or variance, but still both produce random sequences of size across the carpet. These two statistical tests should therefore be interpreted separately.

The Wald-Wolfowitz test shows where sequences of two factors appear to be random or influenced/non-random. The null hypothesis for the Wald-Wolfowitz test is that 1) the sequence of observations was taken from a population with an equal distribution of A and B-type individuals, and 2) the observation were made at random. When the sequence of observations has many repeating values or poor representation of one of the types, it is less likely that the null hypothesis is true. For instance, imagine we flipping a coin ten times. We might expect a result like this, where H = heads and T = tails:

H T H H H T T H T H

Heads was flipped 6 times and tails 4 times, and the pattern appears random: the heads/tails do not alternate evenly, nor do they clump together unnaturally. Indeed, a Wald-Wolfowitz test on this sequence results in a p-value of 0.4, indicating that there is a 40% chance

of flipping this or a similar sequence with a fair coin. With such a high p-value, we accept that this is a fair coin flipped without interference. Now imagine if we flipped a coin ten times, but this was the outcome:

H H H H H H H H T T

Immediately we suspect there is something wrong here. Heads was flipped 8 times and tails only twice, and the two groups cluster together rather than being intermingled. The result of the Wald-Wolfowitz test here is p = 0.002, indicating that there is a 0.2% chance of flipping this sequence with a fair, balanced coin in a neutral setting. From this there are two potential conclusions: either the coin is unbalanced, and heads and tails are not equally likely, or there is a bias or external force that is ensuring heads come up more often (perhaps the flipper is trying to run a gambling scam). This same concept was applied to the knot-size data to see if changes in size occurred in a non-random sequence across the length and width of the carpet. The pair of traits used is whether the region's local mean knot size was bigger (B) or smaller (S) than the overall carpet mean. The sequence of B's and S's represents the units of spatially-grouped data shown in the knot-size plots in Appendix D, moving sequentially across the length or width of the carpet. If the size differences are randomly distributed around the carpet, a Wald-Wolfowitz test would return a non-significant result like in the fair coin flip shown above. However, many of the traits do not follow a random sequence, and result in p-values below the confidence threshold (Table 10.1).

Production Characteristic	Knot Type (μ = 0.491)		Tension Rods - Bottom (μ = 0.494)	
Trait	SY		1	
% of Carpet Width from Left Edge	Region Mean Knot Size	Sequence Group	Region Mean Knot Size	Sequence Group
0	0.5	B	0.51	B
10	0.43	S	0.47	S
14	0.5	B	0.44	S
20	0.46	S	0.48	S
29	0.5	B	0.55	B
30	0.5	B	0.49	S
40	0.5	B	0.46	S
43	0.46	S	0.48	S
50	0.52	B	0.47	S
57	0.47	S	0.46	S
60	0.5	B	0.47	S
70	0.57	B	0.5	B
71	0.5	B	0.55	B
80	0.52	B	0.52	B
86	0.5	B	0.52	B
90	0.46	S	0.5	B
100	0.47	S	0.54	B
P-Value	0.495		0.025	

Table 10.1: Significant and Insignificant Wald-Wolfowitz Tests

Wald-Wolfowitz sequences and p-values for two trait-groups, plotted along the width of the carpet.
S = regional average knot size is **s**maller than full-carpet mean.
B = regional average knot size is **b**igger than full-carpet mean.
Shading given to help visualize randomness of sequences.

There are two possible explanations for this significant result. The first is that the original sample does not have equal numbers of knots bigger or smaller than the mean. Because the data are normally distributed, we know empirically that there *are* equal numbers of knots bigger and smaller than the mean. We can therefore discount the possibility of the sequence drawing from an unbalanced sample. The second explanation for the low p-value is that there is an external force, pattern, or biasing factor that results in a non-random sequence of big and small knots. Because the sequence referenced in the Wald-Wolfowitz tests represents progression along the carpet in either the x- or y-axis, we can conclude that there is a meaningful difference in knot size in different regions of the carpet, and that the different knot sizes are not distributed randomly through the body of the carpet.

Of the 210 sequences tested (one for each trait of each production characteristic, totaling 105, for sequences along both the x- and y-axes, totaling 210), 41 resulted in statistically-significant Wald-Wolfowitz p-values. 38 of those 41 were in the x-axis, representing differences in knot size between the left, right, and center of the carpet along its width. From this, I conclude that widthwise variation is more likely to be linked to differences in production. The rare significance of the sequence in the y-axis implies that variation in that direction is almost always distributed randomly. Going forward, I would be inclined to discard the lengthwise (y-axis) analyses and focus on the x-axis. By cutting out the lengthwise data, the complex multi-variate problem represented in this work is simplified slightly, as the spatial distribution analyses no longer need to be two-dimensional.

Overall, the significant results of the statistical tests indicates that there is some relationship between some production characteristics and knot size. Because the knot sizes have all been centered on the same mean value and within the same range by the standardization scheme, this relationship cannot be in absolute size. Instead, it is in the amount of variance (Levene's tests) and the spatial distribution of that variance in the x-axis (Wald-Wolfowitz tests). Although these relationships did not prove to be especially predictive in this case, it may be possible to tease out more definitive results with another experiment, particularly one that refines the pool of traits to a more manageable number using the Levene's and Wald-Wolfowitz tests, and one that prioritizes widthwise distributions over multi-dimensional ones. Simply expanding and diversifying the sample may even be enough to increase separation and improve predictive power.

Like the knot sizes, the knot shapes also had some clear patterned relationships with the production characteristics (see the knot-shape plots in Appendix D). These visual groupings are supported in nearly every case by Levene's tests for unequal variances (f-statistic) or Student's t-tests for unequal means (t-statistic). The visible clustering patterns are therefore statistically supported, and represent distinct populations tied to the relevant production characteristics and traits.

Communities & Individuals

One of the main themes of this dissertation is the community of practice: a distinct social unit of makers and peripheral participants following a unified technological and social tradition,

in regards to production of certain objects. Being able to identify these communities in the past would provide insight into size, structure, and distribution of weavers in historic contexts. The knot-shape data analyzed in this experiment produced visually distinct “signatures” for the five communities-of-practice (and one solo weaver) represented (Fig. 9.12). Even if the exact cause of the knot-shape variation can’t be tied to a specific production characteristic, there is clearly a patterned difference between groups. This proves the ability of this method to delineate different communities, by showing that they have an underlying similarity in their techno-gestures (knot-tying) that is resistant to personal idiosyncrasy. The Uzbek silk workshops (Khiva and Samarkand) were set up by the same organizations and trained in the same methods on the same materials, and could be considered two production units of the same community-of-practice (Harush 2025, Martinón-Torres et al. 2014). And yet, even these groups are distinguishable at the micro-scale!

When built on a more diverse sample and with dedicated attention, more complicated networks of relationship between communities or across time might be viable outcomes of this work. It is intriguing that a “sum of their parts” approach might be more realistic than analyzing or interpreting production characteristics individually. The “signatures” of the communities represent a holistic view of all their traits rolled into one. A similar conclusion could be reached about the “signatures” of individual weavers.

The individual signatures of weavers is one that I think is particularly worthy of further investigation. Although I wasn’t able to differentiate the two weavers who collaborated on a single carpet in the ethnographic sample (UZ-KH-11), their work wasn’t wholly identical either (Fig. 8.10). Their knots were subtly different: probably too subtle to find it if you didn’t already know

there were two weavers, but different nonetheless. There has been some recent work in the communities-of-practice field in trying to count how many people were involved in a production unit/community, or to identify the individuals in the work (Roux & Krasik 2018:20). While I think it is mostly unrealistic to hope to be able to count weavers in the archaeological record due simply to the low sample size from any specific community, I do think there are opportunities for tracing individuals, and for identifying individuals working in a single carpet. The set of five matched carpets produced in a 17th century Cariene workshop would be an excellent dataset (Fig. 5.27). By applying this method to those carpet and others dated to 17th century Cairo, would these carpets group under one signature, or have their own? Could it be possible to say that those carpets were worked not only in the same workshop from the same cartoon, but actually *by the same person*?

Hidden Traits

Using the knot-shape distribution clouds to make estimates for the historic carpets was made quite difficult by historic distributions that did not match any of the ethnographic data very well (as in Fig. 9.6). These unrepresented distributions tell me that there is a considerably wider range of knot shapes possible than are represented in the ethnographic sample. Because the historic shapes do not appear in the ethnographic data at all, they cannot be estimated by comparison to the ethnographic data.

As has already been mentioned several times, the clear and obvious method for analyzing a complex data set like this is through multi-variate regression. Unfortunately, a robust and

meaningful regression relies on a non-correlative and well-diversified sample. This means that traits that divide the sample into perfectly or predominantly identical groups should be excluded. That was not possible here, as nearly every trait is correlated with at least one other, and some traits are correlated with several other traits. A few traits are even exact duplicates of each other! Excluding correlated traits would have dropped the testable set of variables to only a few (**Experience**, **Weaver**, **Workload**, and **Community**). As these four traits are entirely social-cultural and none is technological, material, or gestural, a limitation like this would have essentially nullified the goals and interests of this project.

A multi-variate regression not only relies on the variables to be uncorrelated, but also for the sample to be well-diversified. This is a step further than general correlation and requires individual traits to be paired with most (or preferably, all) possible companions. For instance, a perfectly-diversified sample of ethnographic carpets would have had each weaver produce a carpet using a curved knife and another using a straight knife. It would have required that a silk-warp, cotton-weft, and wool-pile carpet be woven three times over, once each with continual oversight, intermittent oversight, and no oversight. The sample not only needs to avoid correlation generally, but the diversity needs to be spread evenly across all possible combinations of traits.

Of course, an ethnographic sample with this level of diversity would be essentially impossible to acquire, even with the ability to commission pieces meeting specific criteria. However, even incremental additions would be helpful, and it is very useful that the addition of new carpet and weaver data can be integrated into the existing set without having to throw out

the old group. In theory, ethnographers, students, global hobbyists, or Asian carpet-weavers themselves could add new data to the library continuously, improving the range and distribution of diversity, reducing correlative issues, and improving empirical robusticity with every addition. The addition of new data would also start to fill some holes in this project, where the historic carpets had traits not represented in the modern sample.

In an ethnographic study like this, two types of missing traits are likely: traits that used to exist but are no longer extant, and traits that exist now that did not exist in the past. Some of these are easy to identify. Many of the historic carpets included in this study are double-sided, with minimally- or even entirely un-processed wool as the backing pile. While I would not go so far as to say that no one left on Earth makes carpets like that, they are certainly far less popular now than they seem to have been in the past, and none of the modern weavers included here produce carpets like that. I have only witnessed double-sided carpet-weaving at exhibitions hosted by the Turkmen government explicitly designed to show off the virtuosity of their weavers.

It is likely that ancient weavers had additional tools, techniques, and systems to manage the preparation and weaving of these double-sided textiles, both ones we could imagine or backwards-engineer, and ones we could not. These extra tools and techniques may not be limited to just the physical craft production, but may radiate outwards into more complex social, cultural, economic, and material systems, schemes, and mythologies.

Even if we were able to A) identify a trait that used to exist, B) explain how it was done, and C) understand the larger rippling of that process in ancient society, we would still be faced with one final problem: we have no one to test this process experimentally or ethnographically. I

am sure that if I took one of the double-sided Al-Sabah Collection fragments to any of the weavers in this study, they could make me a copy. In fact, I think that even I could produce a copy with my limited carpet-weaving experience. But the value in ethnographic comparison projects is not in the simple reproduction of artifacts, but rather in the skill, experience, gestures, and instinctive confidence that comes with a specialized artisan. Even if a weaver is capable of the pattern-matching, reverse-engineering, and physical implementation of a particular technique or reproduction of a particular outcome, they will lack the nuance of the ancient maker who did this every day. This is the value of ethnographic experiments normally, that the traditional practitioners have been saturated long-term in the technological, social, material, and mythological landscape of the craft. The depth of their knowledge is why ethnographic collaborations are generally better supported than the use of novice university students who have never tried this craft before and don't know anything of its history or social context. We would still have a very hard time amassing a representative and relevant modern sample if all the living artisans have to learn the technique and reproduce it short-term without being saturated with the larger social-technological context long-term.

The inverse problem, traits that are in use now but weren't in the past, are somewhat more complicated. Some traits in use now are obviously new and not applicable to ancient weavers: mass-manufactured fine-tooth steel beating combs, machine-spun yarns and synthetic dyes, a weaving community that is almost universally literate. These are possible, although perhaps not easy, to exclude from an ethnographic sample. But there are probably some subtler traits that are less clearly modern, or whose variation over time is less intuitive. Handedness, for

instance. Although excluded from the detailed statistical analyses, the handedness of all the weavers in this project was documented. They are all right-handed (or at least, they all report that they are right-handed). There was a clear undercurrent in many discussions that right-handedness was a desirable trait for weaving, and maybe even a necessity. The 100% right-handedness documented here suggests that either the cultural bias against left-handedness is strong enough to entirely exclude left-handed people from artisan spaces, or that some of the reportedly right-handed weavers are actually lefties who have trained themselves to use preference their right in weaving and wider public life. Either and both of these possibilities could have ramifications on the physical structure of the carpet, and almost certainly have ramifications on the social-cultural makeup of weaving communities, the gestures shared by members, and the symbolism and mythologies reproduced by those groups. There is nothing intrinsic to this bias that tells us that it is a new pressure on the weaving industry, but there is also nothing intrinsic to the bias that suggests it always existed in the past either. The bias against left-handedness may not have existed among the Bronze Age populations of the Kopet Dag, or among the weavers of Stein's fragments from Loulan. But as it is so pervasive today, it could be incredibly hard to eliminate that bias in a modern ethnographic sample, or to delineate how an ancient weaving community without that bias might present differently.

Whether it is a trait that used to exist but has died out or a new trait that didn't exist in the past, it is inherently difficult to explain the contributions of these hidden traits to studies like this one. We know that the historic sample mostly does not track with the modern one: we know there is something missing. But there isn't a clear way to know whether there was a modern

factor in the ethnographic sample that should have been excluded, or if there is an ancient factor that should have been included. There is also the possibility that the difference in distributions between the modern and historic samples are not due to a hidden trait at all. These mismatches could be due to the limited and poorly-diversified modern sample! Perhaps with a larger sample and more variations included, the modern distributions will expand and capture the historic ones. It may even be that the historic carpets are more representative of various traits than the modern sample is.

While a better-diversified sample that includes a more comprehensive range of existing techniques would be the easiest and most straightforward way to mitigate these "hidden trait" issues, I posit that there is another way. Rather than working only with carpet-weavers, I would incorporate weavers specializing in other structures. Comparative analyses might be a way to illuminate pressures, traits, and tools that used to be employed in carpet-making but have survived into modern day only in brocades, velvets, or soumaks. And vice versa, if a specific trait in modern carpets is found to not be replicated by any other traditional textile workers, perhaps it should be interpreted as a relatively new practice, rather than one situated in a deep fiber-working tradition.

Defining and understanding tradition and authenticity of modern craftwork is a big issue for many heritage industries. This question of authenticity, often unsupported by any real factual backing or a rigorous understanding of the techniques in question, is what has lead to many of the dubious attributions and imagined provenances of the Victorian and mid-century boom carpets. A Western desire for the "authentic" and the "traditional" incentivizes dealers to

manufacture or exaggerate origins (Baker 1997:363; Eiland III 1993:859; Spooner 1986:202). Buyers hold tight to the romantic idea of the rugged nomad, and the deep-history legacy of a craft is seen as a mark of prestige and worldliness for the buyer. Assumptions about the weaver, her materials, and the imbuement of the carpet with cultural and symbolic meaning are glorified to push a sale.

To think that the enormous number of "tribal" carpets available in the last fifty years were actually produced in remote, nomadic-pastoral communities using exclusively ancient techniques and materials is downright laughable. Carpets are not a mobile product, and weaving carpets regularly, and certainly with any notable economic output, would limit transhumance to only a few moves per year, if that (Baker 1997:364). And similarly, even when a community is truly nomadic-pastoral, that certainly does not mean that they have no contact with sedentary populations, that their materials and techniques are not sourced from sedentary populations, and that their fashions and iconography are not shared and passed through a communal zeitgeist. Regardless of how they were marketed, no more than a few percent of the carpets made in the last two centuries could have been products of the rugged, windswept nomads of imagination.

So what, then, does it mean for carpet weaving to be a traditional craft? To hope to draw a straight, unbroken path between any of the ladies in this study to Loulan or Pazyryk or Thebes would be optimistic at best. Any craft and cultural output, and particularly one with such an expansive temporal and spatial range, goes through phases of transition. Techniques and styles are refined, invented, replaced, or forgotten, they fall in and out of fashion, natural resources dry up and economic incentives shift, populations blend and divide and blend again. This shifting

conception of tradition was documented even in this relatively small-scale study. Many of the weavers expressed a feeling of fulfillment and pride in working in a heritage craft shared with their ancestors, and in reproducing local cultural identity. But many of their techniques have not been in use by this community for even a century yet! The use of a hook in Uzbek carpet weaving is traceable to a 20th century teacher visiting from Azerbaijan, and one of the workshop managers I spoke to here outright said that his weavers used Afghan-Turkmen techniques brought to Uzbekistan in the last fifty years. Clearly, the conception of what is and isn't an ancient skill for a specific group is not well understood even by the practitioners of the craft, much less by carpet dealers and consumers on the other side of the world. As I would classify any sort of hand-weaving to be "traditional" in some sense in the digital age, I was not personally bothered by or invested in drawing specific lineages or excluding modern novelties. But it was incredible (and eye-opening) to see how differently even two people working in the same room interpreted the work, from emotionally ancient to indifferently 1970's.

The notable difference in techniques, cultural associations, and technological diversity between my own experiences in Turkmenistan over the last decade and the writings of Valentina Moshkova, a Soviet anthropologist who documented carpet weaving there in the 1920s-30s, is another reflection of how conceptions of tradition and heritage change, and change rapidly. Moshkova's work documents a wide range of detailed, small-scale variation among different tribal and sub-tribal groups in Central Asia, and a particularly diverse carpet-weaving landscape among the Turkmen. However, with the increasing emphasis put on carpets as a state industry and heritage symbol, the diversity is dying out. Quality-controls and standards designed to ensure that

Turkmen carpets maintain a good global reputation plus the increasing centralization of carpet weaving into state-run workshops is winnowing down the variety of historic and traditional traits. It is clear that many traits have been spread or lost even since Moshkova's surveys a century ago, much less across the ethnic, cultural, technological, and material changes of the last four millennia.

Tradition and authenticity, then, should be perceived as a social construct that is entirely situated within its local context, and not as an inherent or imperative trait carried by techniques, materials, motifs, or structures. Claims of authenticity and deep lineage may fuel carpet sales, but confirming or refuting those claims is not, in of itself, a useful line of archaeological enquiry.

One of the more salients indications of "hidden traits" in this dissertation's results are the many cases where the historic carpet data do not match well to any of the ethnographic data (see Fig. 9.6). While missing or hidden traits is an obvious explanation for these mismatches, another is the simple age of the historic carpets. This study relies entirely on fine-grain measurement of individual knots. Even a "large" knot is less than one square centimeter, and fine knots can be closer to a few square millimeters. Add these tiny units of measurement to the perishable nature of the material, and that is a recipe for problems. The mismatch in data may not indicate a change in technology or a poorly-diversified modern sample, but may be accidental quantification of the taphonomic process. Fibers rot and are eaten by insects and bacteria, dyes leach and chemically decompose, and exposure to water, air, and dirt set off deterioration processes. Textiles are folded, rolled up, wadded into boxes and pots, crushed under bodies and furniture, and become

deformed. Any of these processes could easily affect the small-scale measurements used here. This is a very difficult problem to overcome, and one I do not have a ready solution for.

However, I do want to point out that the historic carpets tested here are quite consistently mismatched to the ethnographic sample despite notably different biographies. They are not all ancient pieces left unprotected in a forgotten cave or grave for centuries or millennia: several are relatively new, dating to the last 150 years, and having spent their lifetimes in rarely-used parlors or rolled up in attics. The late 19th century Baluchi carpets (MU-IN) were not even threadbare, and could be confused for new. It is therefore surprising that nearly all the historic pieces had similar discrepancies from the modern sample. This reinforces the idea that this result may have more to do with missing or hidden traits than with the ravages of time.

It would be imprudent to ignore the possibility of hidden traits affecting analyses like these. Ethnographic comparison may be an effective and reasonable avenue for research like this, but it cannot elucidate everything. The mismatch between the ethnographic and historic knot distributions in this paper are evidence of missing traits. The emphasis, however, should be on finding out what those traits could be (through a wider-reaching ethnographic sample, comparison to other weaving technologies, historical and archaeological research, etc), rather than on discounting ethnographic comparison entirely. Like the evolutionary archaeology framework, the goal should be less to confirm hypotheses and paradigms, and more to identify hypotheses that *don't* work, and to highlight places where data are missing or assumptions are made.

Integrated Textile Approach

In wrapping up this work and through conversation with other textile experts, I have started to wonder if an integrated multi-structural approach might be useful for advancing this project. While specific traits may be hidden or unknown in carpet studies, there may be potential for creative collaboration with other textile structures. If, for instance, the use of a specific type of heddle is known for samits or double-cloths produced in Khotan, it might be reasonable to test carpets for the same structures, even if there is no direct evidence tying that heddle type to carpets of that period. Weaving techniques are rarely exclusive to a single structure, and are passed around and experimented with all the time. If other textile forms are known to employ a particular technique or tool, that could be a way to narrow the reasonable possibilities of technology for a time/place, and to logically winnow possibilities to test with my carpet-specific method.

In addition to using cross-referenced similarities to guide selection of testable techniques, I think my method for measuring carpet knots may be useful in other textile types too. Although designed for the individual, independent, discrete, and robust knots in carpets, I think that, with a bit of re-engineering, it might be possible to use a similar method to map and measure the crossing-over points in flat-woven textiles. Being able to discretely and consistently measure individual features is a sticking point in research into textile variation, but with a large-scale sample of defined measurements at crossing points, some variation research may become viable.

Machine-Learning, Image-Filtering & Automated Processing

More than three million dots were hand-drawn in QGIS to mark the corners of the carpet knots studied here. This took me almost a year of full-time work, and the help of volunteers. It is evident that an expanded sample of knot measurements from more ethnographic and historic carpets, and even from the unsampled areas of these same carpets or from other textile structures entirely, would help to refine outcomes and clarify patterns. But the workload associated with that is daunting. Here arises one huge positive outcome of this dissertation: the reference sample of dots. Although I certainly hope the sample can have direct application in onward historic studies, I think its value as a testing and training unit is much, much higher.

When originally formulating the earliest iterations of this method for my Master's project in 2017, I collaborated with several machine-learning and image-processing experts to see if we could find a way to have a computer consistently and accurately find, mark, and measure knots from a reference photo. Of course, I hoped to avoid doing it by hand and to speed the project. At the time, we concluded that the technology wasn't quite there yet – we could get filtering algorithms to catch about 60% of knots, but never more than that, and the 60% that were captured were always those at the middle of the bell-curve, excluding the more unusual (and probably diagnostic) knots.

When I returned to this method in 2022 to analyze the doctoral carpets, I again looked into using a machine-learning image-filtering method to automate the measurement process. At that time, I came to the conclusion that it was probably possible with newly-available technology, but A) I do not have the skills to code a tool like that, B) even if I had the skills, writing and

troubleshooting the tool would take longer than measuring the knots by hand would, and C) even if the tool could be made to work, its work would still have to be checked by hand in its early implementation and prototyping phase. Ultimately, I decided, it wasn't worth it.

But now, I think, this could be fully automated. With my photographs and human-generated dots as a learning dataset and the rapidly-improving machine-learning imagery models publicly available in the last year, I do not think the barrier for entry of subsequent projects is nearly as high as it was for me. If an automated program could measure the knots, huge quantities of new data should become available relatively quickly. Most major museums have high-resolution photos of their carpets already, which could be easily incorporated into a master database. Even hobbyist carpets could be uploaded, allowing for insight into the learning process and novice indicators that this project did not capture in its work with only skilled adult weavers. The opportunity for new professional projects and citizen science is immense, as is the potential refinement of my methodology and outcomes if the input data could be better diversified through an orders-of-magnitude bigger sample.

A similar but related consideration should be made about the pattern-matching required to make the historic estimations. In its current formulation, this is an inherently subjective task, one which I struggled with greatly. So many of the patterns either did not seem to match at all, or matched multiple distributions equally well. While ideally a diversified sample would make some of those patterns clearer, I doubt they will ever become indisputable. It would therefore be useful to use a machine-learning algorithm to perform the pattern-matching, particularly if it could be trained on successful predictions. This might introduce some objectivity and replicability

that human-matched estimates inherently lack, and it is possible that the computer, less clouded by assumptions and biases, could pick up on subtle differences that human eyes gloss over.

Conclusion

This project had two immediate goals in preparation for research into four long-term goals. The first immediate goal was to determine if technological, idiosyncratic, or social characteristics present during production leave a consistent, measurable trace in the carpet, as measured by knot size and shape. To this I believe I can say, definitively, yes: some production traits do leave measurable traces, as supported by the various statistical tests and visual clustering of data. Not all of the 34 tested variables seem to create traceable outcomes of course, but testing the larger set initially is an important step. By testing a larger group, it clarifies the visual and statistical differences between patterned and unpatterned traits, as well as helps to identify points where correlative or confounding factors may be affecting the data. With a larger and more diverse sample, I think it is possible that the patterns identified here might be refined and/or strengthened, and perhaps that some of the variables excluded from study may be linked to similar patterns too. I also hold out hope that some of the characteristics that seemed to have no predictive power here will turn out to have some when a better-diversified sample allows for more robust multi-variate regression analysis.

The second immediate goal was to evaluate to what extent these measurable links could be used to backwards-engineer the production characteristics of historic carpets. On the whole, this portion of the research was less successful than I had hoped. With only a small handful of the

traits producing better-than-random predictive outcomes in the visible variables, I can only assume that a similar ratio applies to the estimates of invisible traits (the ultimate point of interest). However, I did learn some useful information that will be useful for similar studies going forward.

First, a difference in variance between traits seems to be a good predictor for the trait's ultimate success in estimating historic characteristics. This could be used to refine onward tests and direct resources and attention more efficiently. This project was somewhat hindered by an overwhelmingly unknown dataset and theory, wherein I had little or no intuition for which (if any) outcomes were likely. The use of a variance test to refine the variable list going forward is a useful antidote to that issue. Similarly, it seems that knot sizes vary in a meaningful and patterned way almost, if not entirely, in the widthwise direction. Again, this should allow for more focused and intentional research going forward, and slightly reduced complexity in analyzing large, multi-variate data by excluding lengthwise variables.

Based on the outcomes of the proximal goals, four longer-term goals and potential avenues of research were presented for this methodology and associated results. First, I am interested in how the estimation of production characteristics aligns with attributions of historic carpets and their associated cultural-technological contexts. A little bit of that onward potential was explored here, by showing that some of the fragment groups contain individual pieces that are not well-matched to the rest, and potentially should not be grouped together. If a more detailed and robust comparative network can be established, these types of results might be able to expand. Better clarity on fragment origins as well as confirmation of full carpets is possible. I

am optimistic here, as even the limited power of this project was able to identify some fragments that seem out-of-place in their attributions and associations.

A second long-term goal is to use better understanding of individual carpets to clarify our understanding of larger social-technological systems and communities of practice. Rather than relying on tools and other evidence to tell us about carpets and carpet structure, what can carpet structure tell us about tools and other factors in the ancient community? With a better outline of ancient technologies, tools, processes, and pressures, it may be possible to draw wider conclusions about cultural contact, resource distribution, economic pressures, division of labor, migration, symbolism, and aesthetics. In the same way that the Pazyryk carpet is used as evidence of a trade relationship in prestige goods between the sedentary Achaemenids and the Saka nomads, an understanding of the spread of curved carpet knives could elucidate trade networks or migration patterns of Bronze Age weavers and their wider communities. This in turn could help to clarify the technological evolution of carpets by giving new insight into technological relationships, directions of exchange, and instances of independent innovation. Again, this project showed promising early results: the consideration of the estimated knotting order in 19th century Baluchi carpets exemplifies the type of historical contextualizing that clearer understanding of techniques, tools, and idiosyncrasies could give.

The third long-term goal is to use the estimation of production characteristics to group carpets even without an associated attribution. By linking carpets from disparate contexts, it may be possible to triangulate origin and cultural-demographic relationships. The so-called “Bactrian group” carpets, a potential treasure-trove of information, are assumed to come from a single

cultural origin. If this assumption could be confirmed or refuted, that could re-frame discussions on their origin and trade, and refocus attention on objects that are particularly representative or particularly unusual for the group. Again, there are encouraging early results here. The distinct clustering of communities-of-practice and individual weavers' work here is evidence of the method's ability to pick up on multi-variate pressures, and to represent groups as a complicated interaction of their many parts. If the modern carpets here clustered along their weaving communities, it is reasonable to expect historic carpets to do the same.

Finally, I hope that this and similar projects can be a step towards a better understanding of carpet technological evolution, and provide better insight into the lived experiences of novelty, creativity, invention, and experimentation among ancient artisans. With a more detailed and better-provenanced network of carpet traits, more complex and robust phylogenetic tests should be possible. These in turn can be used to trace the sharing, innovation, and abandonment of techniques, indicate where conformity was the norm vs. where virtuosity was encouraged, and provide new details on individual experiences of gender, class, (dis)ability, creativity, etc.

I believe this dissertation is a useful case study for several issues of carpet studies and textile archaeology. First, it emphasizes a detailed, small-scale, discrete classification system for carpets that does not generalize trait complexes, doesn't assume trait co-morbidity, doesn't place traits in a value hierarchy, and doesn't default to dubious assumptions about tribal and cultural groups. This, I think, is an important feature for textile research, which generally lacks the hard classification schemes present in the typologies of other media.

The majority of post-Medieval extant carpets are classified using an aesthetics-driven system, where similar motifs, color schemes, and composition styles are used to assign carpets to generalized categories. These categories, although many generally relate to a specific time and place in carpet manufacturing history, are not absolute dating or provenance mechanisms, but are widely used as such. This leads to an attribution system that is based on circular comparative networks with little empirical scaffolding or validating external evidence. Although some more detailed classifications add basic macro-scale structural details like the knot shape to the aesthetic analysis, and even finer structural details sometimes appear in formal academic analyses, there is overall very little nuance in the categorization system.

My scheme, based on more than 70 distinct and clearly defined variables designed specifically for Asian knotted carpets, is a notable contribution. It encourages a more distributed view of carpet features and does not emphasize or preference any small aspect over another. This helps to force a more balanced view of similarity and difference, and encourages users to think about more influences on the carpets' production, including ones that are no longer accessible from the carpet itself (such as the weaver's use of a drawn cartoon, or her years of experience). By including (usually) unknowable details in the scheme, I believe a user is pushed to consider more than what is obvious in front of them. This typology is perhaps the most immediately useful and widely applicable outcome of this dissertation.

This project also tests the use of individual knots as the unit of measurement on a grand scale (almost a million!), allowing for greatly expanded sample sizes compared to what is normally possible in textile archaeology, where whole pieces are often the unit of measurement. With

carpets surviving so rarely, a more creative method of expanding the sample is required to draw robust statistical conclusions. Although certainly not novel to this project, I documented the process of linking modern ethnographic analogues to historic research, and for using conclusions drawn from those analogues to check hypotheses about historic pieces. To my knowledge, this is the only time this type of comparative work has been attempted on knotted carpets, and I believe there is potential to push this comparison further.

Finally, I identified a few potential guidelines for future research, indicating where complexity can be reduced and non-predictive variables can be discarded to simplify analysis and streamline sampling. I was even able to give some early-stage evidence that this technique has the power to refute and refine attributions, at least at a basic level. As perhaps the most iconic material culture of middle Asia and a victim of uninformed romantic public imagination for over a century, the archaeology of knotted carpets does not benefit solely from success, but from the attention and the attempt.

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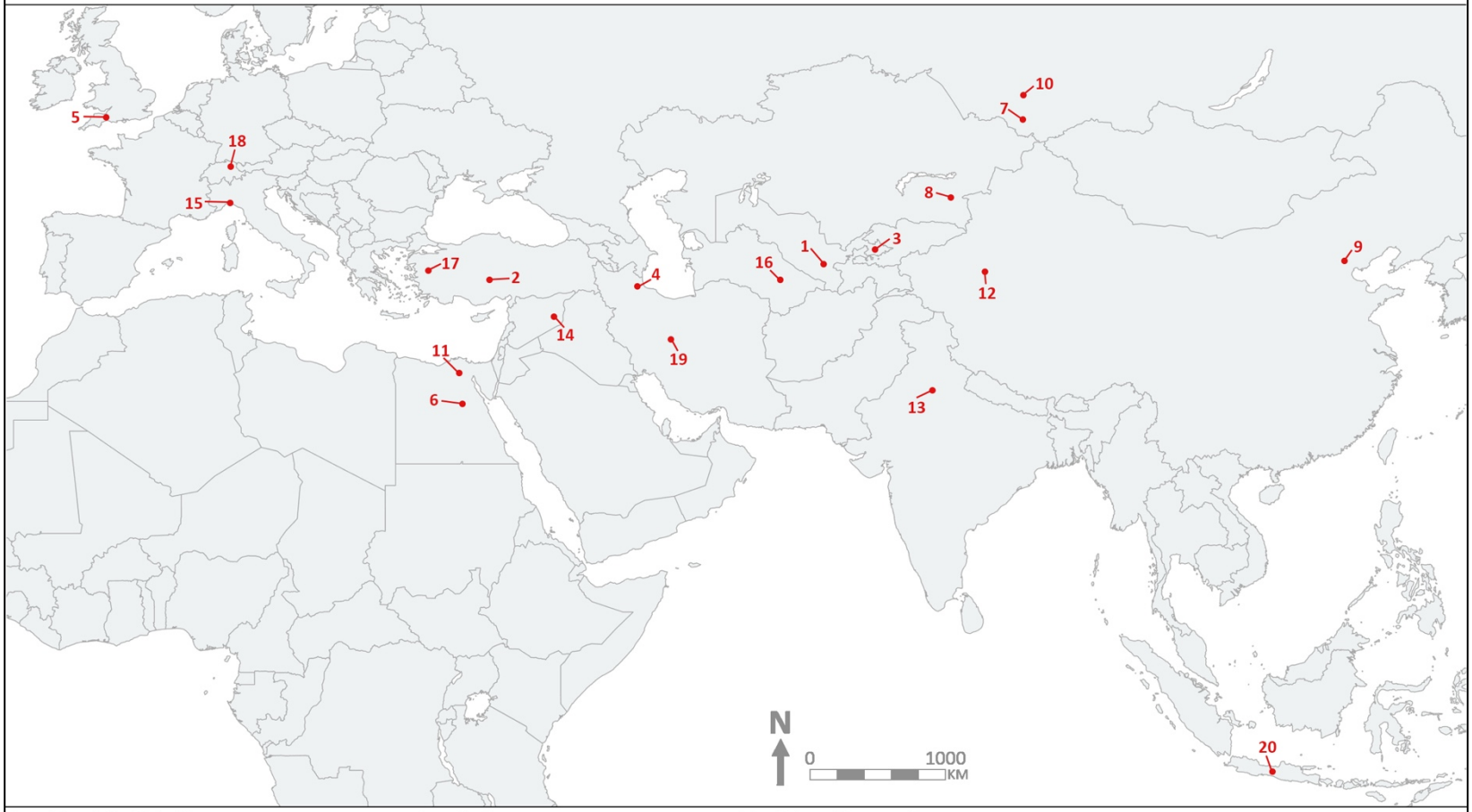
Appendix A. Maps

This section contains maps for all the locations mentioned in the text. This includes modern and historic cities, archaeological sites, the extent of kingdoms and empire (date given), generalized regions for cultural groups, and major geographic features like mountain ranges and basins. A summary of the references is given at the end of the section; full citations are given in the Bibliography.

All figures by V. Sluka.

Cities & Archaeological Sites (A-J)

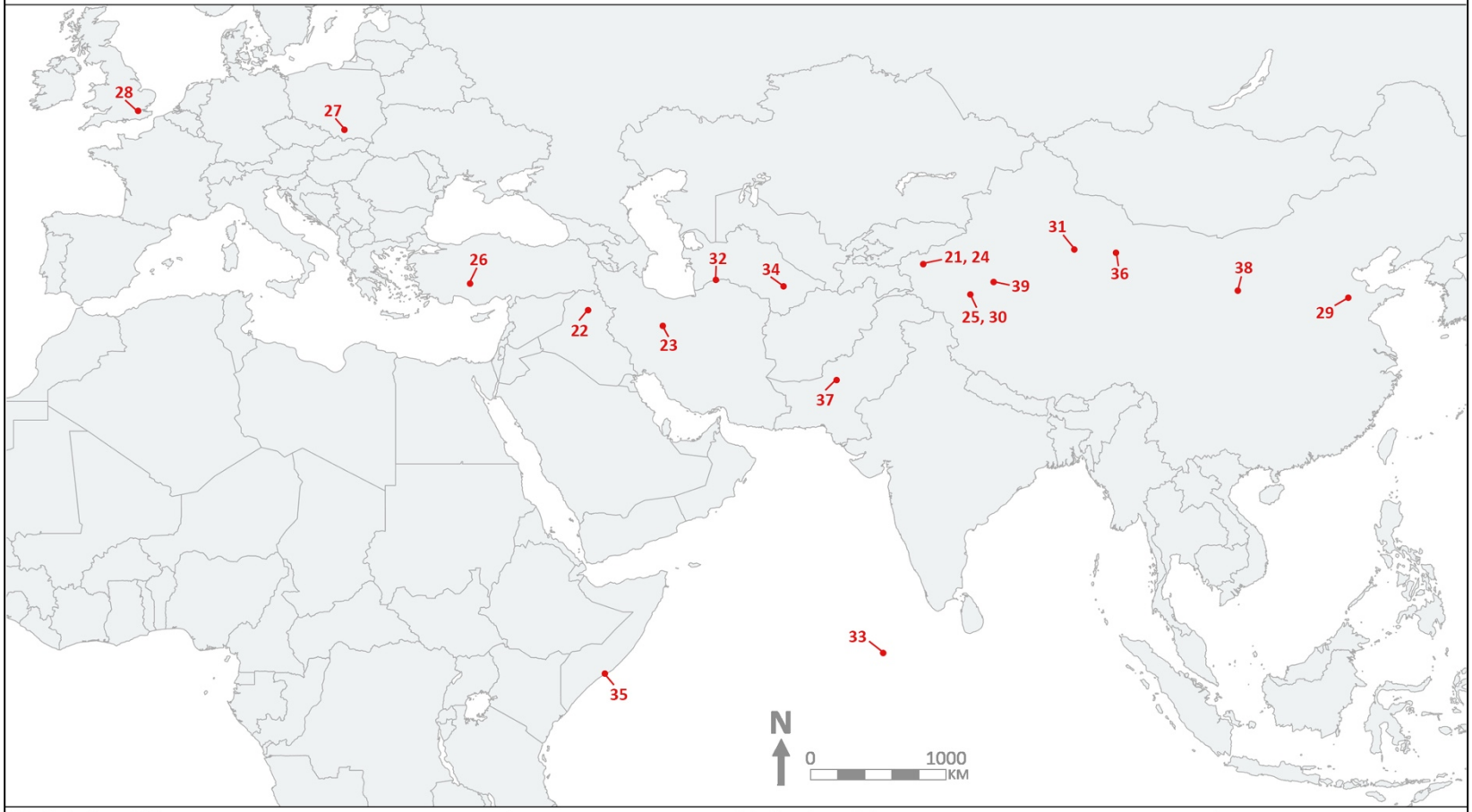
Figure A.1



1	Afrasiab, Uzbekistan	6	el Badari, Egypt	11	Cairo / Fustat, Egypt	16	Gonur Depe, Turkmenistan
2	Aksaray, Turkey	7	Bashadar, Russia	12	Chärchän, China	17	Gördes, Turkey
3	Andijan, Uzbekistan	8	Begash, Kazakhstan	13	Delhi, India	18	Irgenhausen, Switzerland
4	Ardabil, Iran	9	Beijing, China	14	Dura Europos, Syria	19	Isfahan, Iran
5	Axminster, United Kingdom	10	Bisyk, Russia	15	Genoa, Italy	20	Java, Indonesia

Cities & Archaeological Sites (K-N)

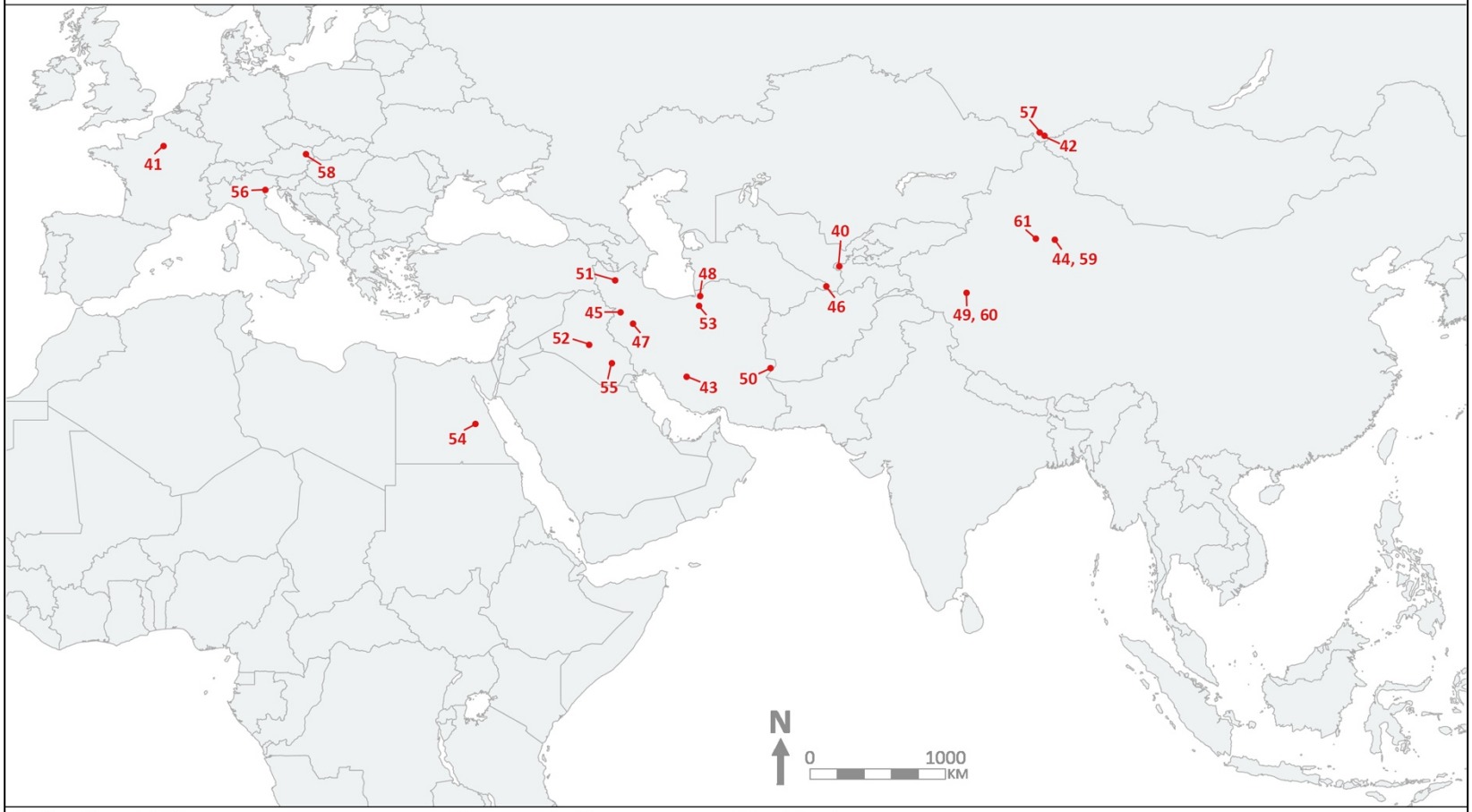
Figure A.2



21 Kaladun, China	26 Konya, Turkey	31 Loulan, China	36 Magao / Dunhuang, China
22 Kar-Tukulti-Ninurta, Iraq	27 Krakow, Poland	32 Magtymguly, Turkmenistan	37 Mehrgarh, Pakistan
23 Kashan, Iran	28 London. United Kingdom	33 Maldives	38 Ningxia, China
24 Kashgar, China	29 Longshan, China	34 Merv, Turkmenistan	39 Niya, China
25 Khotan. China	30 Lop, China	35 Mogadishu, Somalia	

Cities & Archaeological Sites (O-Z)

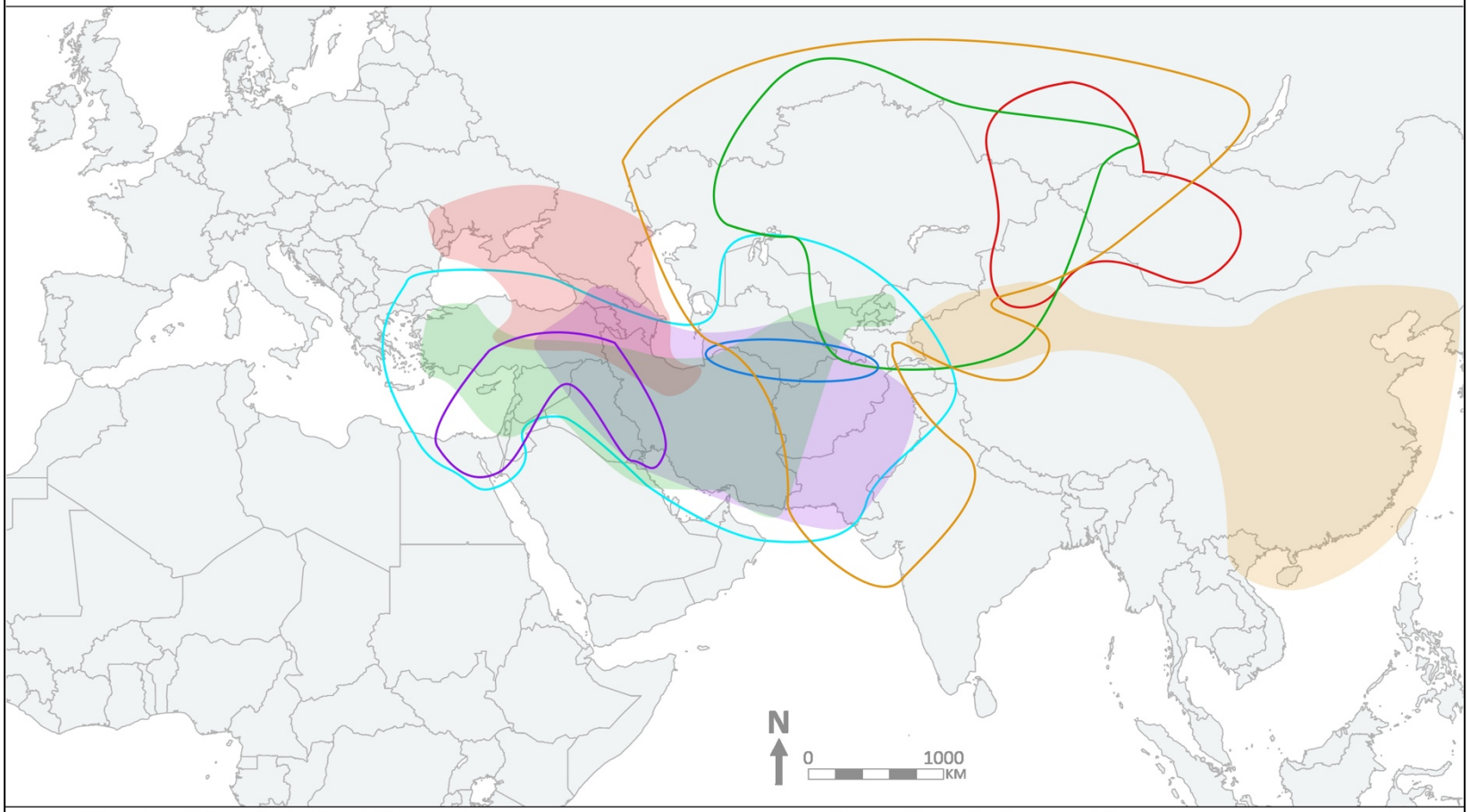
Figure A.3



40 Panjikent, Tajikistan
41 Paris, France
42 Pazyryk, Russia
43 Persepolis, Iran
44 Qizilchoqa, China
45 Sanandaj, Iran
46 Sapalli Tepe, Uzbekistan
47 Seh Gabi, Iran
48 Shah Tepe, Iran
49 Shanpula, China
50 Sharh-i Sokhta, Iran
51 Tabriz, Iran
52 al-Tar, Iraq
53 Tepe Hissar, Iran
54 Thebes / Luxor, Egypt
(Tomb of Kha & Merit, Tomb of Madja)
55 Ur, Iraq
56 Venice, Italy
57 Verkh-Kaldzhin, Russia
58 Vienna, Austria
59 Yanghai, China
60 Yarkand, China
61 Yingpan, China

Kingdoms, Empires, & Cultural Groups (< 150 CE)

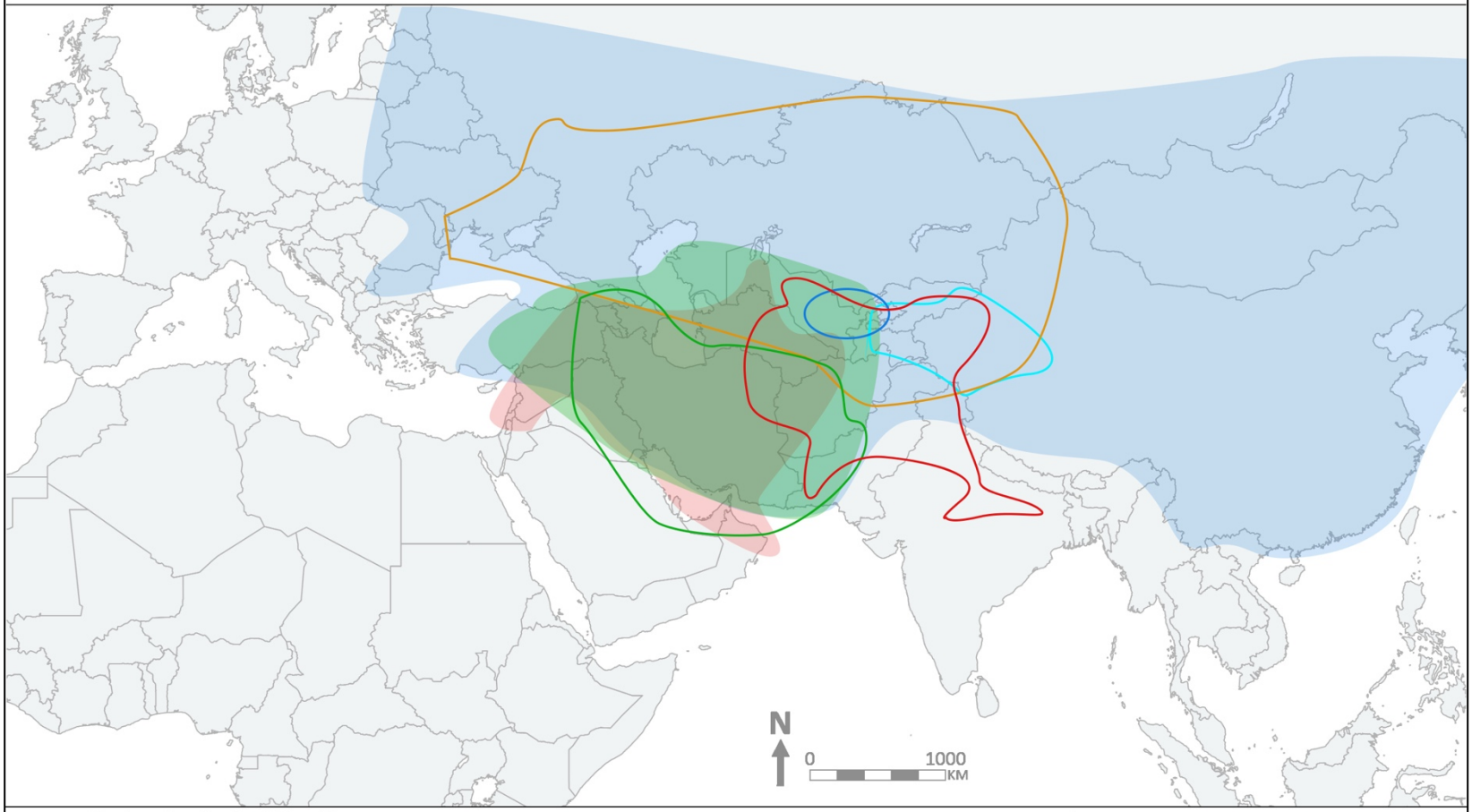
Figure A.4



- Afanasievo Culture (c. 3000 BCE) [1,2]
- Bactria-Margiana Arch. Complex (c. 2200 BCE) [4]
- Andronovo Culture (c. 1600 BCE) [3]
- Eastern Scythian (Saka) Culture (c. 700 BCE) [5, 8]
- Assyria (c. 650 BCE) [6a]
- Achaemenid Empire (c. 500 BCE) [7]
- Western Scythian Culture (c. 300 BCE) [8]
- Seleucid Empire (c. 280 BCE) [6j]
- China, Han Dynasty (c. 0 CE) [6b]
- Parthian Empire (c. 90 BCE) [6f]

Kingdoms, Empires, & Cultural Groups (150 - 1550 CE)

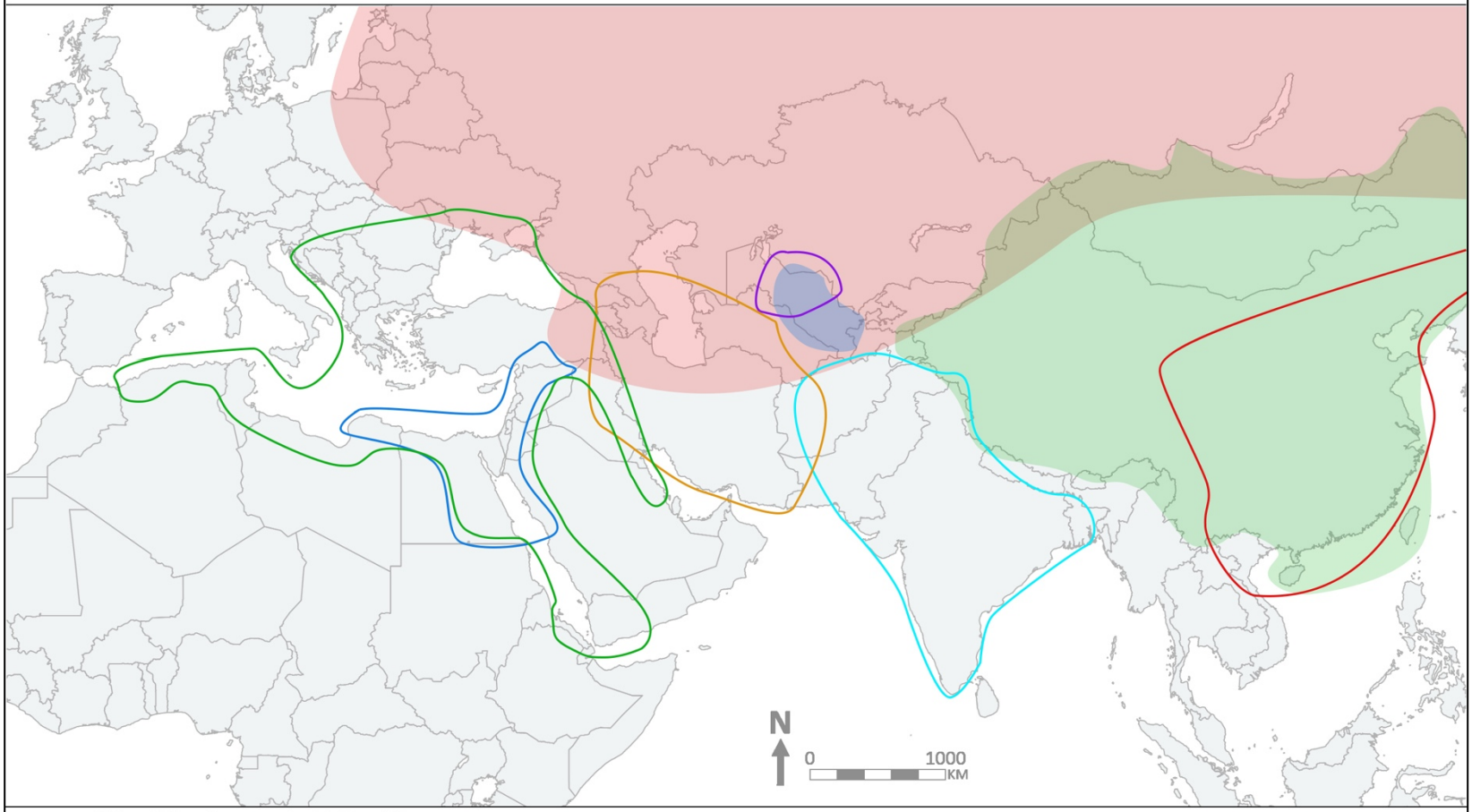
Figure A.5



- Kushan Empire (c. 150 CE) [9]
- Sogdia (c. 300 CE) [10]
- Sassanid Empire (c. 620 CE) [6i]
- Western Turkic Khaganate (c. 625 CE) [11]
- Kingdom of Khotan (c. 1000 CE) [12]
- Seljuk Empire (c. 1100 CE) [6k, 13]
- Mongol Empire (c. 1280 CE) [6c]
- Timurid Empire (c. 1400 CE) [14]

Kingdoms, Empires, & Cultural Groups (>1550 CE)

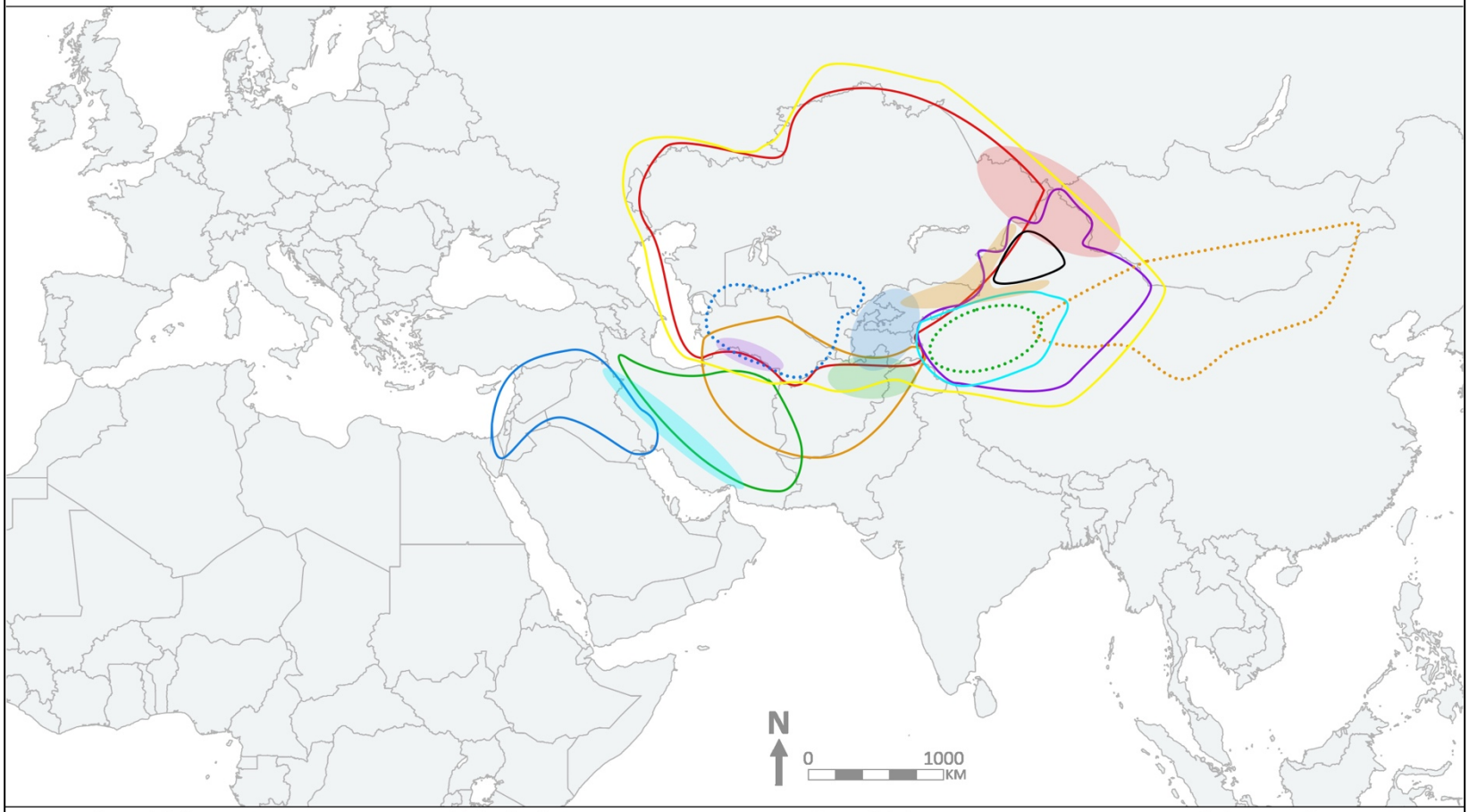
Figure A.6



- China, Ming Dynasty (c. 1440 CE) [15]
- Mamluk Sultanate (c. 1450 CE) [16]
- Ottoman Empire (c. 1550 CE) [6e]
- Safavid Empire (c. 1600 CE) [17]
- Khanate of Khiva (c. 1700 CE) [18]
- Mughal Empire (c. 1700 CE) [6d]
- China, Qing Dynasty (c. 1750 CE) [6g]
- Emirate of Bukhara (c. 1800 CE) [19]
- Tsarist Russia (c. 1850 CE) [6h]

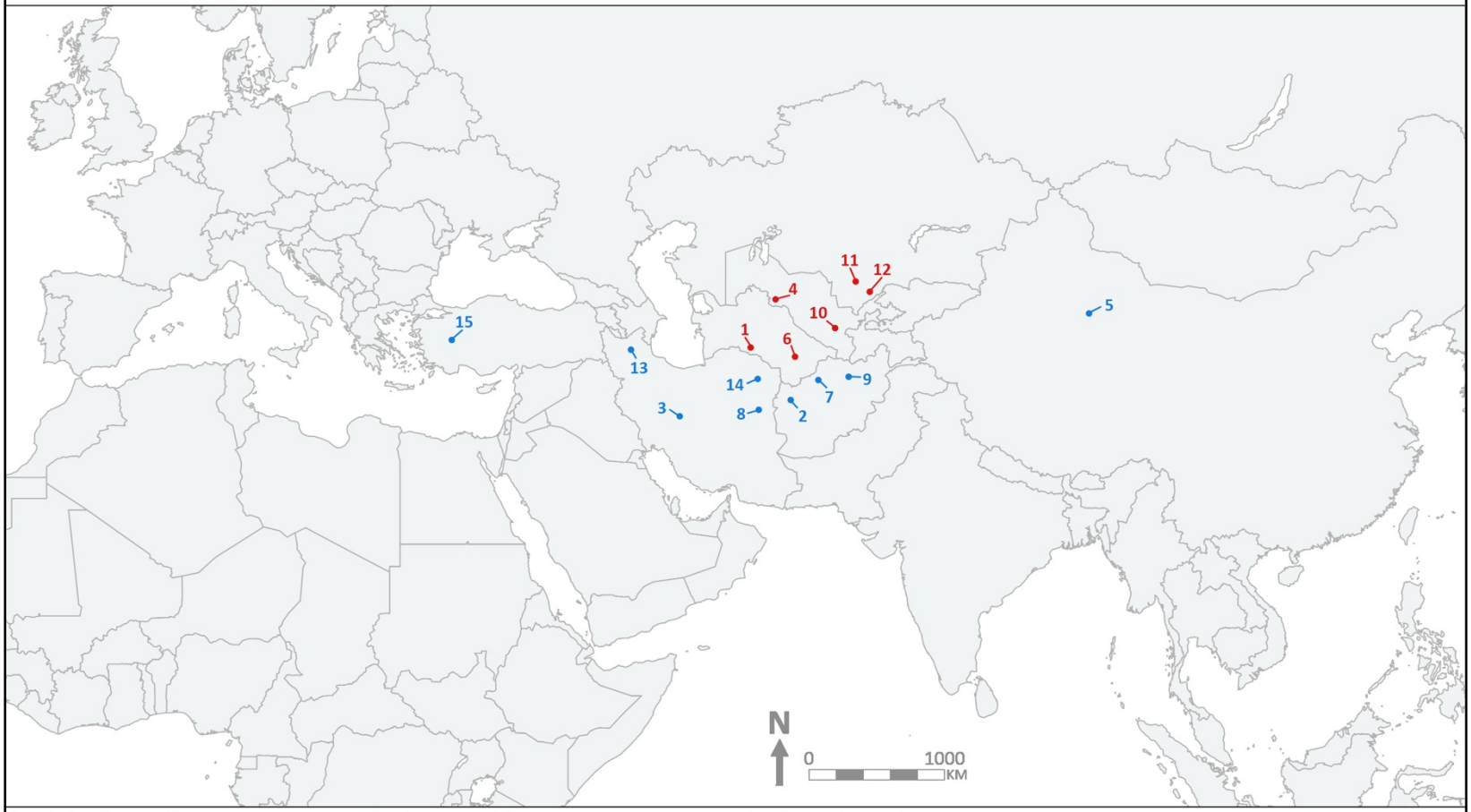
Geological Features & Regions

Figure A.7



Study Locations

Figure A.8 *(large-format reproduction of Fig. 1.1)*



1 Ashgabat, Turkmenistan
2 Herat, Afghanistan
3 Isfahan, Iran
4 Khiva, Uzbekistan
(including villages of Angarik, Ingilis, and Gondimiyon)
5 Loulan, China
6 Mary, Turkmenistan
7 Maymana, Afghanistan
8 Qaen, Iran
9 Samangan Province, Afghanistan
10 Samarkand, Uzbekistan
11 Shauldir, Kazakhstan
12 Shymkent, Kazakhstan
13 Tabriz, Iran
14 Torbat-e Heydarieh, Iran
15 Ushak, Turkey

Color Key:
Ethnographic Data
Historic Data

References (Abridged)

[1] Trautmann et al. 2023
[2] Honeychurch et al. 2021
[3] Jia et al. 2017
[4] Sarianidi 2002
[5] Davis-Kimball et al. (eds) 1995
[6] Encyclopedia Britannica 2025
[7] O'Brien (ed) 2007
[8] Juras et al. 2017
[9] Di Castro 2005
[10] Smithsonian Institution 2025
[11] Dosymbaeva & Zholdasbekov (eds) 2013
[12] Mallory & Mair 2000
[13] Peacock 2015
[14] World History Encyclopedia 2025
[15] Robinson 2021
[16] Amitai 2023
[17] Encyclopaedia Iranica 2025
[18] Wright 2008
[19] Bregel 2003

All geological features, regions, cities, and sites are synthesized by the author from Google Maps and Wikipedia, Oct. 2025.

Appendix B. Carpet Structural Diagrams

This section contains diagrams representing the structure of every study carpet, including both the ethnographic and historic samples. These diagrams are a holistic illustration of the production characteristic data, and also give extra details on small-scale variations that are not captured in the documentation system.

All figures by V. Sluka

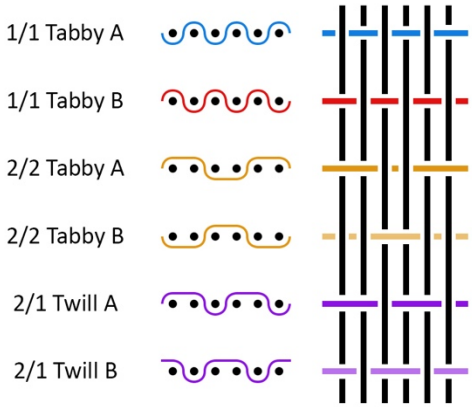
Structural Diagrams Key



WARP

Black warps are on-level with the weaving plane. Gray warps are depressed behind the weaving plane, away from the weaver.

There are three Warp Patterns (I, II, III).



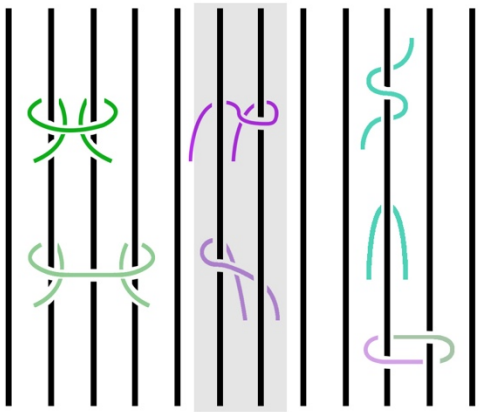
*examples not exhaustive

WEFT

Blue and red represent the two sheds of a 1/1 tabby, which are the most common in carpets. Purple and orange are used for twills and higher-order tabbies. Different saturations are used when more than 2 sheds are present.

There are sixteen Weft Patterns (A-R). These patterns are defined by how individual knots align with the weft, and the colors do not always match.

Where it is unknown how each pick interacts with successive picks or the side-binding, the wefts stop at the edge of the weaving zone.



KNOTS

Symmetric knots are shown in green, asymmetric knots in purple, and wrap knots in teal. Unusual knots forms are shown desaturated. Knots whose shape could not be determined are shown with a green-and-purple link. When mismatched knots are identified, they are shown distributed randomly through diagrams.

A grey shaded section shows where the central part of the carpet has been condensed; the shaded knots, warp, and weft patterns repeat to full-width.

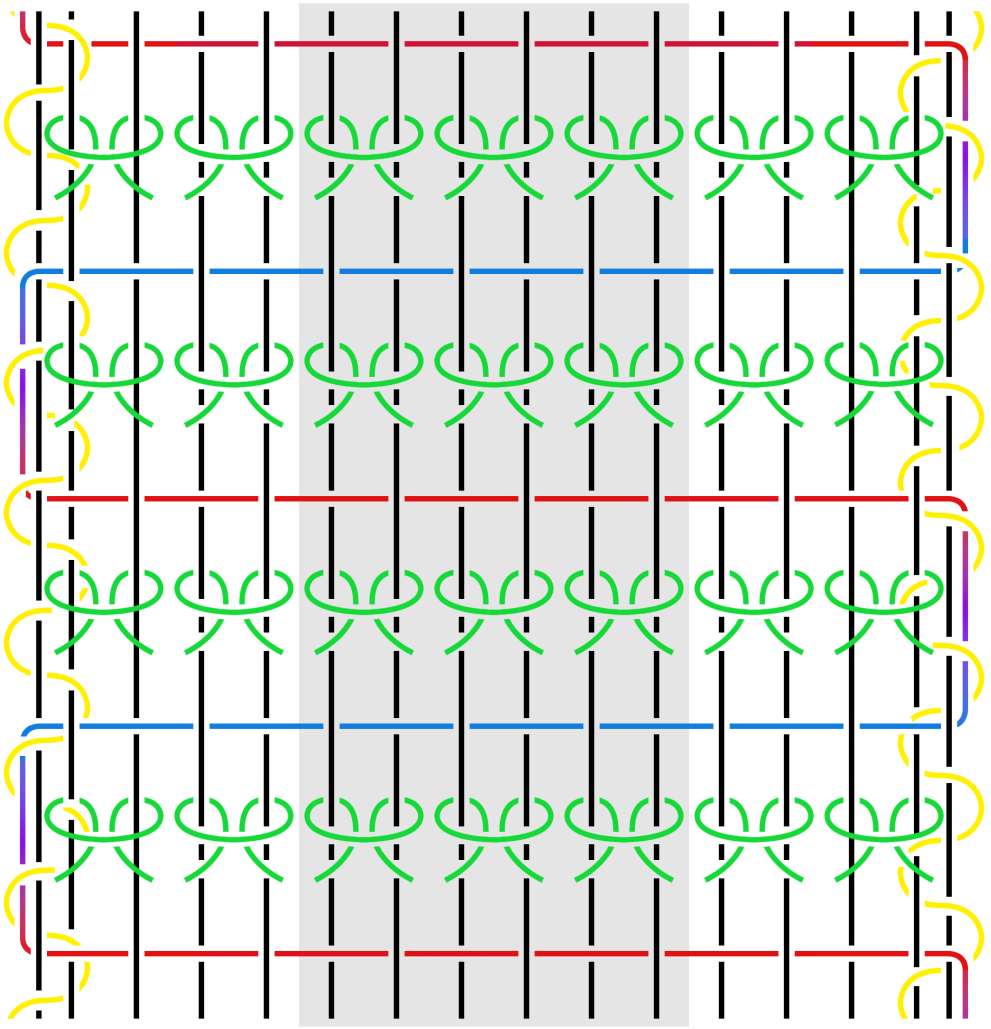
*examples not exhaustive



SIDE BINDINGS

Side bindings are shown in yellow when they are made of a separate yarn/skein from the wefts. When it is unclear, bindings are shown in yellow and the wefts end at the edges of the weaving zone.

KZ-SH-1 **Figure B.1**



Weaver: Madina Ahmetova (Мадина Ахметова)
Workshop: Altyn Orda [Алтын Орда]
Shymkent, Kazakhstan
Woven 2021
Location: Private Collection

Total Size (l x w): 0.897 x 0.423 meters
Survey: 14

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C; D
Knot Spacing: 0
Knot-Row Offset: 0

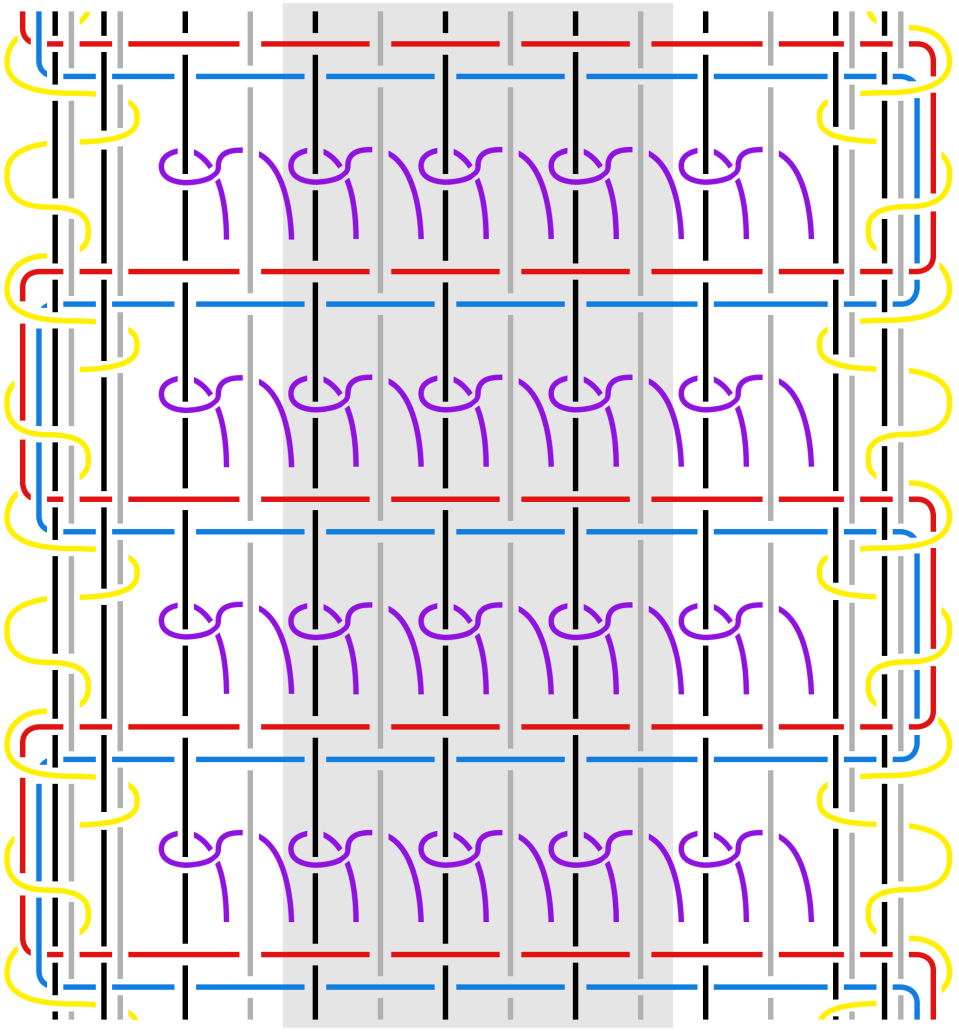
Weft Shot Pick Count: 1
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 2:2
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

KZ-SH-2 **Figure B.2**



Weaver: Kulyash Aidarbekova (Куляш Айдарбекова)
Workshop: Altyn Orda [Алтын Орда]
Shymkent, Kazakhstan
Woven 2021
Location: Private Collection

Total Size (l x w): 0.424 x 0.411 meters
Survey: 14

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

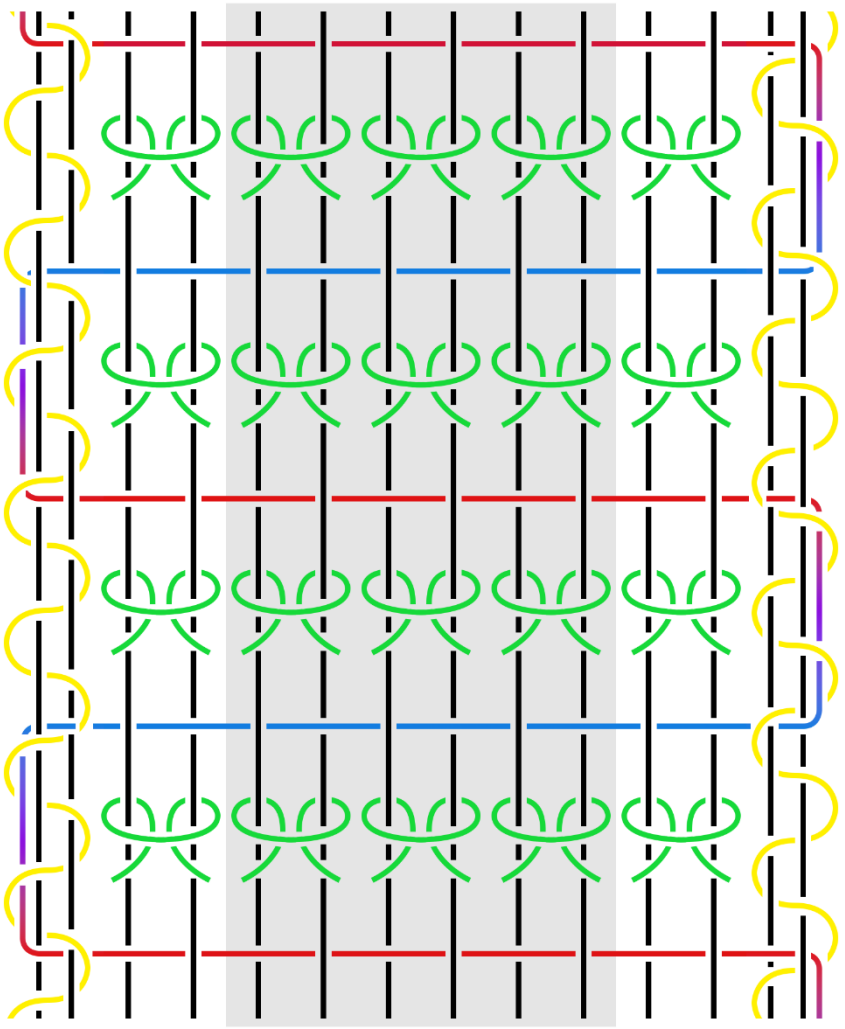
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Tabby
Binding Warps: 2:2
Binding-Weft Overlap: S

Notes:

- binding added at regular intervals, 1 whole and 1 half tabby per row of knots

KZ-OT-1 **Figure B.3**



Weaver: Sholpan Zhycinbek (Шолпан Жүсінбек)
Workshop: (NA)
Shauldir, Kazakhstan
Woven 2021
Location: Helen Louise Allen Textile Collection, Univ. Wisconsin

Total Size (l x w): 0.700 x 0.477 meters
Survey: 15

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

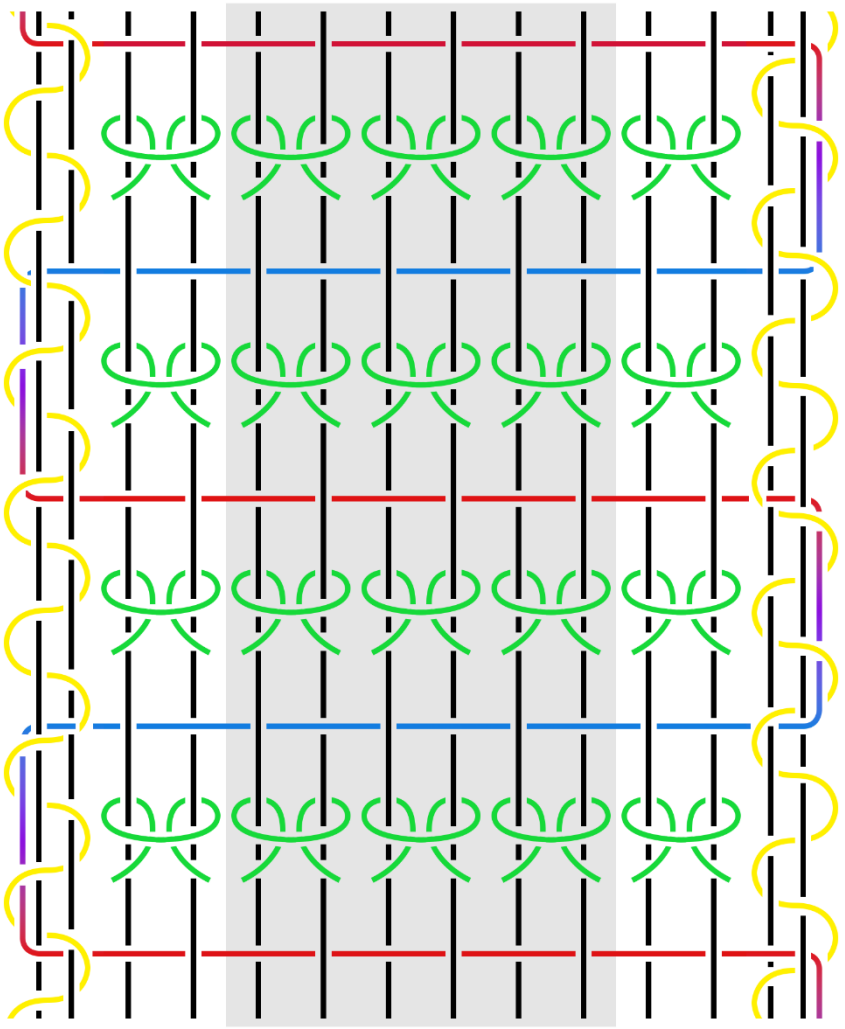
Weft Shot Pick Count: 1
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 2:2
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

KZ-OT-2 **Figure B.4**



Weaver: Sholpan Zhycinbek (Шолпан Жүсінбек)
Workshop: (NA)
Shauldir, Kazakhstan
Woven 2021
Location: Private Collection

Total Size (l x w): 0.674 x 0.486 meters
Survey: 15

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

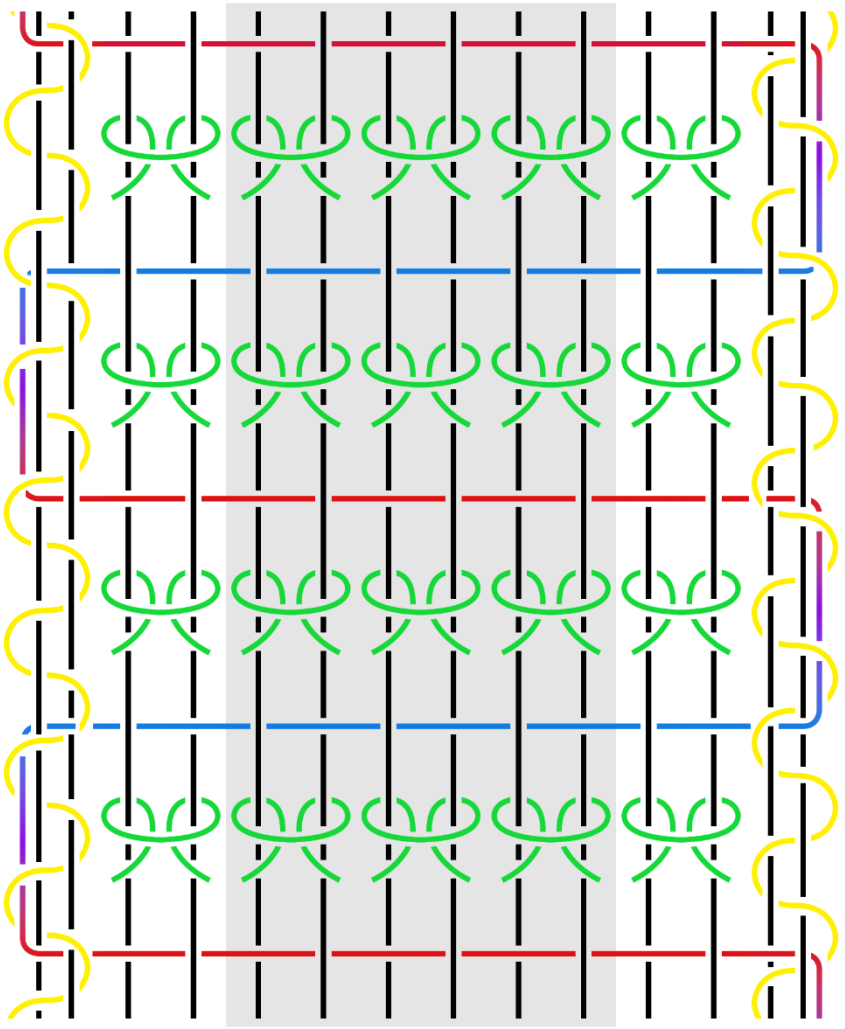
Weft Shot Pick Count: 1
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 2:2
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

KZ-OT-3 **Figure B.5**



Weaver: Sholpan Zhycinbek (Шолпан Жүсінбек)
Workshop: (NA)
Shauldir, Kazakhstan
Woven 2021
Location: Not Collected

Total Size (l x w): 0.686 x 0.481 meters
Survey: 15

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

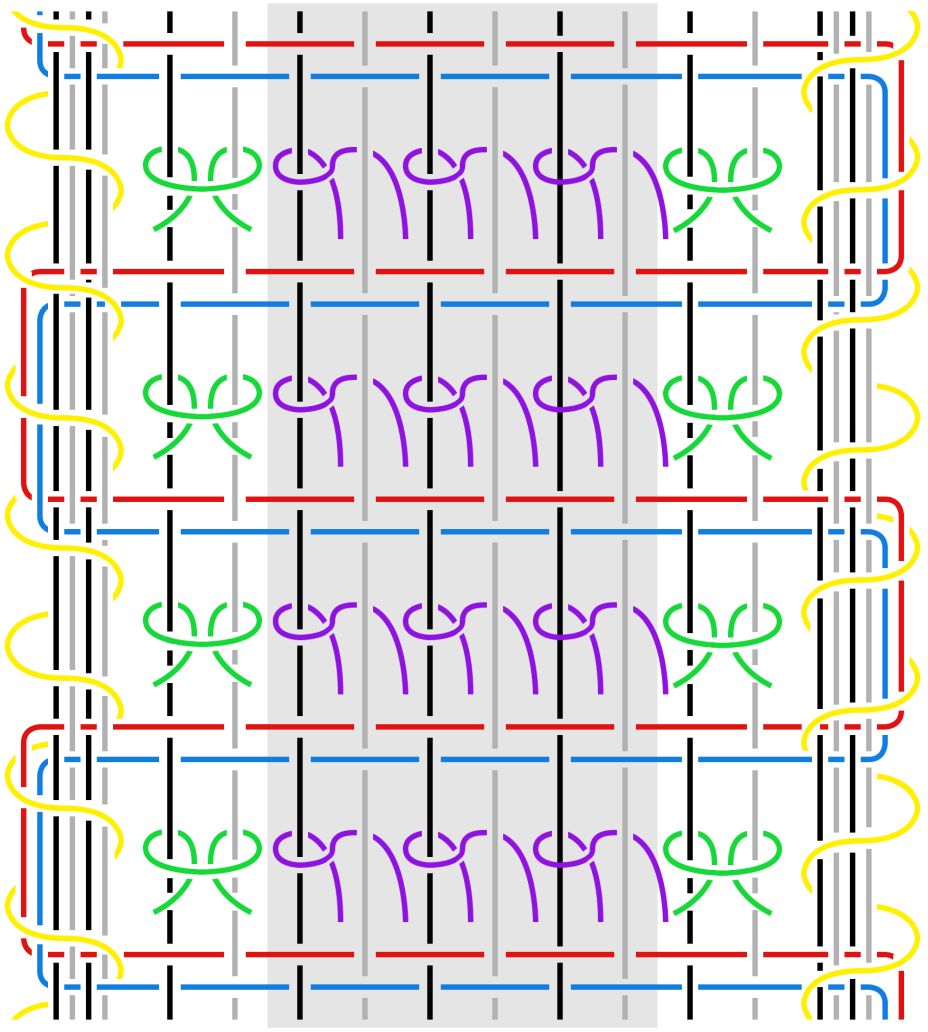
Weft Shot Pick Count: 1
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 2:2
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

TK-MA-1 **Figure B.6**



Weaver: Anonymous C (“Christina”)
Workshop: (NA)
Mary, Turkmenistan
Woven 2021
Location: Private Collection

Total Size (l x w): 0.984 x 0.481 meters
Survey: 16

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: D
Knot Spacing: 0
Knot-Row Offset: 0

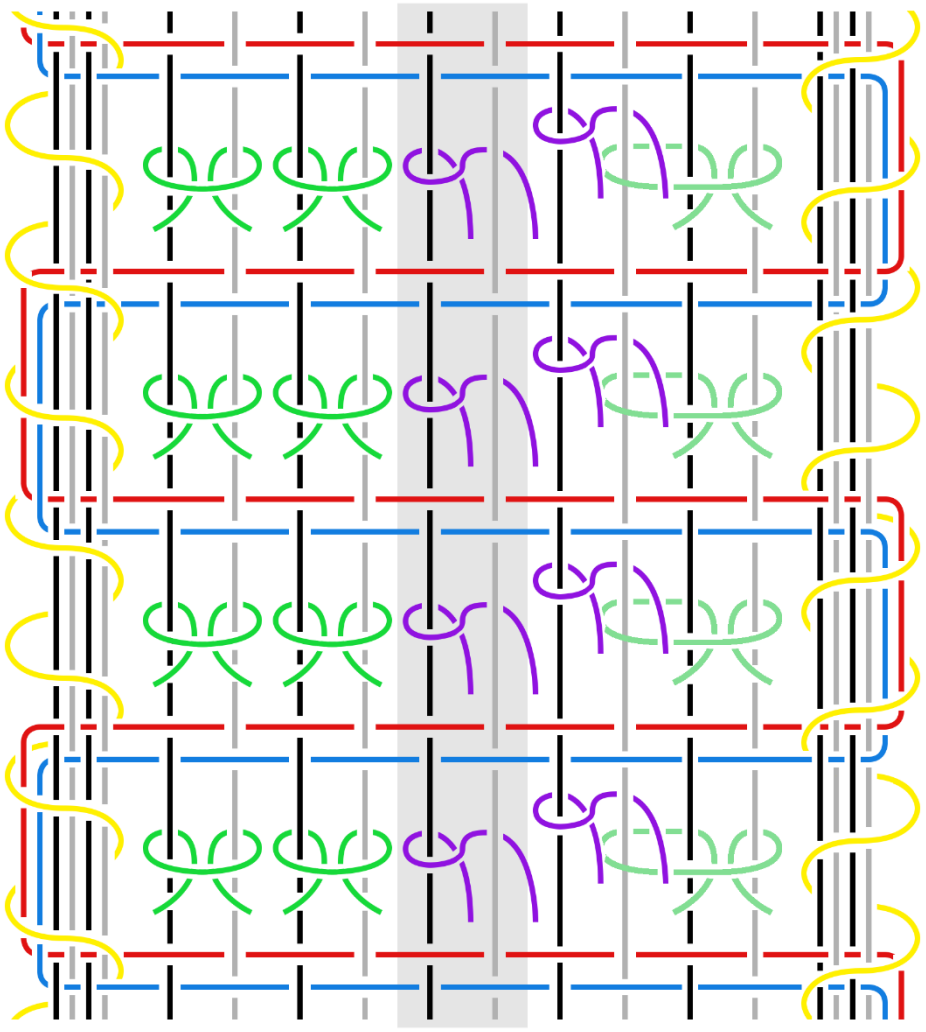
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: 4:1
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

TK-MA-2 Figure B.7



Weaver: Anonymous A (“Anna”)
Workshop: (NA)
Mary, Turkmenistan
Woven 2021
Location: Helen Louise Allen Textile Collection, Univ. Wis.

Total Size (l x w): 1.045 x 0.526 meters
Survey: 16

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: D
Knot Spacing: 0
Knot-Row Offset: 0

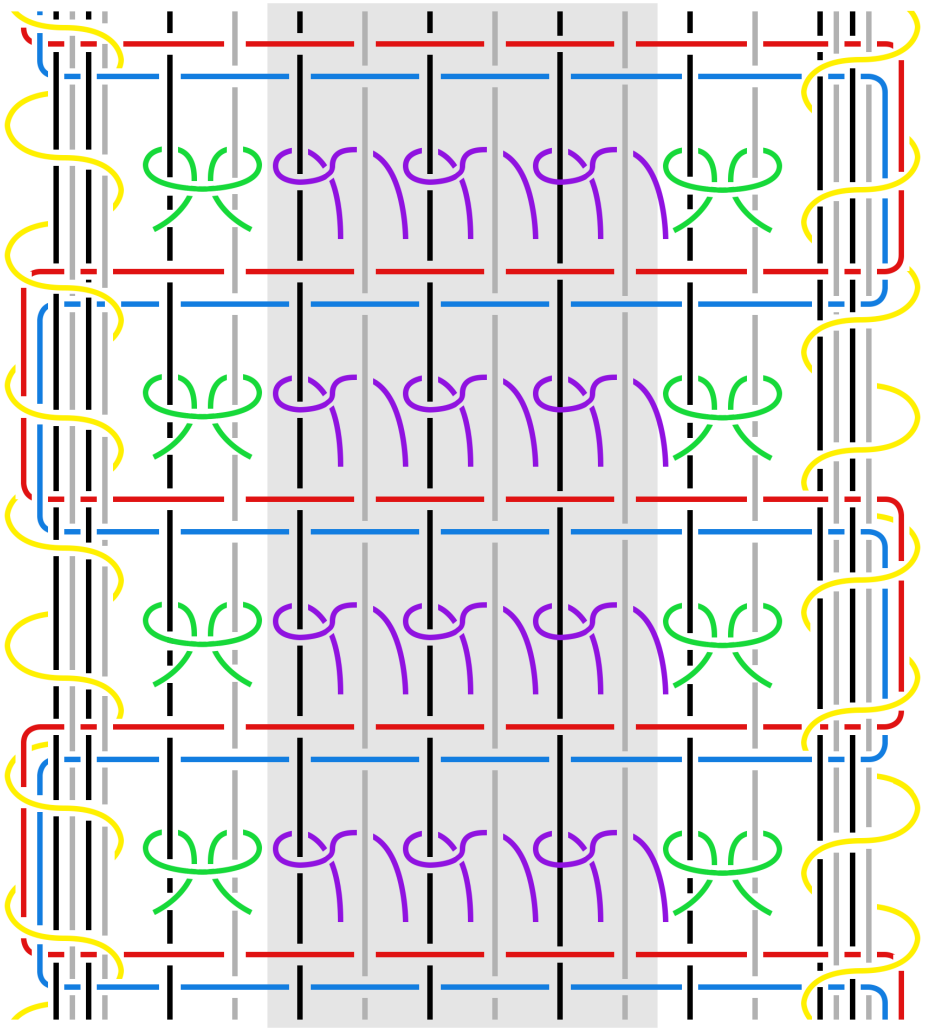
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: 4:1
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

TK-MA-3 Figure B.8



Weaver: Anonymous B (“Barbara”)
Workshop: (NA)
Mary, Turkmenistan
Woven 2021
Location: Private Collection

Total Size (l x w): 1.059 x 0.517 meters
Survey: 16

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: D
Knot Spacing: 0
Knot-Row Offset: 0

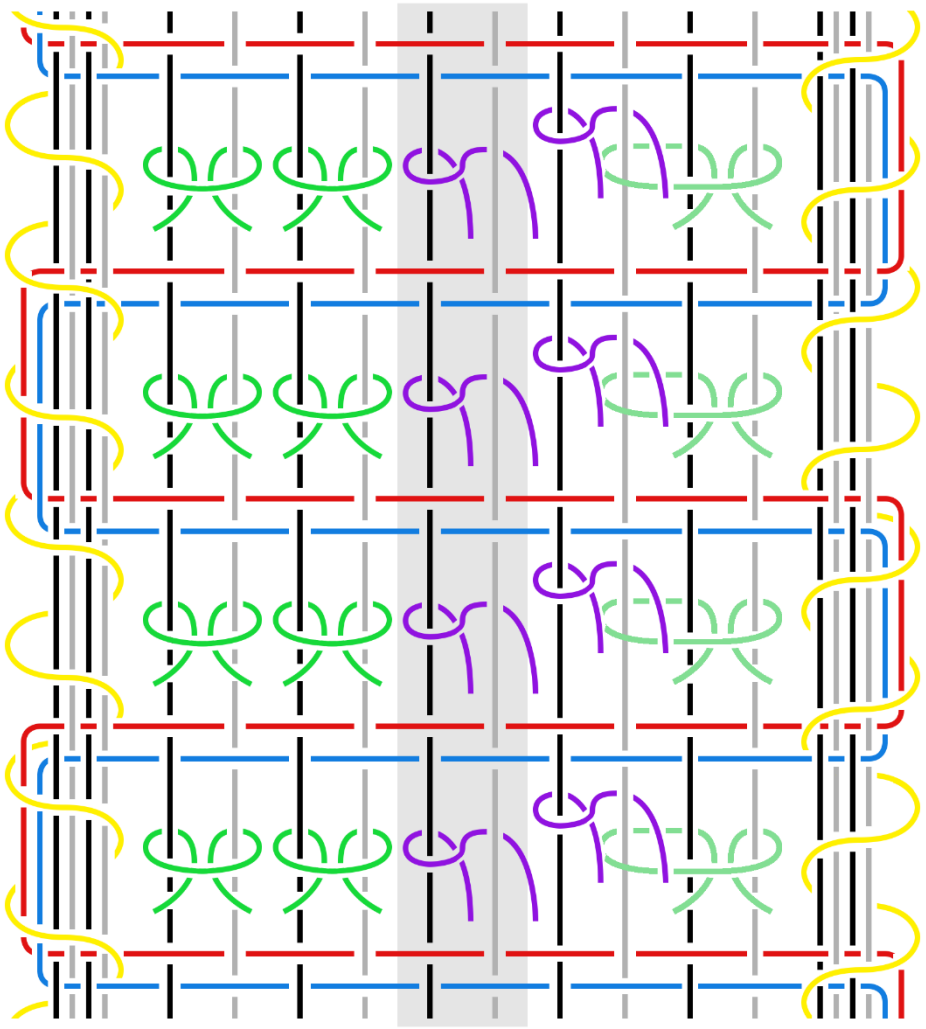
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: 4:1
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

TK-MA-4 Figure B.9



Weaver: Anonymous B (“Barbara”)
Workshop: (NA)
Mary, Turkmenistan
Woven 2021
Location: Private Collection

Total Size (l x w): 1.005 x 0.518 meters
Survey: 16

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: D
Knot Spacing: 0
Knot-Row Offset: 0

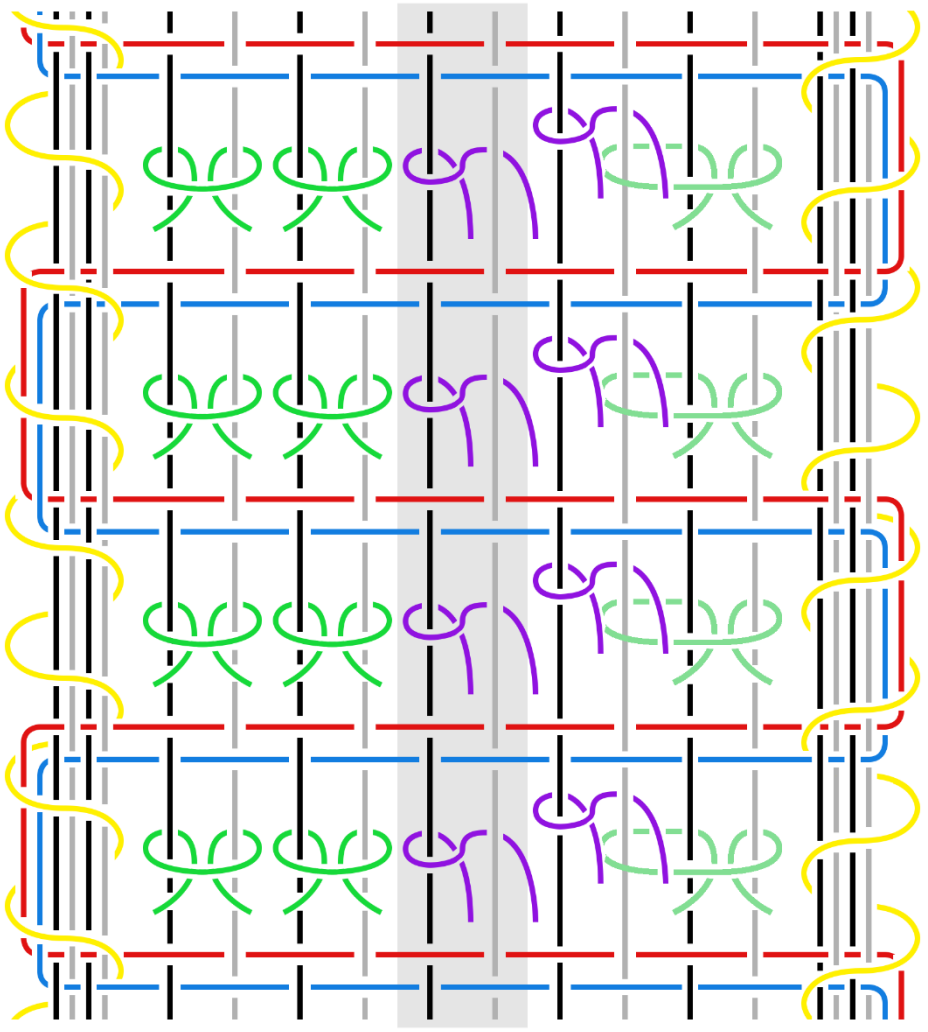
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: 4:1
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

TK-MA-5 Figure B.10



Weaver: Anonymous A (“Anna”)
Workshop: (NA)
Mary, Turkmenistan
Woven 2021
Location: Private Collection

Total Size (l x w): 1.038 x 0.521 meters
Survey: 16

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: D
Knot Spacing: 0
Knot-Row Offset: 0

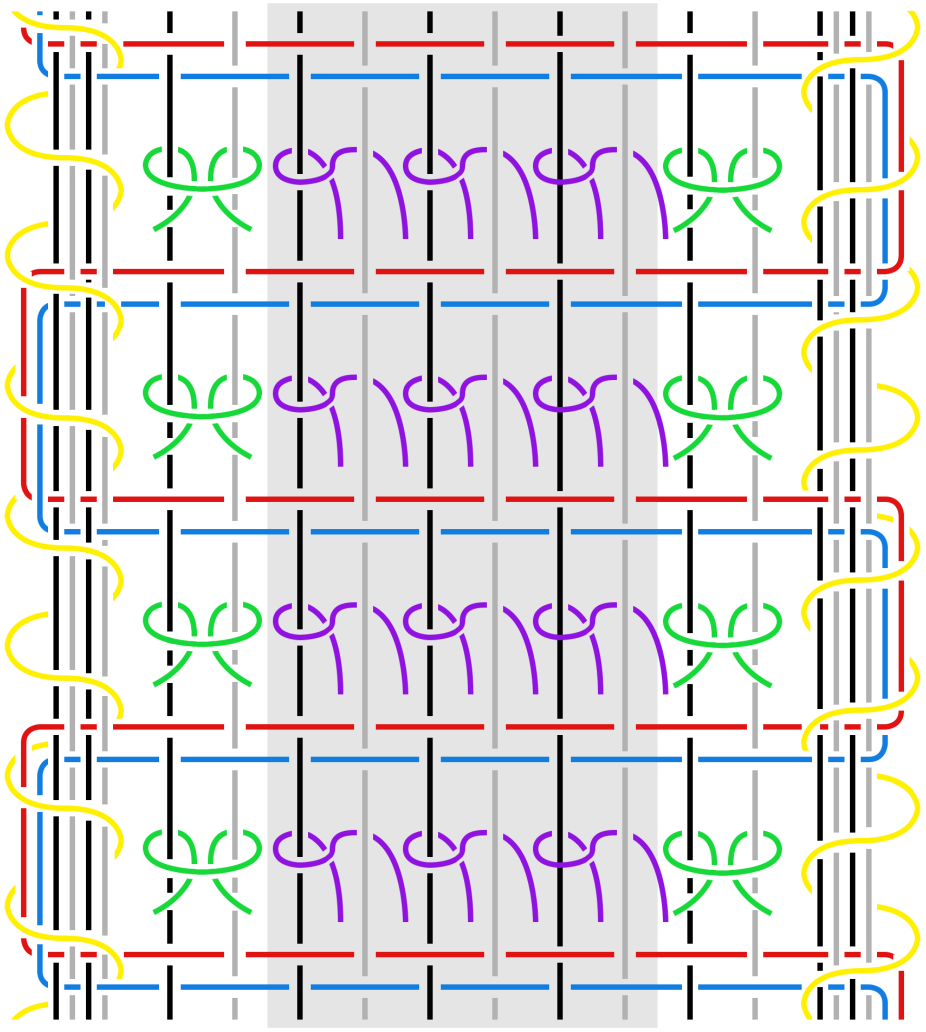
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: 4:1
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

TK-MA-6 Figure B.11



Weaver: Anonymous A (“Anna”)
Workshop: (NA)
Mary, Turkmenistan
Woven 2021
Location: Private Collection

Total Size (l x w): 1.018 x 0.512 meters
Survey: 16

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: D
Knot Spacing: 0
Knot-Row Offset: 0

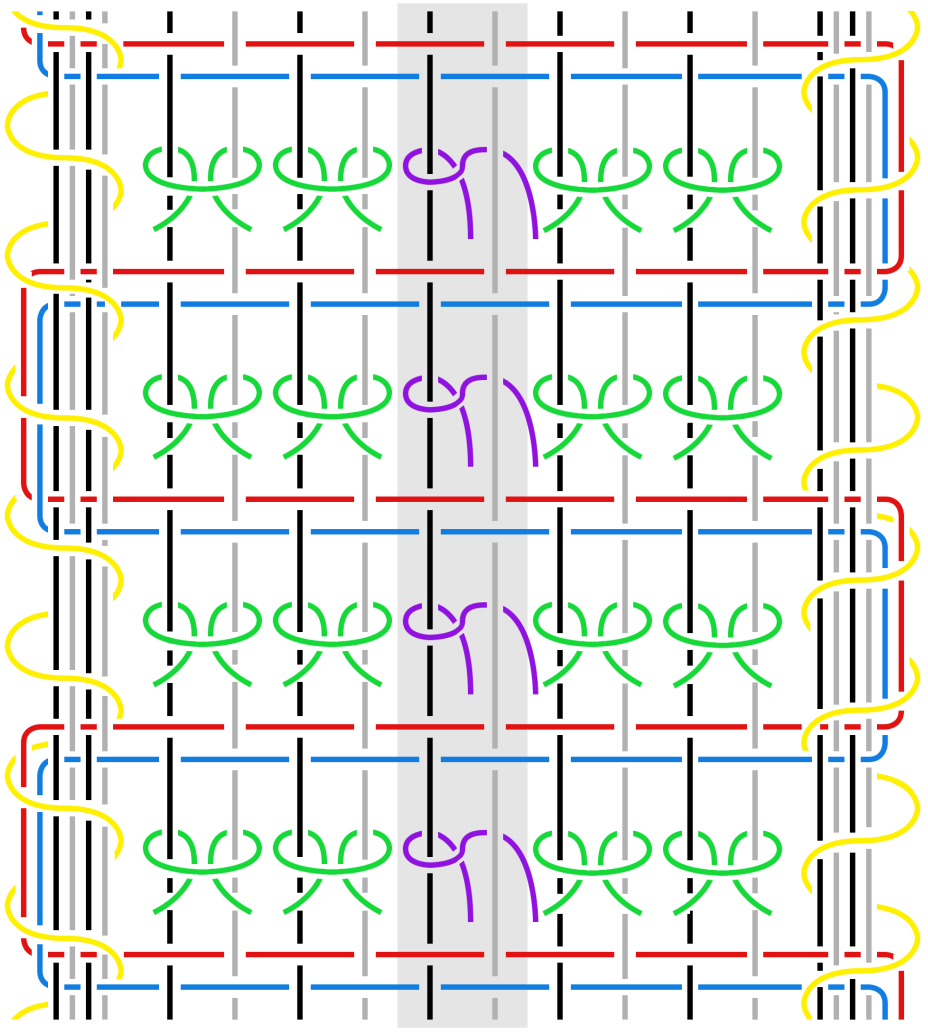
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: 4:1
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

TK-MA-7 Figure B.12



Weaver: Anonymous C (“Christina”)
Workshop: (NA)
Mary, Turkmenistan
Woven 2021
Location: Private Collection

Total Size (l x w): 0.993 x 0.548 meters
Survey: 16

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: D
Knot Spacing: 0
Knot-Row Offset: 0

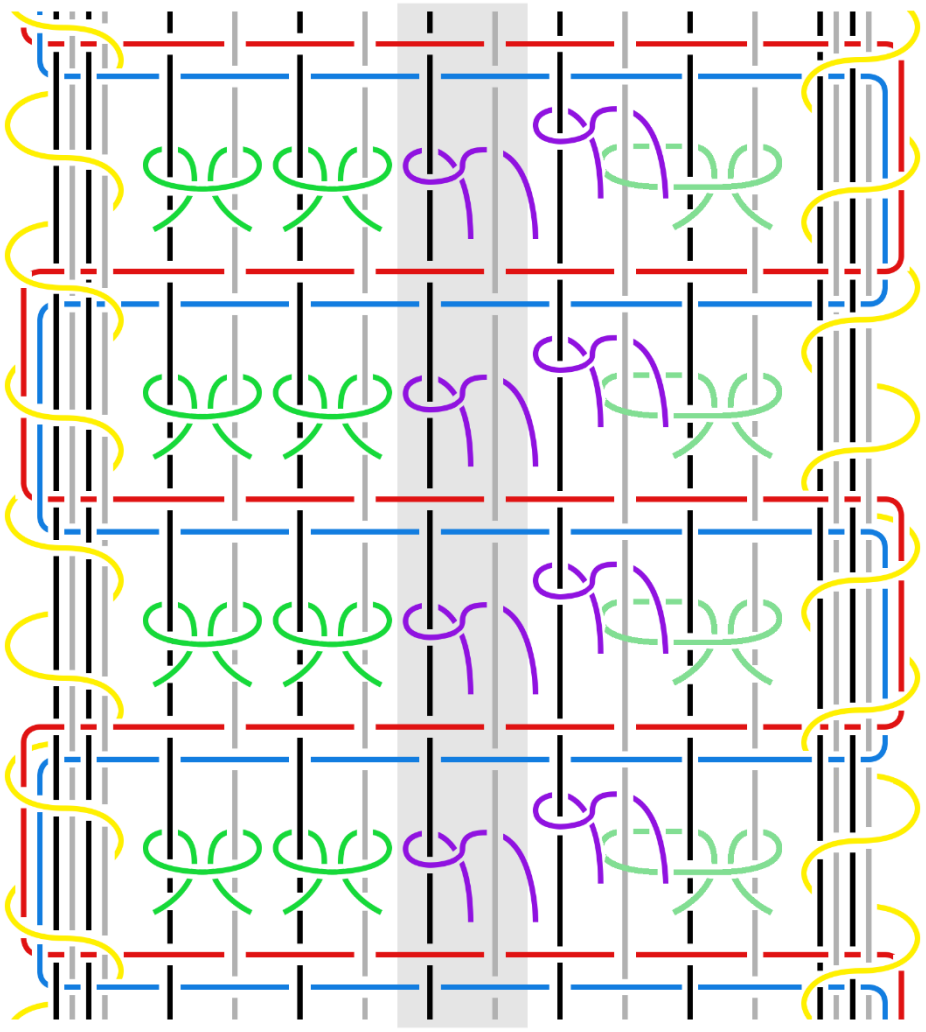
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: 4:1
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

TK-MA-8 Figure B.13



Weaver: Anonymous E (“Eleanora”)
Workshop: (NA)
Mary, Turkmenistan
Woven 2021
Location: Private Collection

Total Size (l x w): 1.028 x 0.537 meters
Survey: 16

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: D
Knot Spacing: 0
Knot-Row Offset: 0

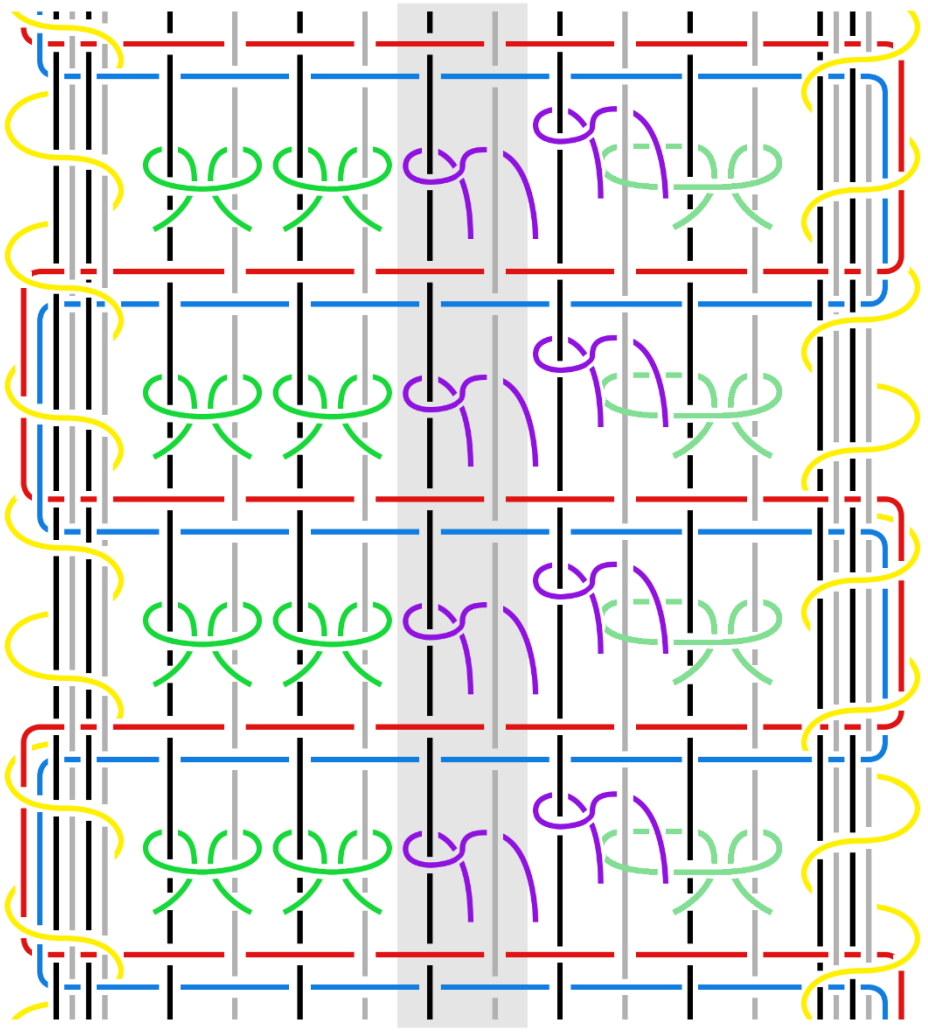
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: 4:1
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

TK-MA-9 Figure B.14



Weaver: Anonymous D (“Dorothy”)
Workshop: (NA)
Mary, Turkmenistan
Woven 2021
Location: Private Collection

Total Size (l x w): 1.047 x 0.532 meters
Survey: 16

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: D
Knot Spacing: 0
Knot-Row Offset: 0

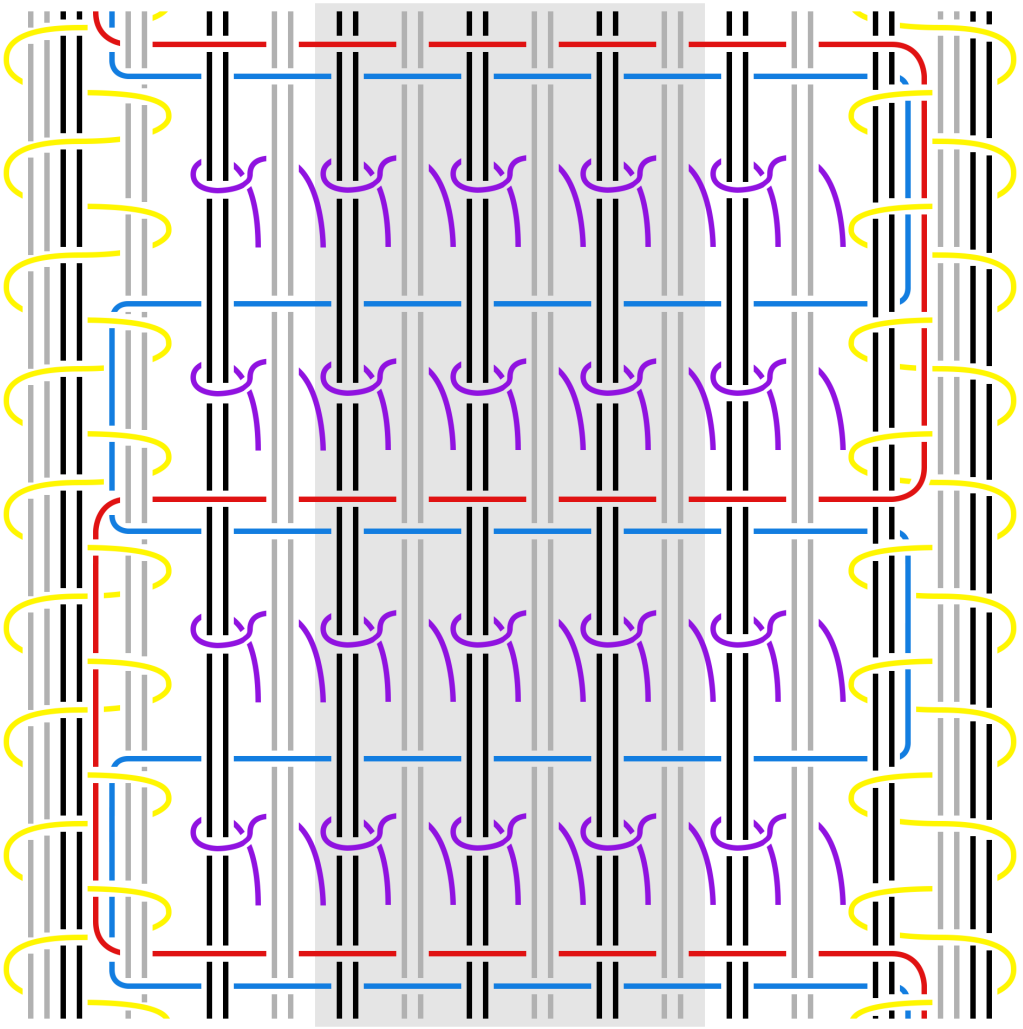
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: 4:1
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

UZ-KH-1 **Figure B.15**



Weaver: Durdiposhsha Omonova
Workshop: (NA)
Angarik, Khiva, Uzbekistan
Woven 2021
Location: Private Collection

Total Size (l x w): 1.134 x 0.800 meters
Survey: 6

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: A; D
Knot Spacing: 0
Knot-Row Offset: 0

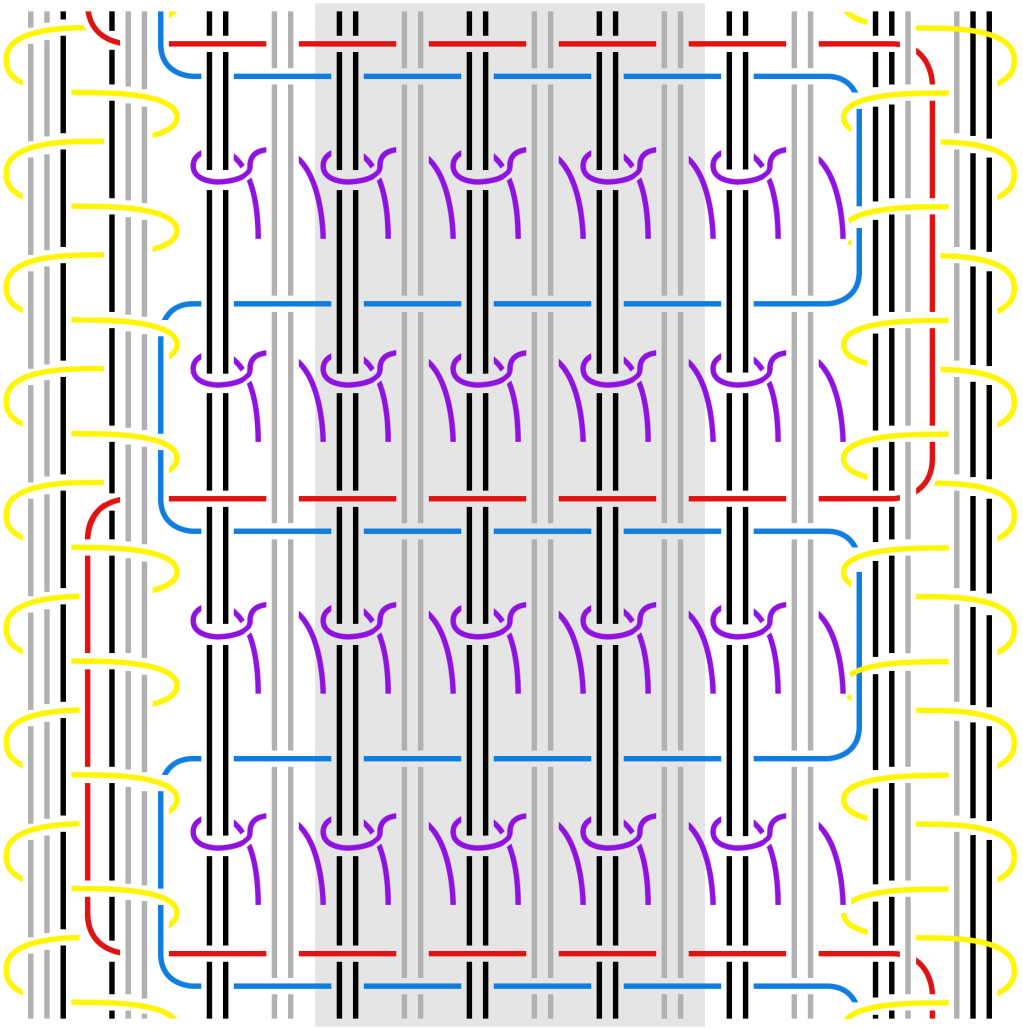
Weft Shot Pick Count: 1:2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 6:2
Binding-Weft Overlap: S

Notes:

- binding added at regular intervals, 4 picks per row of knots

UZ-KH-2 **Figure B.16**



Weaver: Durdiposhsha Omonova
Workshop: (NA)
Angarik, Khiva, Uzbekistan
Woven 2021
Location: Private Collection

Total Size (l x w): 1.269 x 0.800 meters
Survey: 6

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: A; D
Knot Spacing: 0
Knot-Row Offset: 0

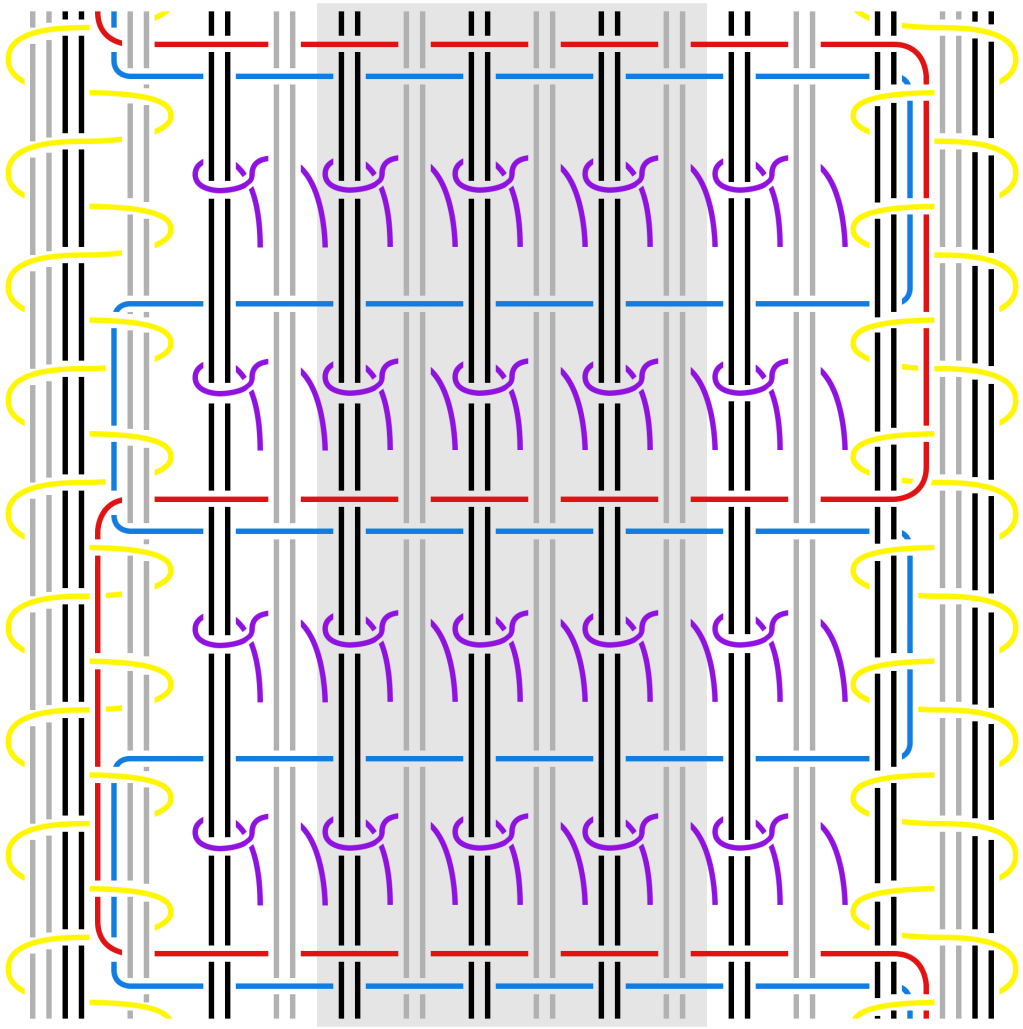
Weft Shot Pick Count: 1:2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 6:2
Binding-Weft Overlap: S

Notes:

- binding added at regular intervals, 4 picks per row of knots

UZ-KH-3 Figure B.17



Weaver: Mehribon Haitova
Workshop: (NA)
Ingilis, Khiva, Uzbekistan
Woven 2021
Location: Private Collection

Total Size (l x w): 1.265 x 0.818 meters
Survey: 11

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: A; D
Knot Spacing: 0
Knot-Row Offset: 0

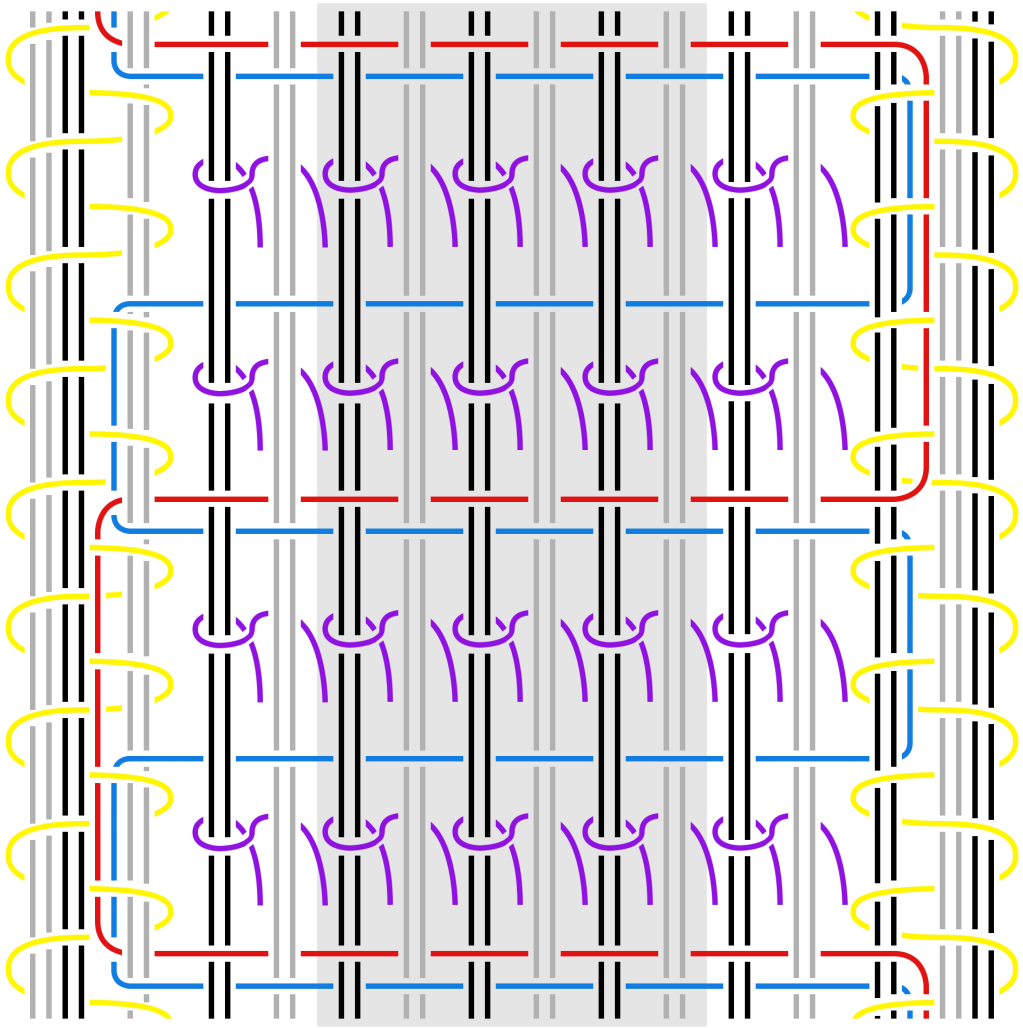
Weft Shot Pick Count: 1:2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 6:2
Binding-Weft Overlap: S

Notes:

- binding added at regular intervals, 4 picks per row of knots

UZ-KH-4 Figure B.18



Weaver: Mehribon Haitova
Workshop: (NA)
Ingilis, Khiva, Uzbekistan
Woven 2021
Location: Private Collection

Total Size (l x w): 1.173 x 0.815 meters
Survey: 11

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: A; D
Knot Spacing: 0
Knot-Row Offset: 0

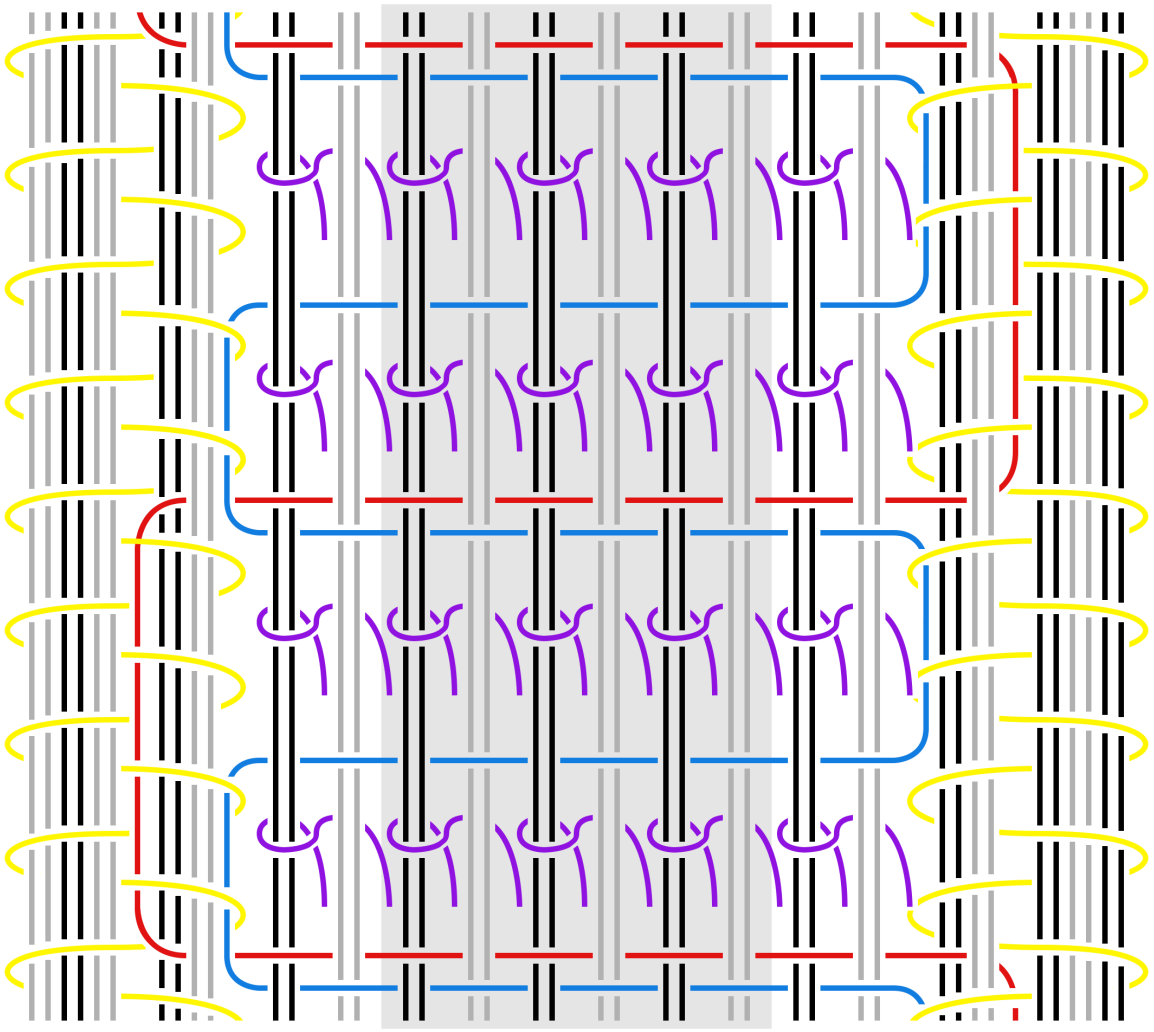
Weft Shot Pick Count: 1:2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 6:2
Binding-Weft Overlap: S

Notes:

- binding added at regular intervals, 4 picks per row of knots

UZ-KH-5 Figure B.19



Weaver: Dilbar Omonova
Workshop: (NA)
Gondimiyon, Khiva, Uzbekistan
Woven 2021
Location: HLATC, Univ. Wisconsin

Total Size (l x w): 1.152 x 0.801 meters
Survey: 12

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: A; D
Knot Spacing: 0
Knot-Row Offset: 0

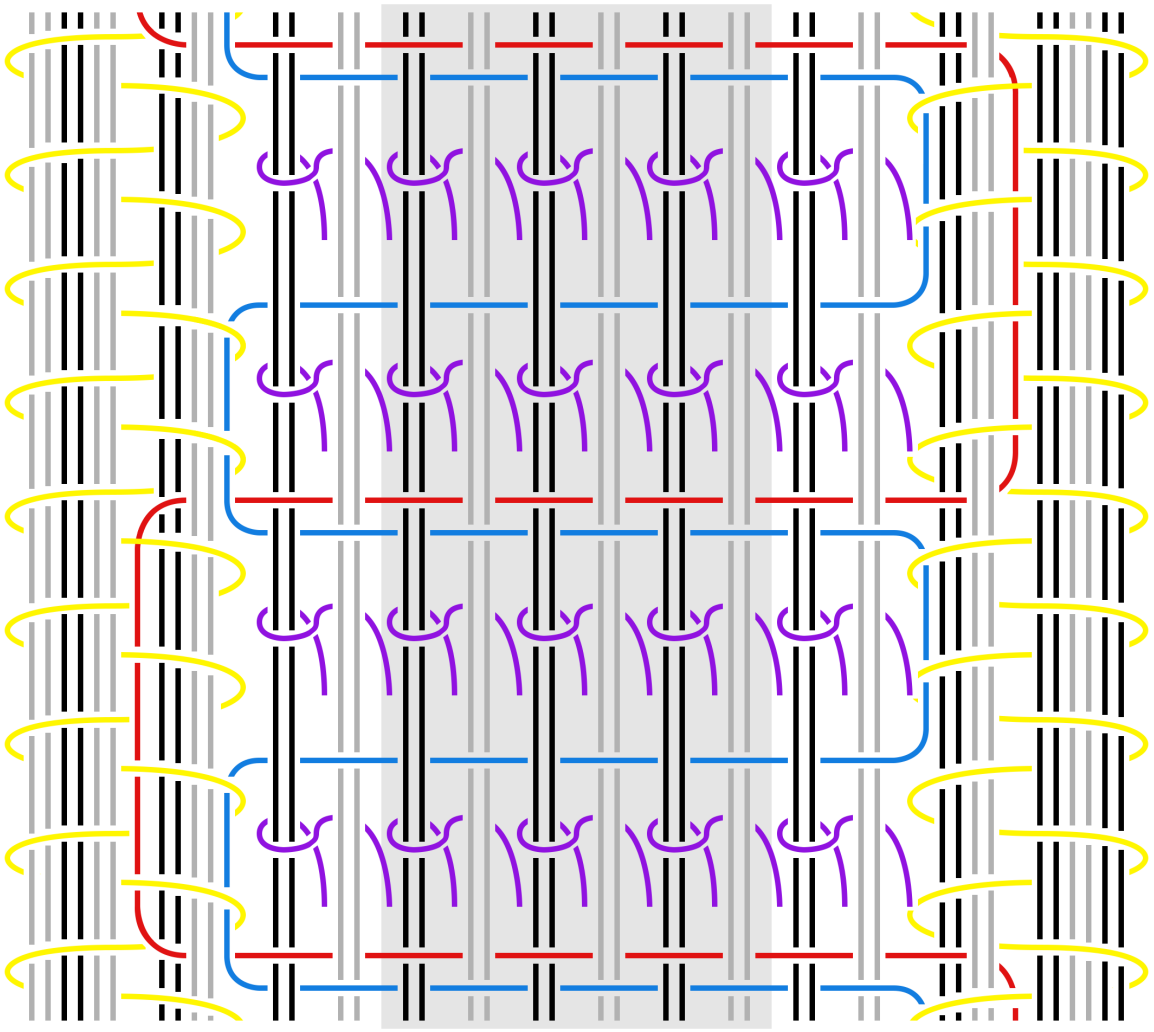
Weft Shot Pick Count: 1:2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 10:2
Binding-Weft Overlap: S

Notes:

- binding added at regular intervals, 4 picks per row of knots

UZ-KH-6 Figure B.20



Weaver: Dilbar Omonova
Workshop: (NA)
Gondimiyon, Khiva, Uzbekistan
Woven 2021
Location: Private Collection

Total Size (l x w): 1.128 x 0.809 meters
Survey: 12

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: A; D
Knot Spacing: 0
Knot-Row Offset: 0

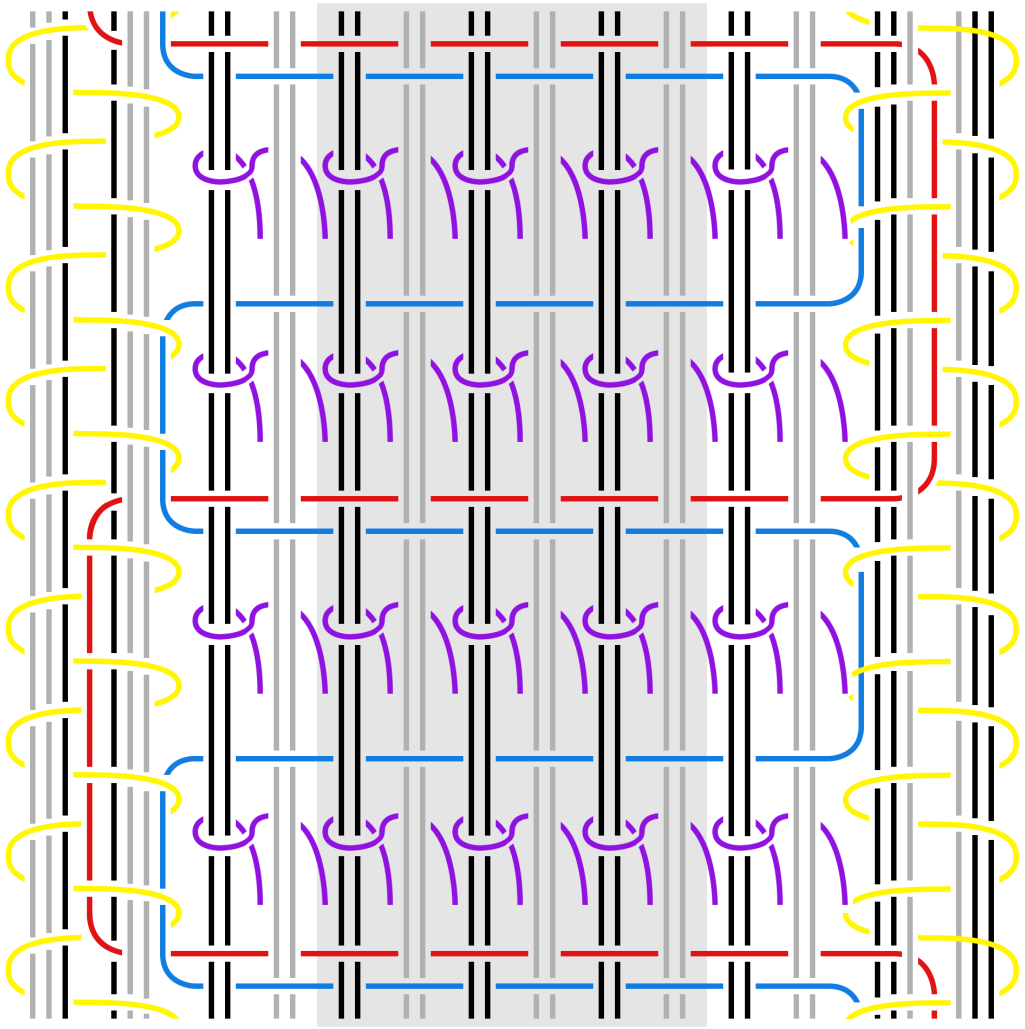
Weft Shot Pick Count: 1:2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 10:2
Binding-Weft Overlap: S

Notes:

- binding added at regular intervals, 4 picks per row of knots

UZ-KH-7 Figure B.21



Weaver: Anonymous F (“Stephanie”)
Workshop: (NA)
Gondimiyon, Khiva, Uzbekistan
Woven 2021
Location: Private Collection

Total Size (l x w): 1.162 x 0.802 meters
Survey: 13

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: A; D
Knot Spacing: 0
Knot-Row Offset: 0

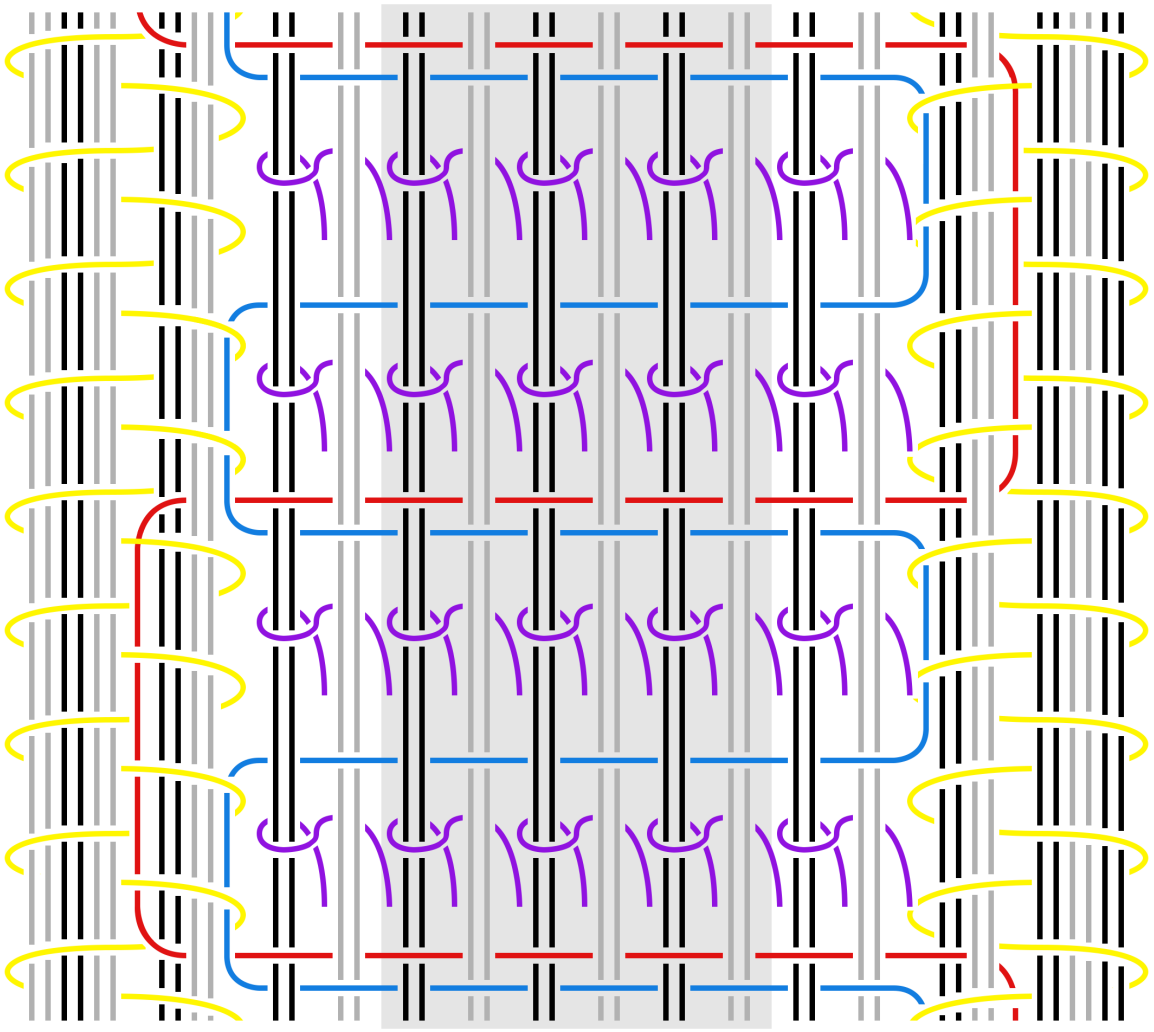
Weft Shot Pick Count: 1:2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 6:2
Binding-Weft Overlap: S

Notes:

- binding added at regular intervals, 4 picks per row of knots

UZ-KH-8 Figure B.22



Weaver: Anonymous F (“Stephanie”)
Workshop: (NA)
Gondimiyon, Khiva, Uzbekistan
Woven 2021
Location: Private Collection

Total Size (l x w): 1.141 x 0.817 meters
Survey: 13

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: A; D
Knot Spacing: 0
Knot-Row Offset: 0

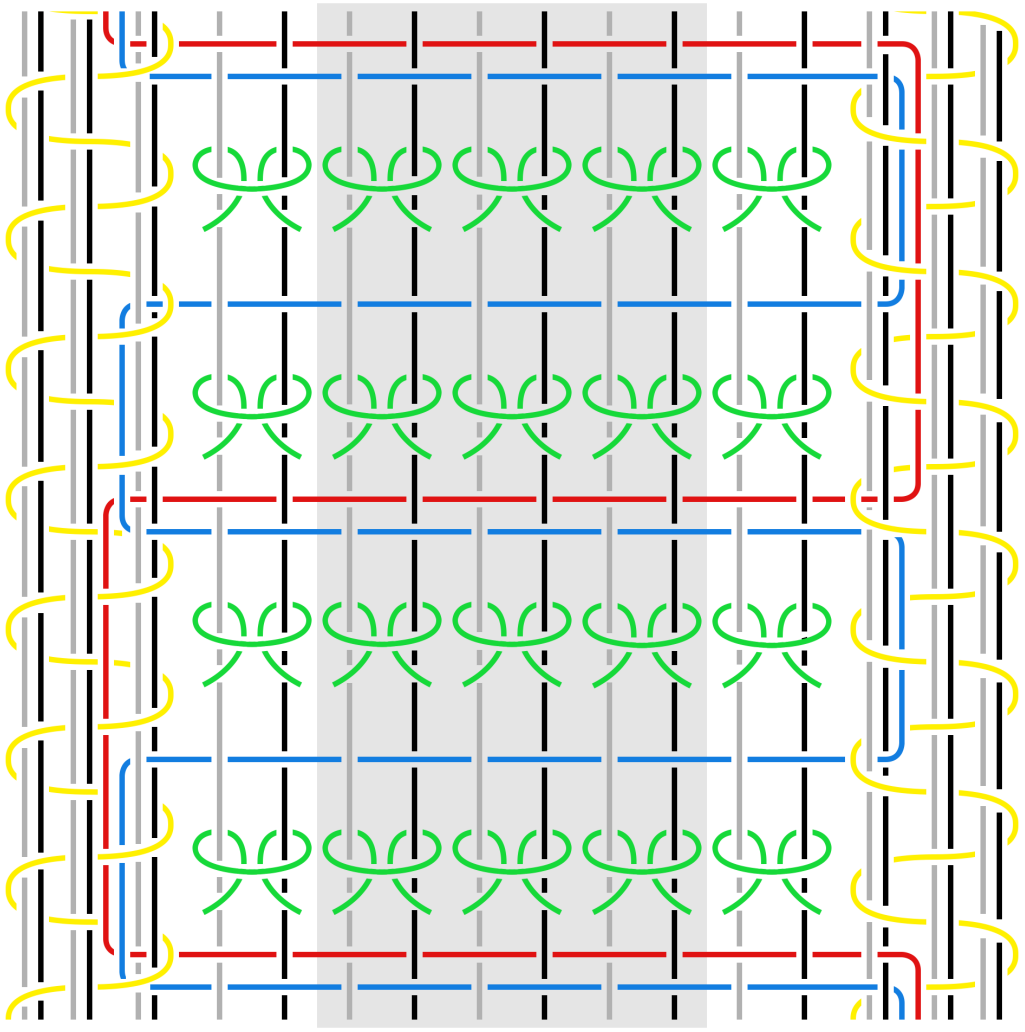
Weft Shot Pick Count: 1:2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 10:2
Binding-Weft Overlap: S

Notes:

- binding added at regular intervals, 4 picks per row of knots

UZ-KH-9 Figure B.23



Weaver: Halima Matyaqubova
Workshop: Silk Carpet Workshop
Khiva, Uzbekistan
Woven 2021
Location: Not Collected

Total Size (l x w): 1.700 x 1.000 meters
Survey: 7

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: A; D
Knot Spacing: 0
Knot-Row Offset: 0

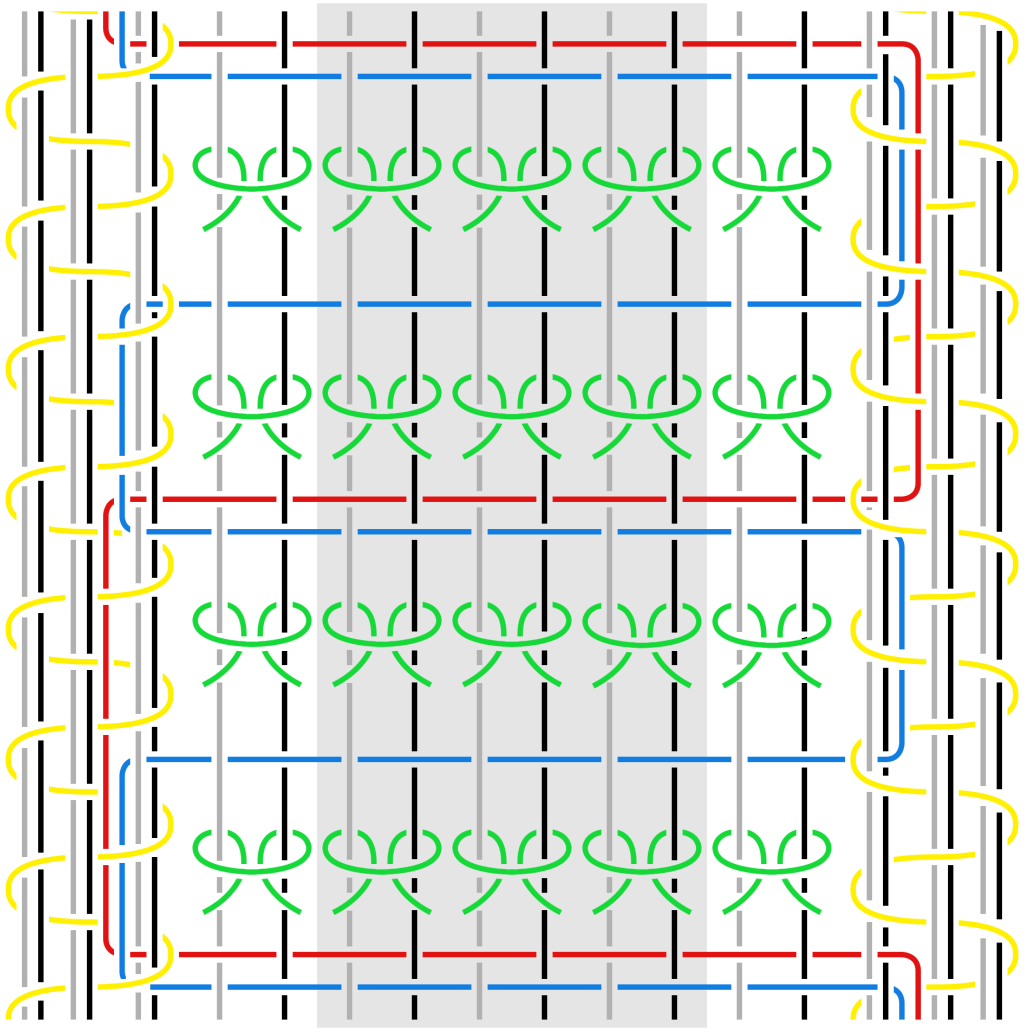
Weft Shot Pick Count: 1:2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 6:3
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

UZ-KH-10 Figure B.24



Weaver: Halima Matyaqubova
Workshop: Silk Carpet Workshop
Khiva, Uzbekistan
Woven 2021
Location: Not Collected

Total Size (l x w): 2.000 x 1.200 meters
Survey: 7

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: A; D
Knot Spacing: 0
Knot-Row Offset: 0

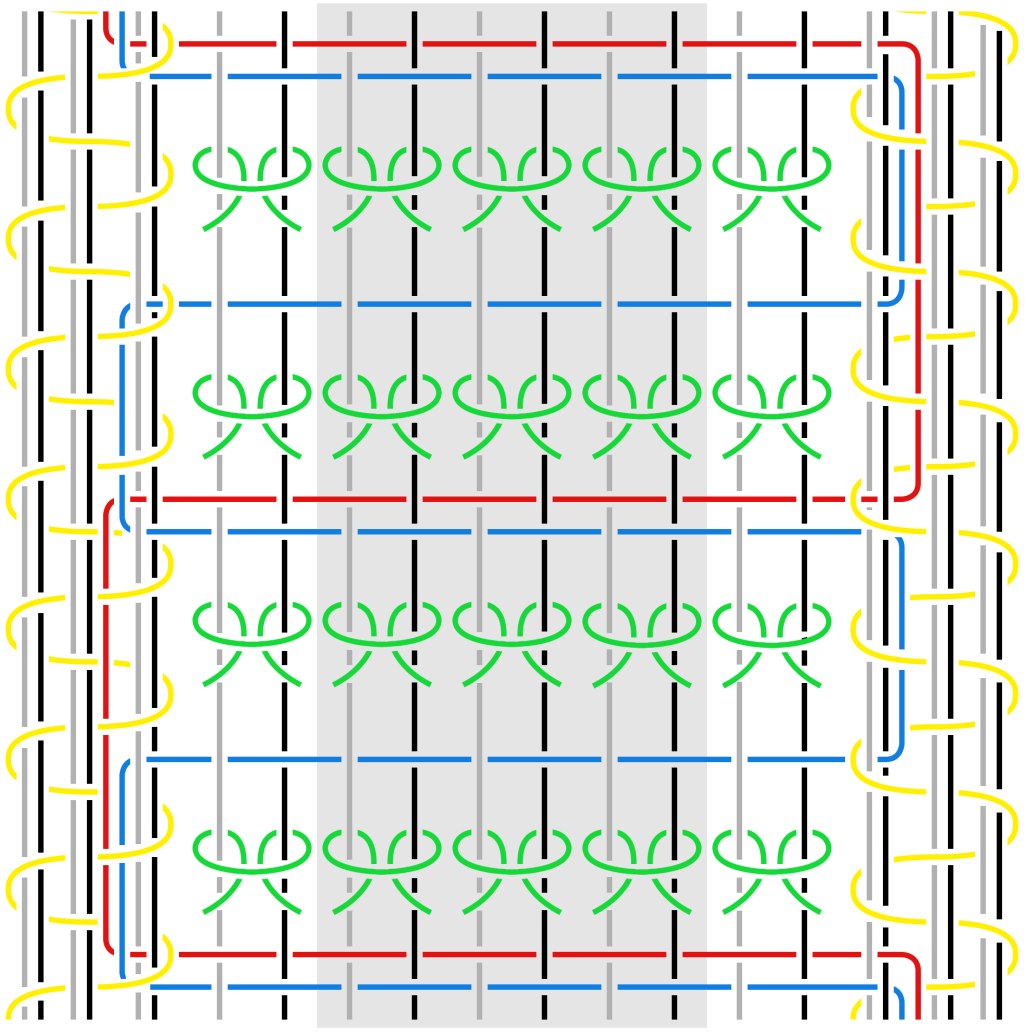
Weft Shot Pick Count: 1:2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 6:3
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

UZ-KH-11 **Figure B.25**



Weaver: Maloxat Qurbonova & Nazokat Aminova
Workshop: Silk Carpet Workshop
Khiva, Uzbekistan
Woven 2021
Location: Not Collected

Total Size (l x w): 1.900 x 1.210 meters
Survey: 8/9

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: A; D
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 1:2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 6:3
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

UZ-KH-12 Figure B.26

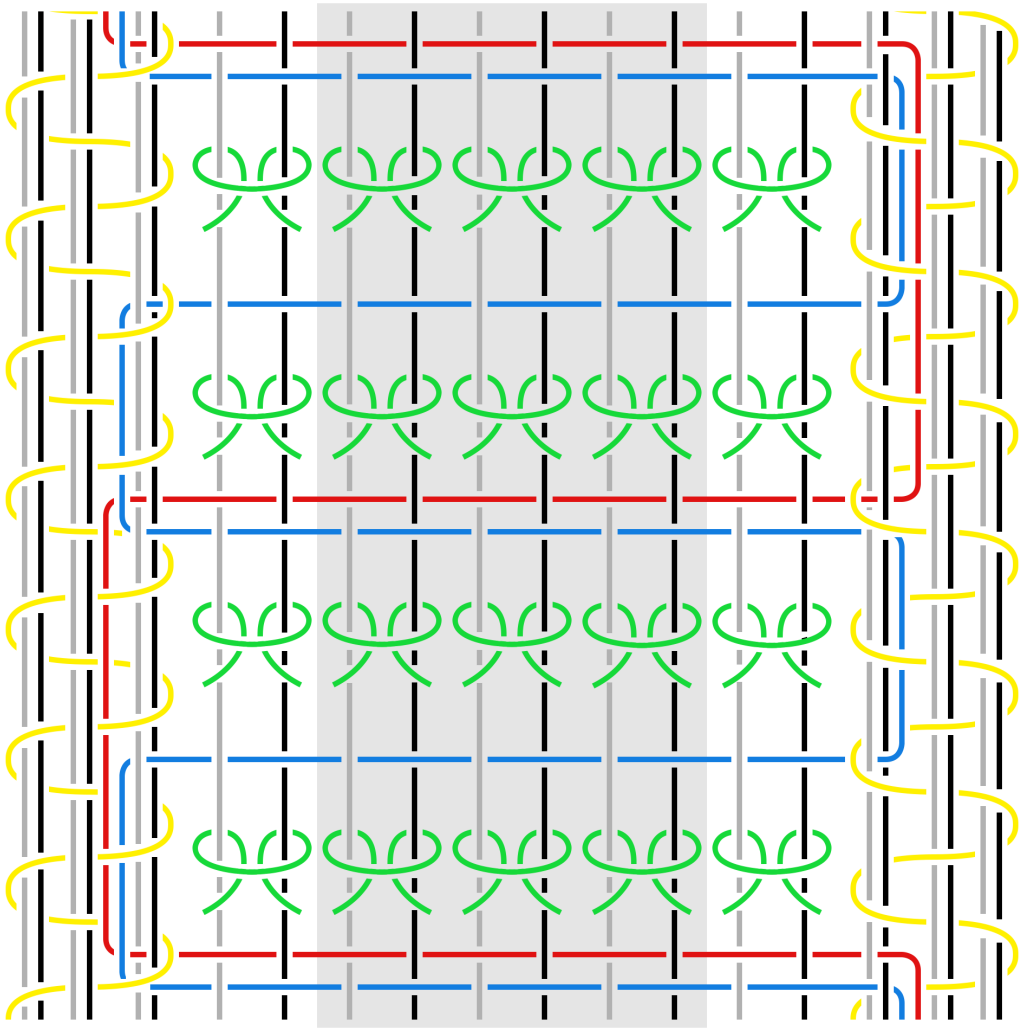
Weaver: Maloxat Qurbonova
Workshop: Silk Carpet Workshop
Khiva, Uzbekistan
Woven 2021
Location: Not Collected

Total Size (l x w): 1.800 x 0.790 meters
Survey: 8

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: A; D
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 1:2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Tabby
Binding Warps: 6:3
Binding-Weft Overlap: S



Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

UZ-KH-13 Figure B.27

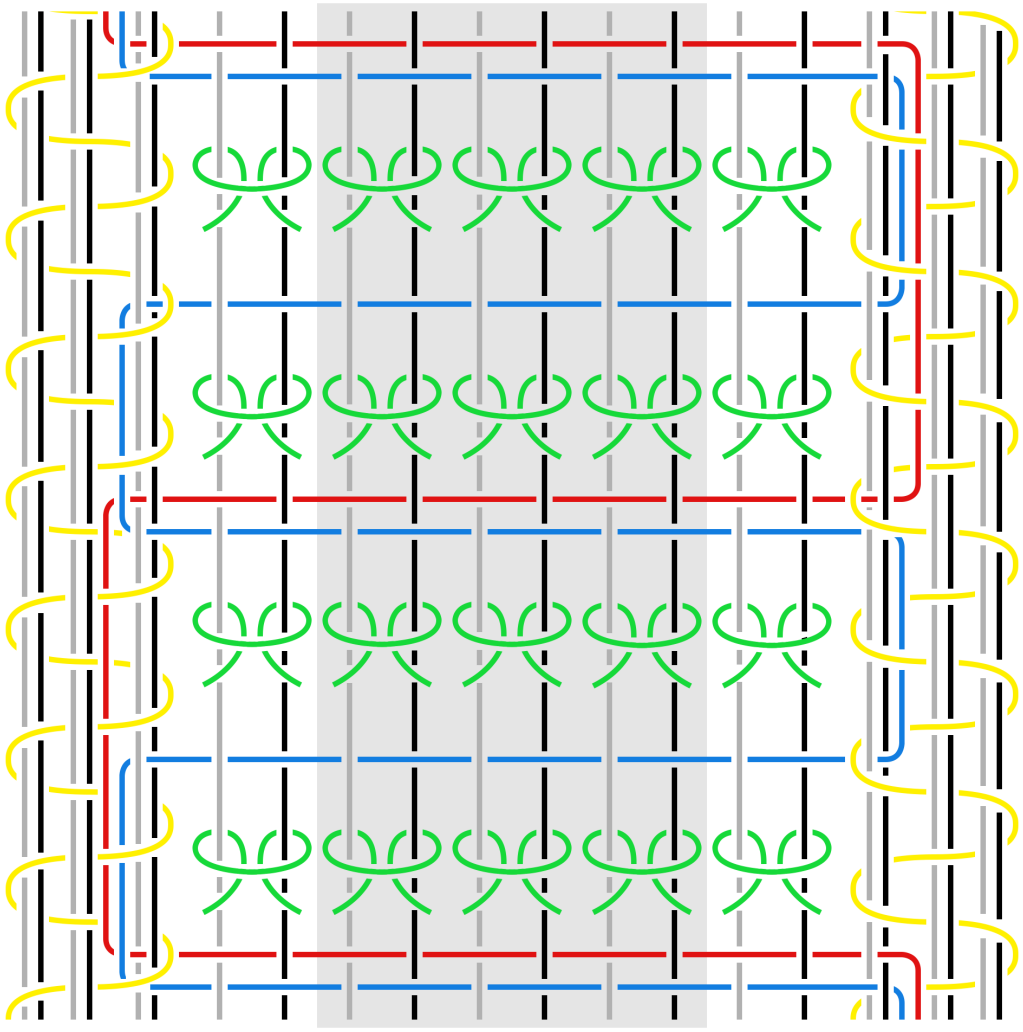
Weaver: Nazokat Aminova
Workshop: Silk Carpet Workshop
Khiva, Uzbekistan
Woven 2021
Location: Not Collected

Total Size (l x w): 1.240 x 2.500 meters
Survey: 9

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: A; D
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 1:2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

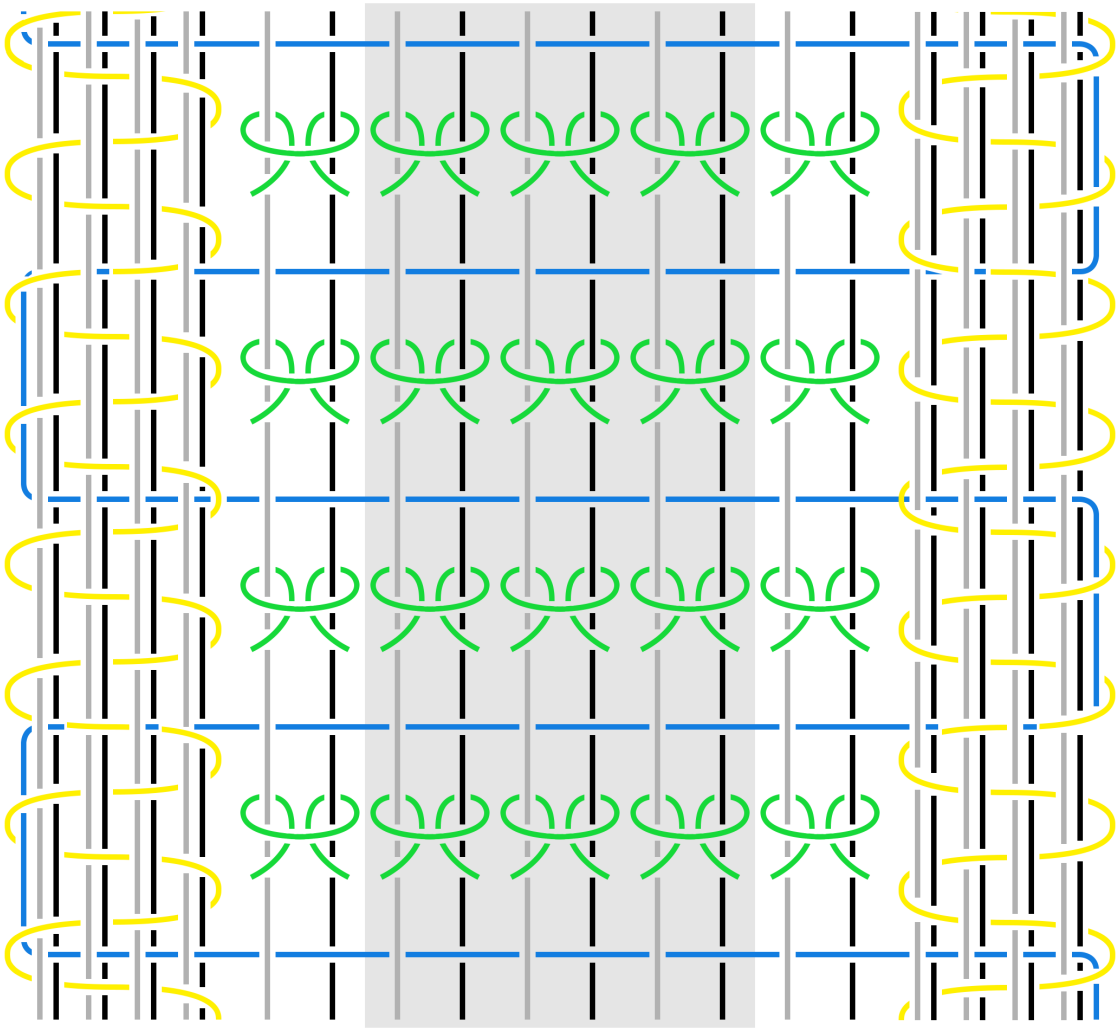
Binding Weave Pattern: Tabby
Binding Warps: 6:3
Binding-Weft Overlap: S



Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

UZ-SK-1 **Figure B.28**



Weaver: Nigora
Workshop: Silk Carpet Workshop
Samarkand, Uzbekistan
Woven 2021
Location: Not Collected

Total Size (l x w): 1.800 x 1.200 meters
Survey: 1

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: A
Knot Spacing: 0
Knot-Row Offset: 0

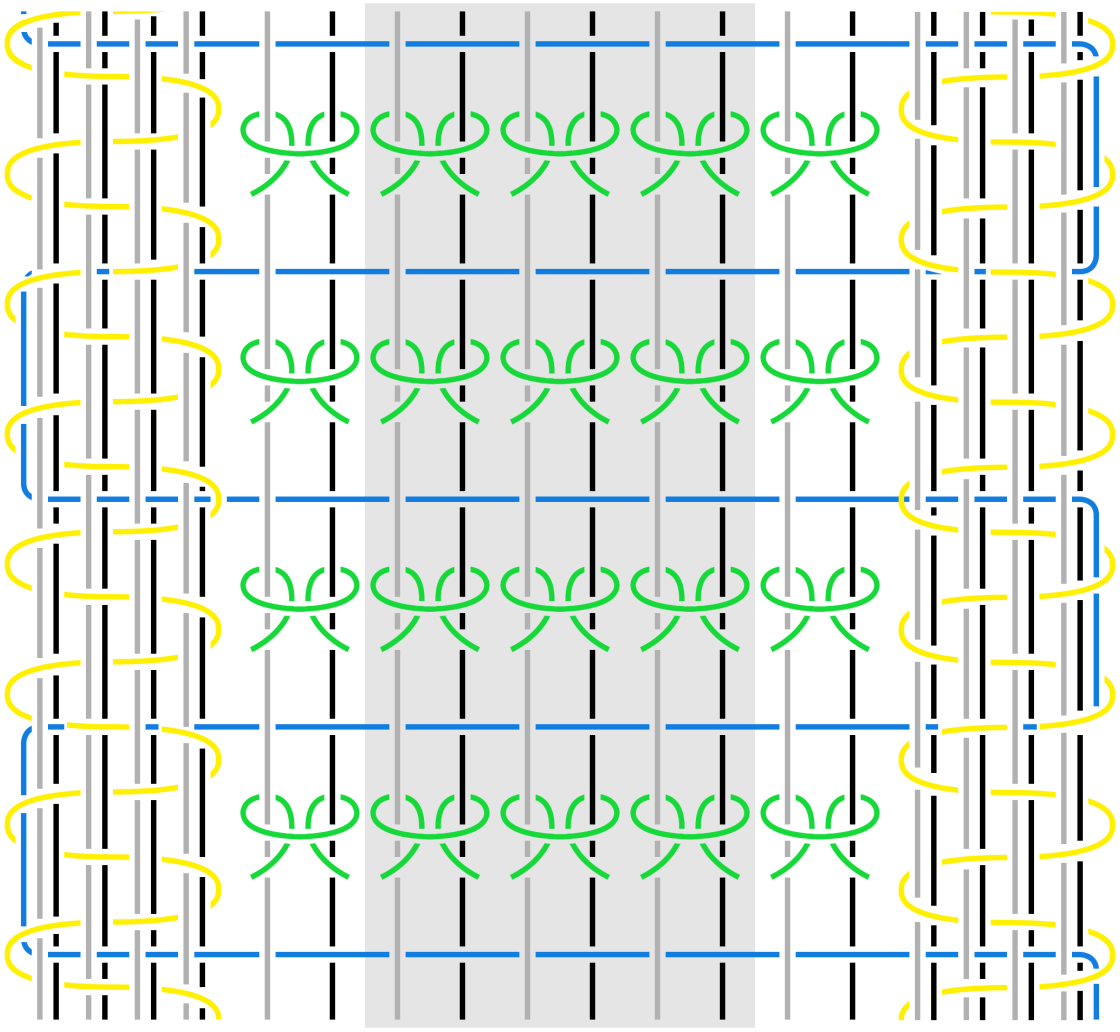
Weft Shot Pick Count: 1
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Tabby
Binding Warps: 8:4
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

UZ-SK-2 **Figure B.29**



Weaver: Muftuna Narzulloeva
Workshop: Silk Carpet Workshop
Samarkand, Uzbekistan
Woven 2021
Location: Not Collected

Total Size (l x w): 1.550 x 1.150 meters
Survey: 2

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: A
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 1
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Tabby
Binding Warps: 8:4
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting

UZ-SK-3 **Figure B.30**

Ethnographic

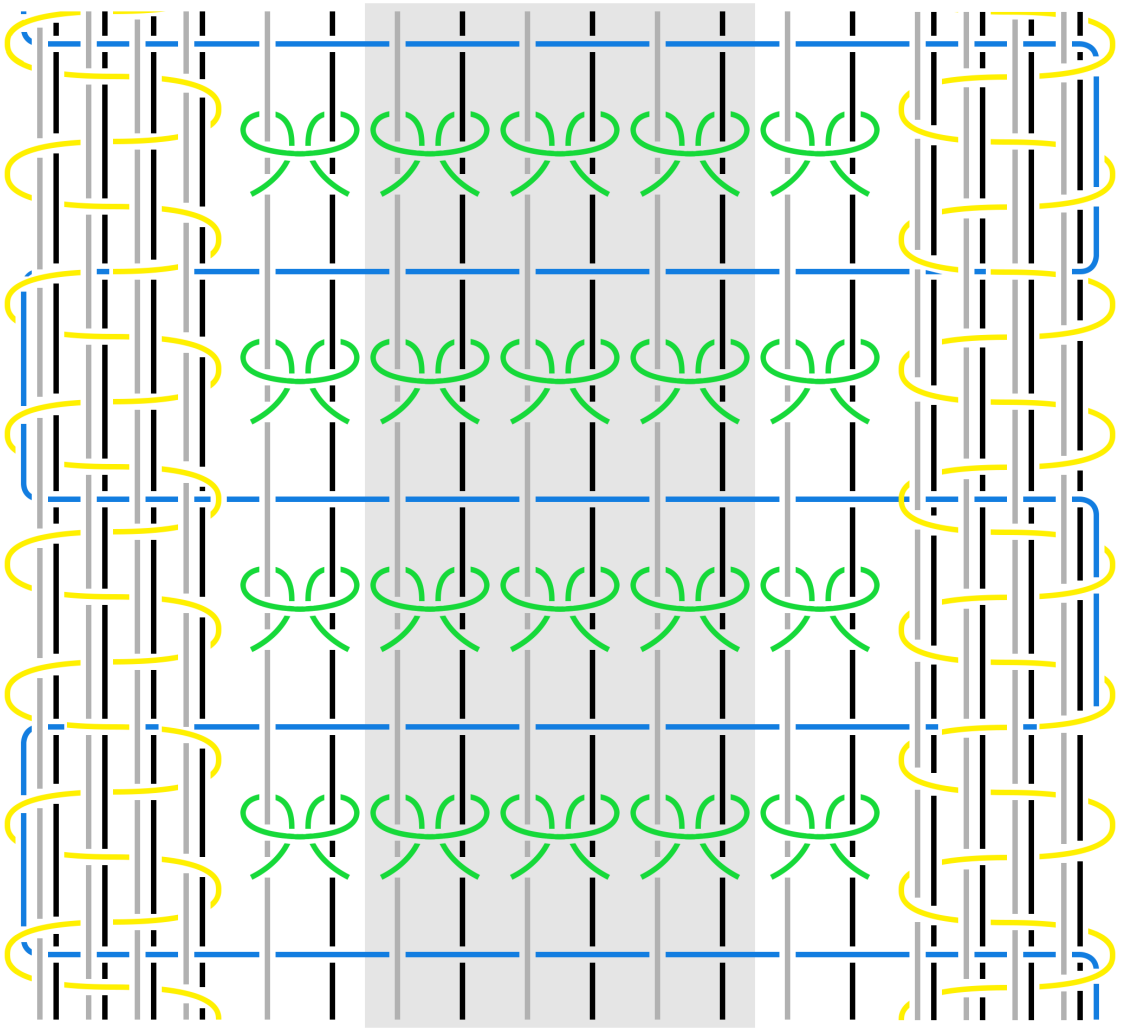
Weaver: Bashorat
Workshop: Silk Carpet Workshop
Samarkand, Uzbekistan
Woven 2021
Location: Not Collected

Total Size (l x w): 2.040 x 1.500 meters
Survey: 4

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: A
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 1
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Tabby
Binding Warps: 8:4
Binding-Weft Overlap: S



Notes: binding not added at regular intervals; picks added as necessary to keep level with knotting

MU-AS-1 **Figure B.31**

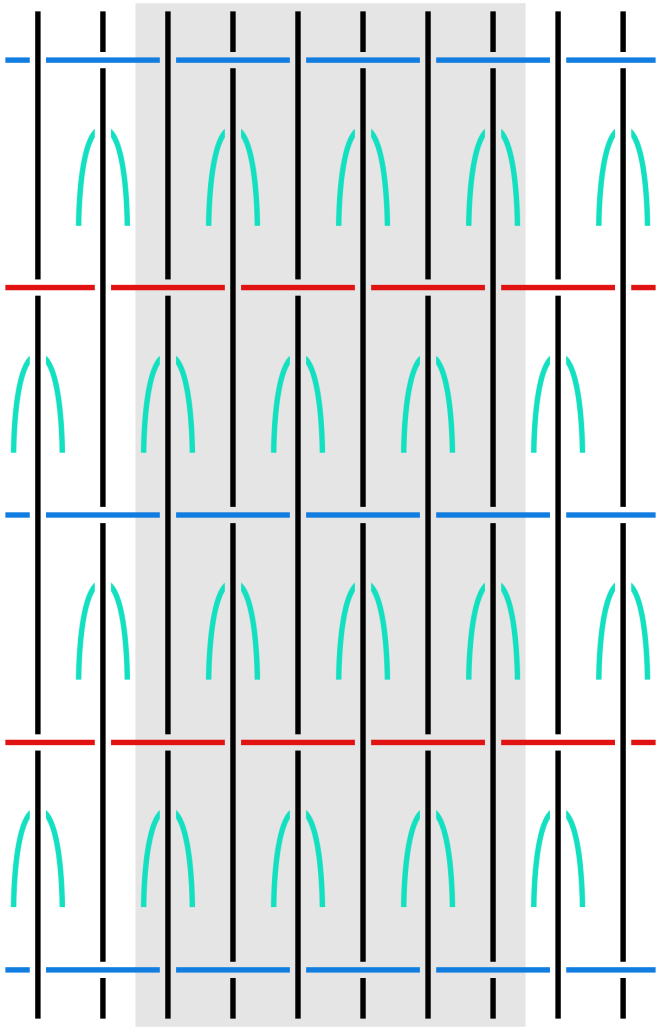
Attribution: Maymana, Faryab Province, Afghanistan
Woven 380 – 540 CE
Location: Al-Sabah Collection (LNS 63 R)
Kuwait City, Kuwait

Total Size (l x w): 0.410 x 0.550 meters

Knot Type: WR
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C
Knot Spacing: 1
Knot-Row Offset: 1

Weft Shot Pick Count: 1
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: Wrap
Binding Warps: ?
Binding-Weft Overlap: ?



MU-AS-2a **Figure B.32**

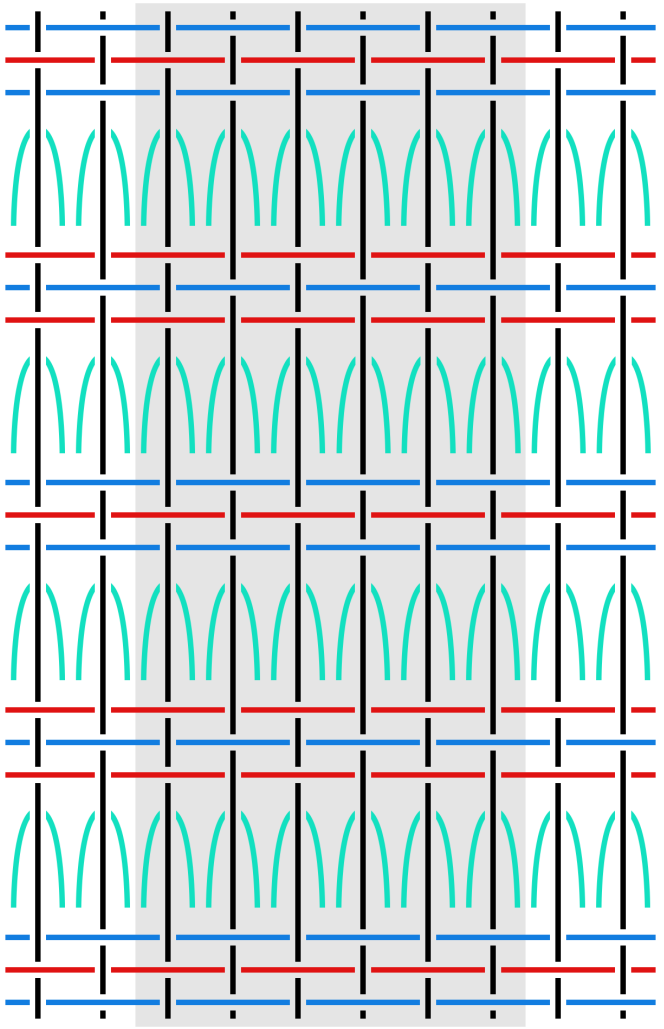
Attribution: Samangan Province, Afghanistan
Woven 1010 - 1160 CE
Location: Al-Sabah Collection (LNS 58 R a)
Kuwait City, Kuwait

Total Fragment Size (l x w): 0.390 x 0.240 meters

Knot Type: WR
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C; D
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 3
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



MU-AS-2b **Figure B.33**

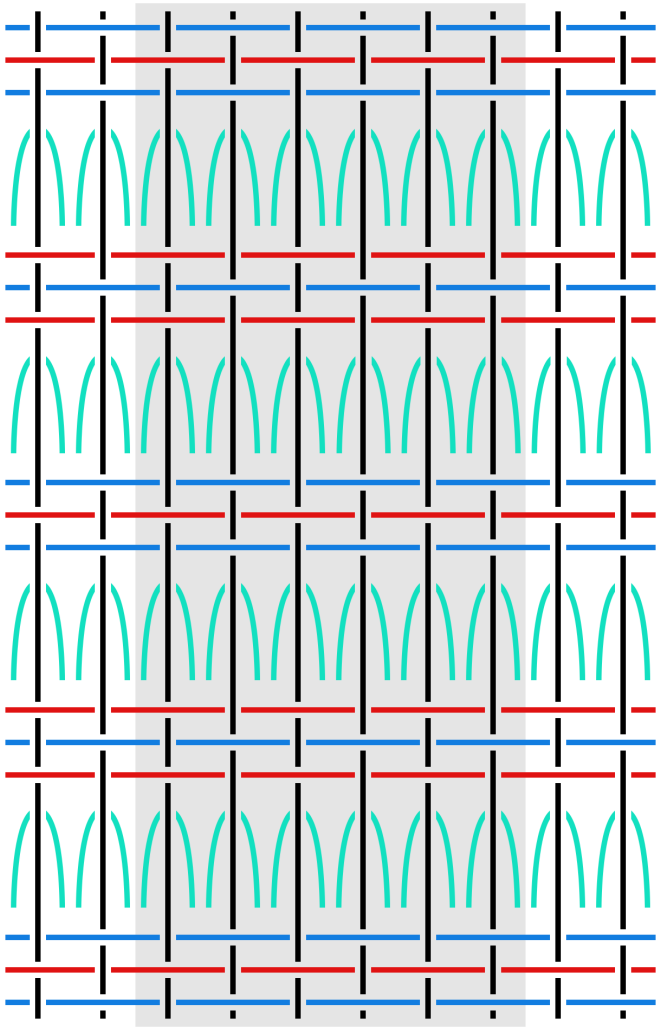
Attribution: Samangan Province, Afghanistan
Woven 1010 – 1160 CE
Location: Al-Sabah Collection (LNS 58 R b)
Kuwait City, Kuwait

Total Fragment Size (l x w): 0.120 x 0.140 meters

Knot Type: WR
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C; D
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 3
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



MU-AS-3 **Figure B.34**

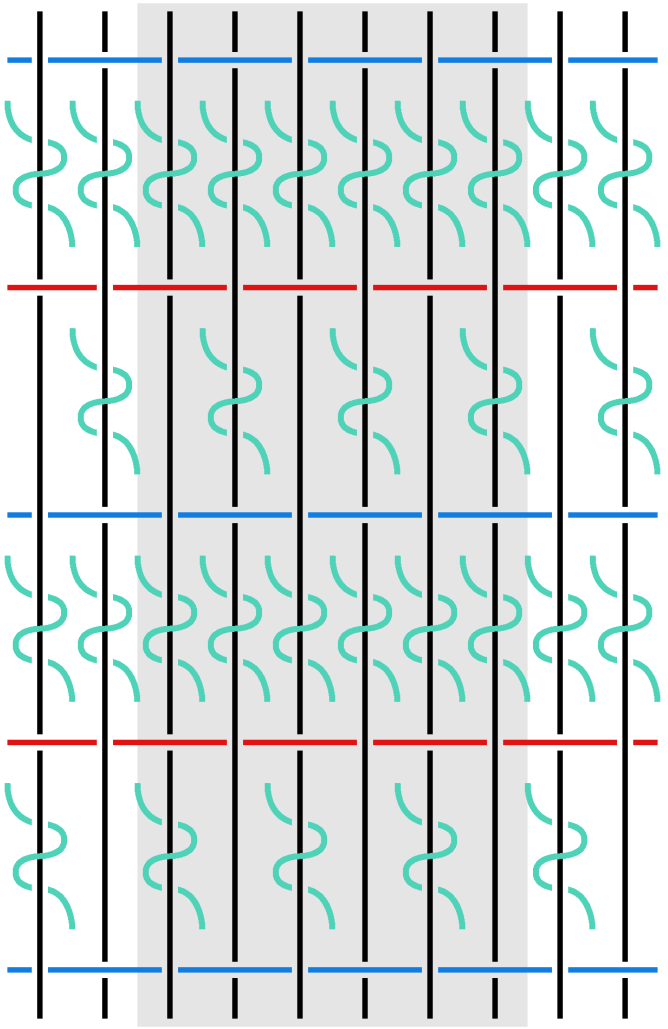
Attribution: Unknown; assumed to be Eastern Persia
Woven 378 – 598 CE
Location: Al-Sabah Collection (LNS 51 R a)
Kuwait City, Kuwait

Total Fragment Size (l x w): 0.880 x 0.290 meters

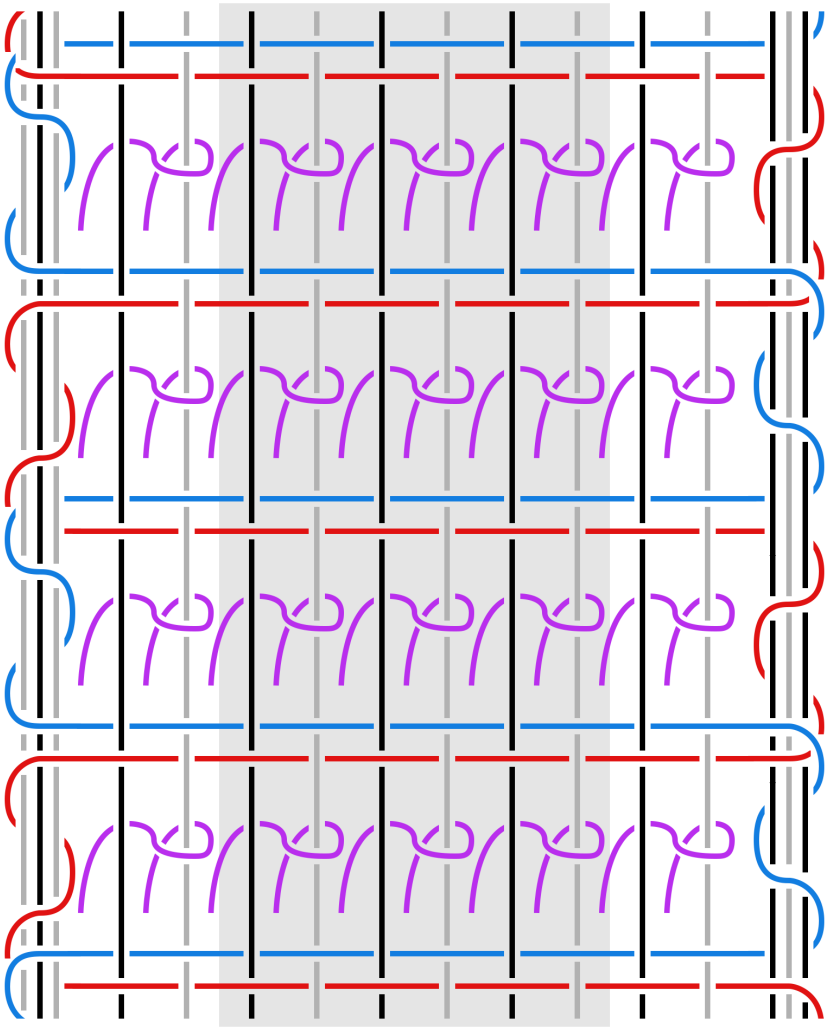
Knot Type: WR
Knot Direction: Z
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C; D
Knot Spacing: 0; 1
Knot-Row Offset: 0

Weft Shot Pick Count: 1
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



MU-AS-4a **Figure B.35**



Attribution: Unknown; assumed to be Eastern Persia
Woven 543 – 638 CE
Location: Al-Sabah Collection (LNS 71 R a)
Kuwait City, Kuwait

Total Fragment Size (l x w): 0.515 x 0.490 meters

Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

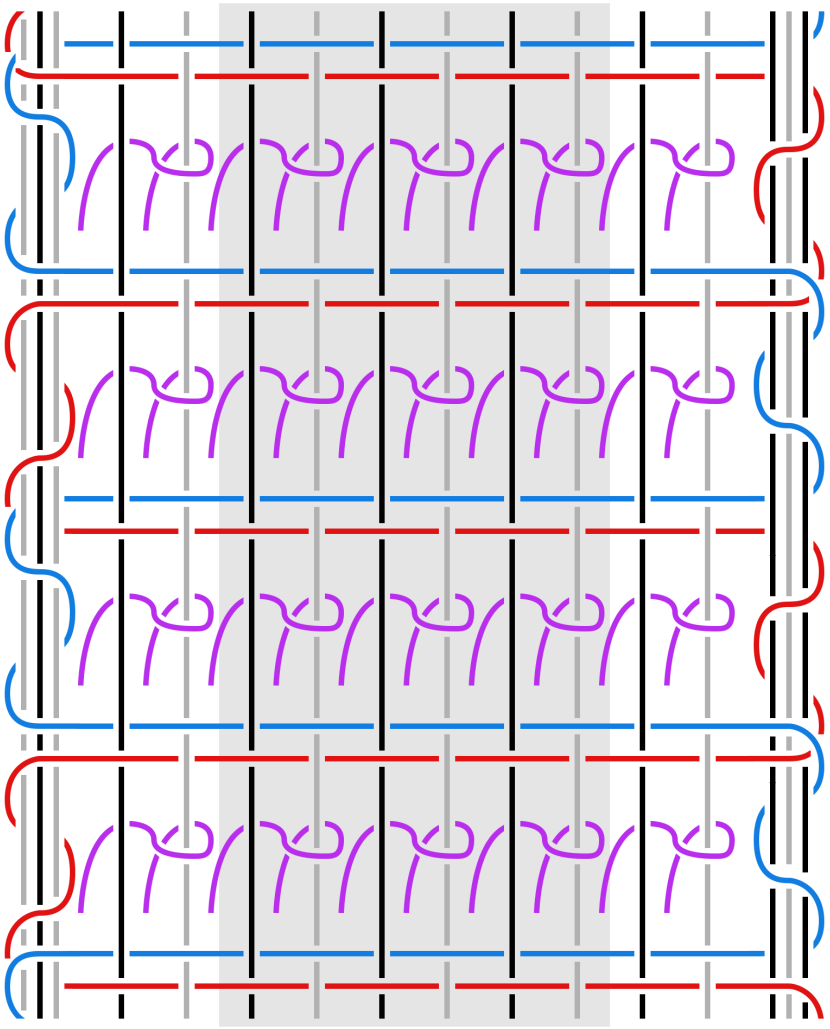
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: 3:1
Binding-Weft Overlap: C

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting
- knots at edges have extra-long pile, presumably to cover the binding and create a fringed effect

MU-AS-4b **Figure B.36**



Attribution: Unknown; assumed to be Eastern Persia
Woven 543 – 638 CE
Location: Al-Sabah Collection (LNS 71 R b)
Kuwait City, Kuwait

Total Fragment Size (l x w): 0.130 x 0.130 meters

Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

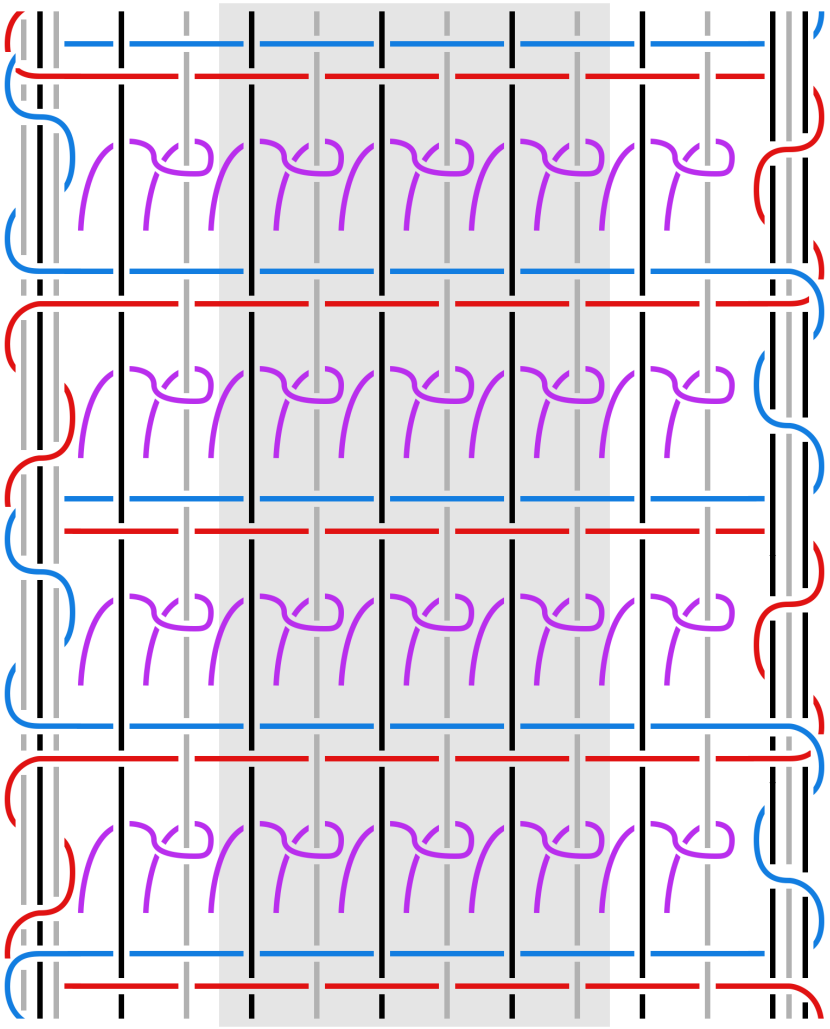
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: 3:1
Binding-Weft Overlap: C

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting
- knots at edges have extra-long pile, presumably to cover the binding and create a fringed effect

MU-AS-4c **Figure B.37**



Attribution: Unknown; assumed to be Eastern Persia
Woven 543 – 638 CE
Location: Al-Sabah Collection (LNS 71 R c)
Kuwait City, Kuwait

Total Fragment Size (l x w): 0.130 x 0.110 meters

Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: 3:1
Binding-Weft Overlap: C

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting
- knots at edges have extra-long pile, presumably to cover the binding and create a fringed effect

MU-AS-5 **Figure B.38**

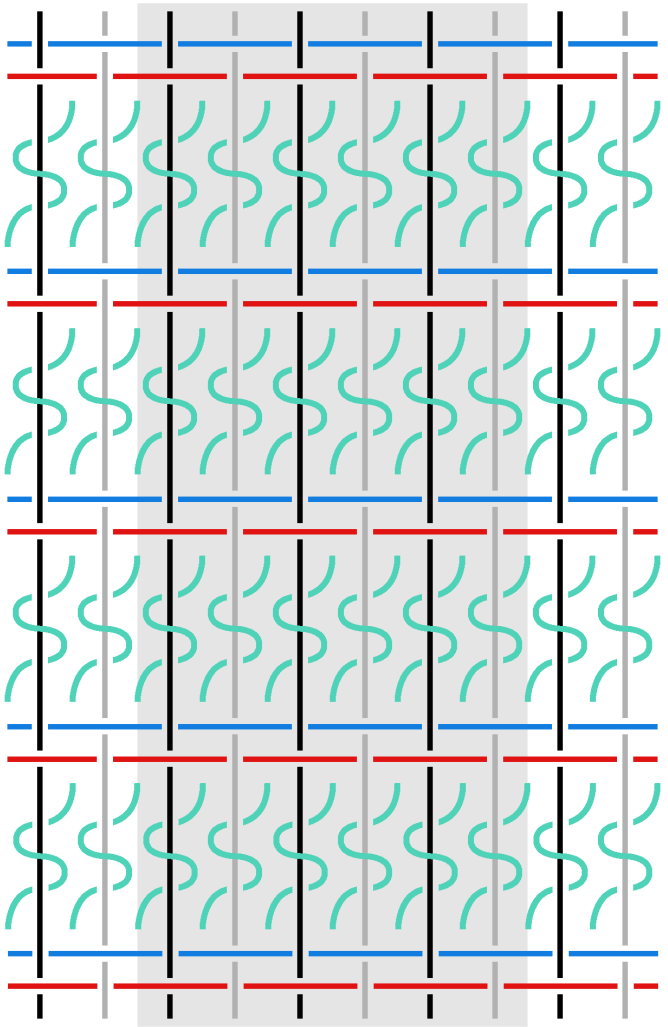
Attribution: Unknown; assumed to be Eastern Persia
Woven 540 – 585 CE
Location: Al-Sabah Collection (LNS 70 R)
Kuwait City, Kuwait

Total Fragment Size (l x w): 0.180 x 0.220 meters

Knot Type: WR
Knot Direction: S
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C; D
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



Notes:

- random weft shots are missing their second pick; no apparent pattern and not frequent

MU-AS-6 Figure B.39

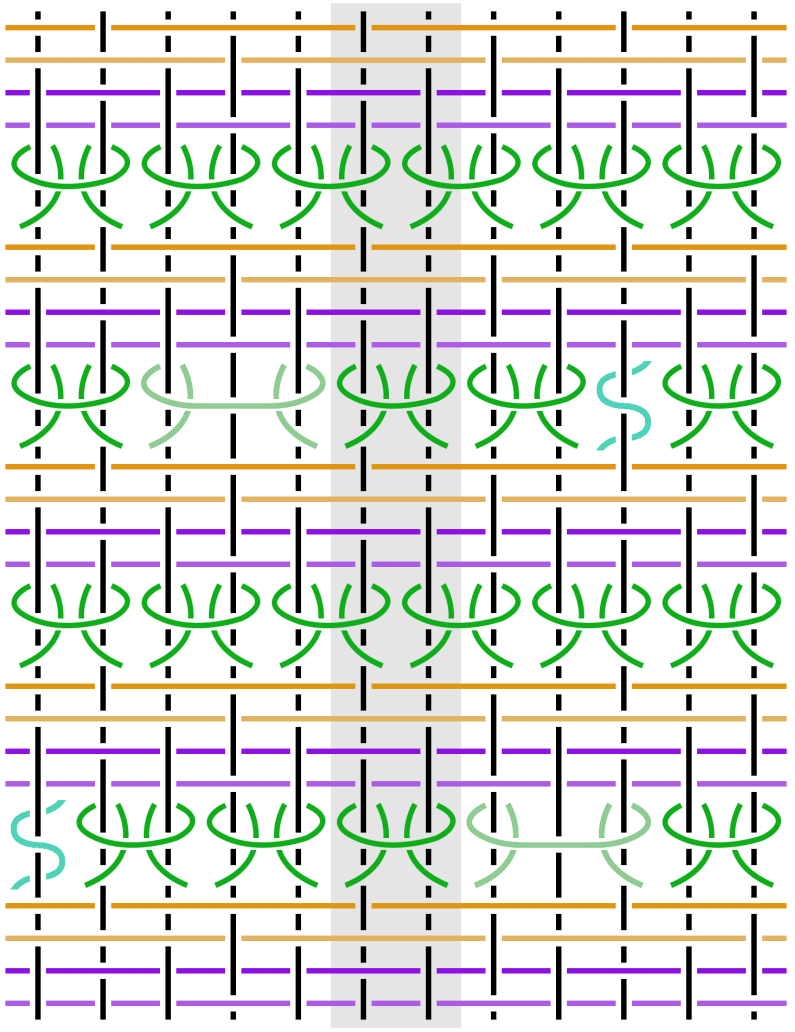
Attribution: Samangan Province, Afghanistan
Woven 1150 – 1260 CE
Location: Al-Sabah Collection (LNS 54 R)
Kuwait City, Kuwait

Total Fragment Size (l x w): 0.255 x 0.105 meters

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: J; L; Q; R
Knot Spacing: 0
Knot-Row Offset: 1

Weft Shot Pick Count: 4
Weft Shot Weave: Twill
Weft Weave Size: 1/3; 3/1
Weft Offset Pattern: Regular

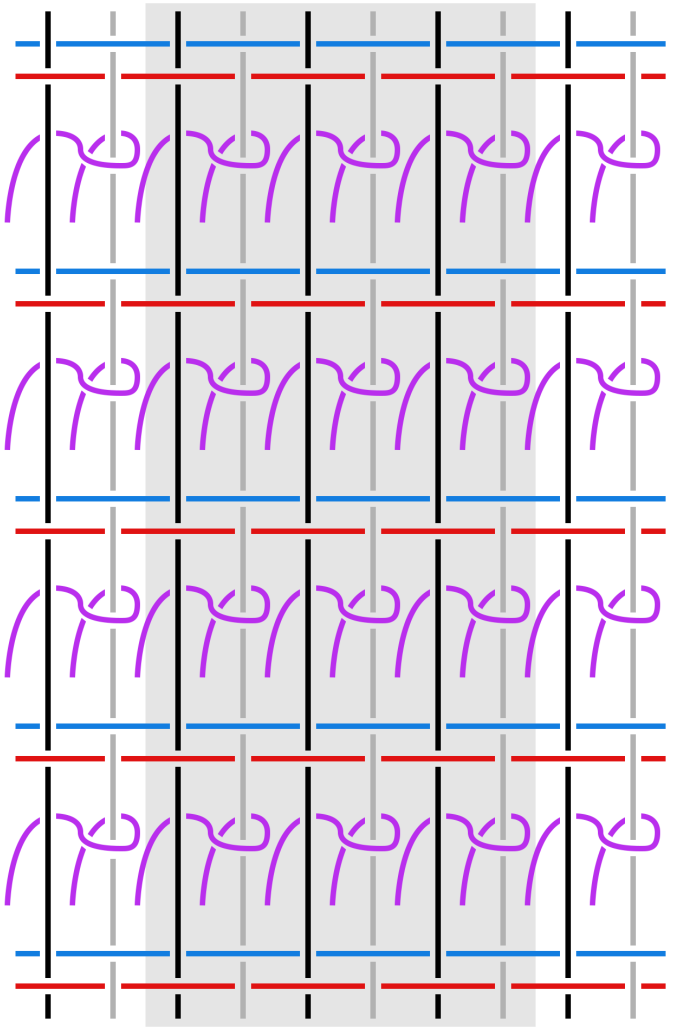
Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



Notes:

- triple-warp symmetric knots and single-warp wrap knots distributed at random; presumably a way to smooth design?

MU-AS-7 Figure B.40



Attribution: Maymana, Faryab Province, Afghanistan
Woven 130 – 270 CE
Location: Al-Sabah Collection (LNS 64 R)
Kuwait City, Kuwait

Total Fragment Size (l x w): 1.140 x 0.330 meters

Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- although consistently uses 2 picks per weft shot, different numbers of strands are drawn together in each shot; possibly as a way to level out uneven knotting?
- warps very close together, making very tall and narrow knots

MU-AS-8 **Figure B.41**

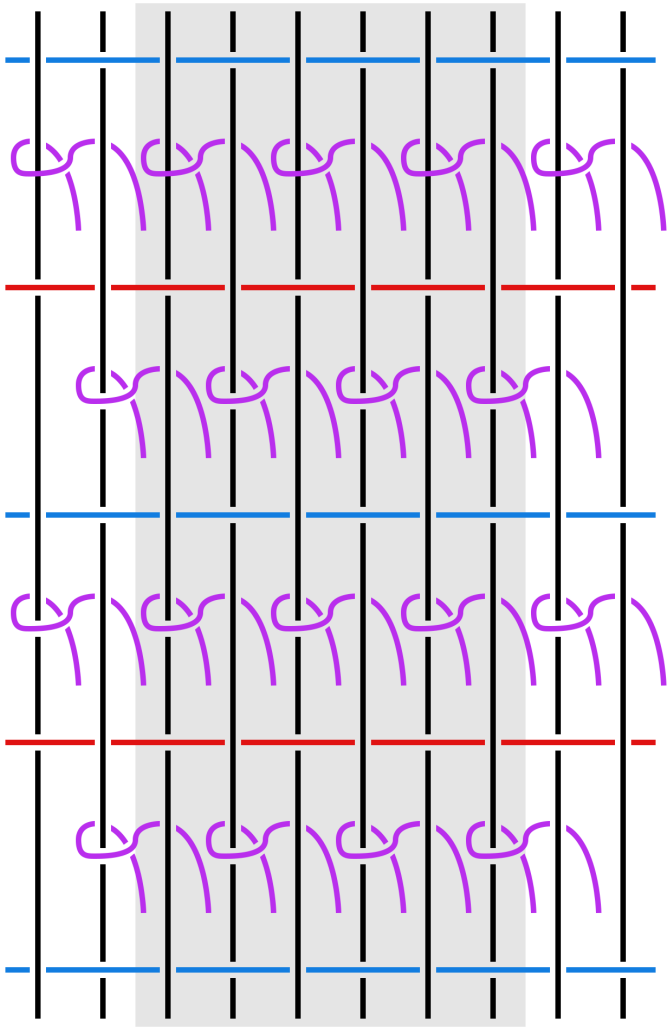
Attribution: Samangan Province, Afghanistan
Woven 565 – 655 CE
Location: Al-Sabah Collection (LNS 61 R c-f)
Kuwait City, Kuwait

Total Unit Size (l x w): 0.977 x 1.111 meters
Frag. C: 0.340 x 0.345 m
Frag. D: 0.425 x 0.270 m
Frag. E: 0.175 x 0.120 m
Frag. F: 0.820 x 0.610 m

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: D
Knot Spacing: 0
Knot-Row Offset: 1

Weft Shot Pick Count: 1
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

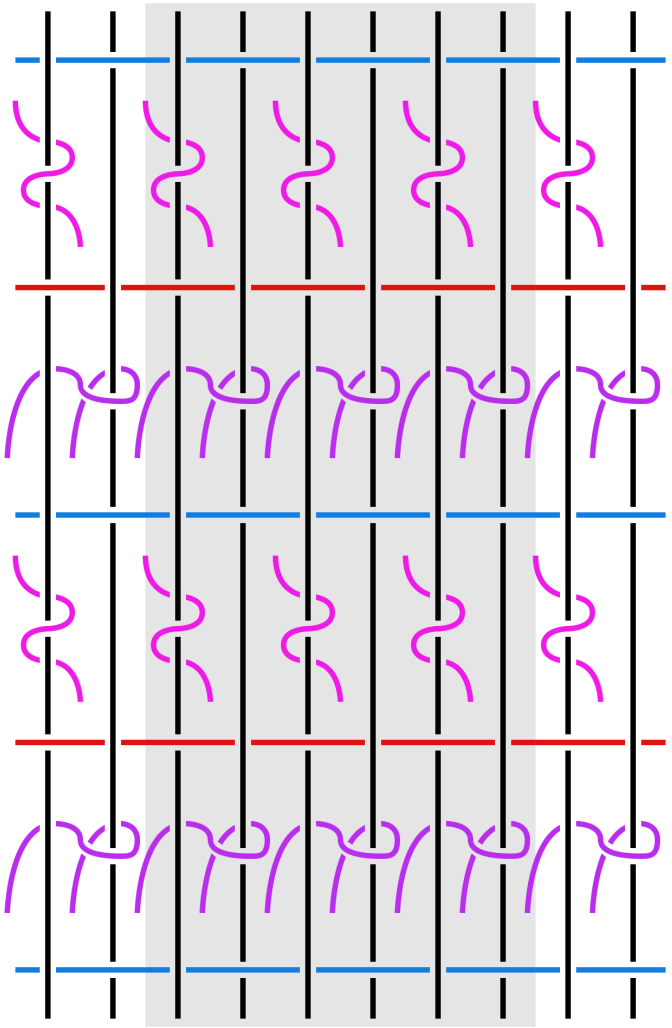
Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



Notes:

- although consistently uses 1 pick per weft shot, different numbers of strands are drawn together in each shot; possibly as a way to level out uneven knotting?
- warps very close together, making very tall and narrow knots

MU-AS-9ab **Figure B.42**



Attribution: Samangan Province, Afghanistan
Woven 220 – 410 CE
Location: Al-Sabah Collection (LNS 47 R a-b)
Kuwait City, Kuwait

Total Unit Size (l x w): 1.980 x 0.620 meters
Frag. A: 1.415 x 0.620 m
Frag. B: 0.565 x 0.400 m

Knot Type: AS; WR
Knot Direction: L; Z
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C; D
Knot Spacing: 0; 1
Knot-Row Offset: 0

Weft Shot Pick Count: 1
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- alternate rows of knots are tall/thick (asymmetric knots), or short/narrow (wrap knots)
- in photos, wrap knots sometimes get 'swallowed' by weft and can be hard to see
- although part of the same catalogue entry as MU-AS-17 and MU-AS-18, the three groups are structurally/ materially different, suggesting different original pieces

MU-AS-9c **Figure B.43**

Attribution: Samangan Province, Afghanistan
Woven 220 – 410 CE
Location: Al-Sabah Collection (LNS 47 R c),
Kuwait City, Kuwait

Total Fragment Size (l x w): 0.380 x 0.260 meters

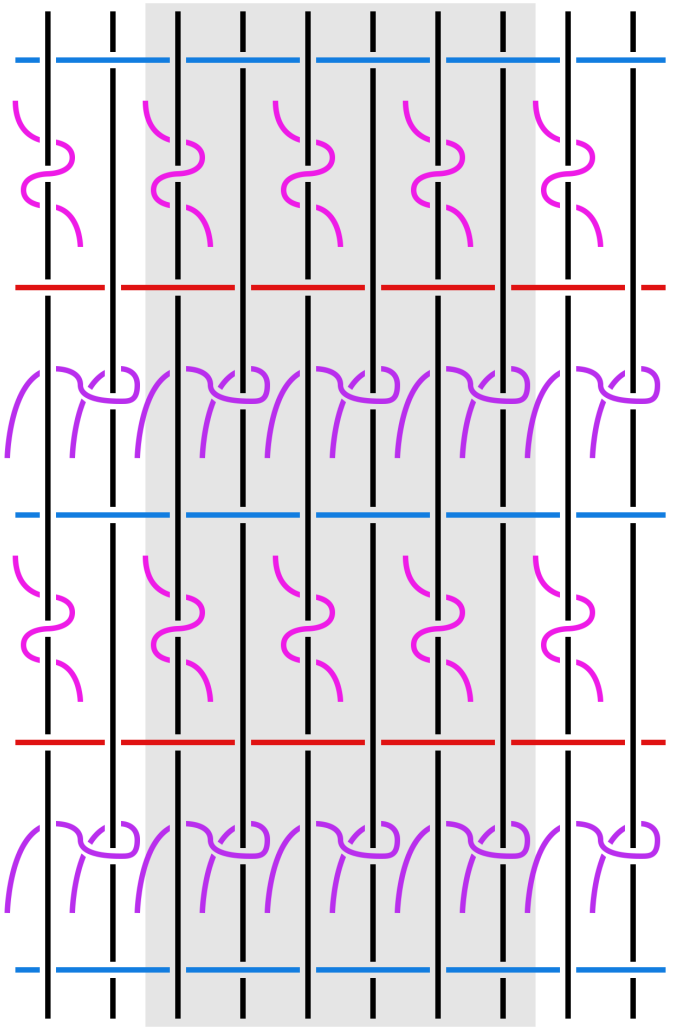
Knot Type: AS; WR
Knot Direction: L; Z
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C; D
Knot Spacing: 0; 1
Knot-Row Offset: 0

Weft Shot Pick Count: 1
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- alternate rows of knots are tall/thick (asymmetric knots), or short/narrow (wrap knots)
- in photos, wrap knots sometimes get 'swallowed' by weft and can be hard to see
- although part of the same catalogue entry as MU-AS-17, the two groups are structurally different suggesting different original pieces



MU-AS-9d **Figure B.44**

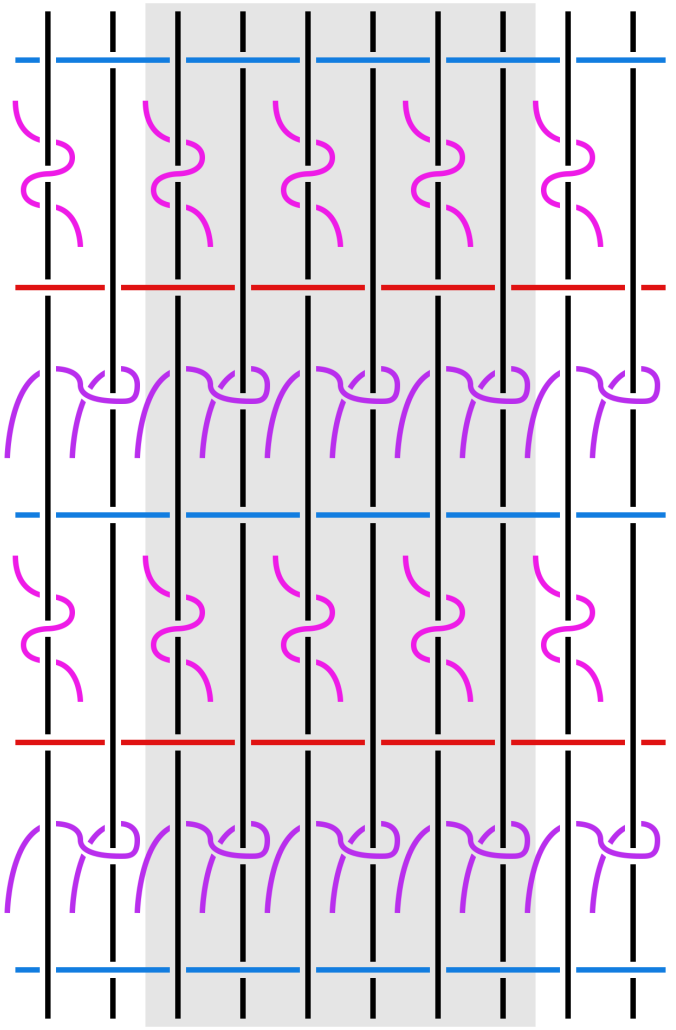
Attribution: Samangan Province, Afghanistan
Woven 220 – 410 CE
Location: Al-Sabah Collection (LNS 47 R d)
Kuwait City, Kuwait

Total Fragment Size (l x w): 0.915 x 0.250 meters

Knot Type: AS; WR
Knot Direction: L; Z
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C; D
Knot Spacing: 0; 1
Knot-Row Offset: 0

Weft Shot Pick Count: 1
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

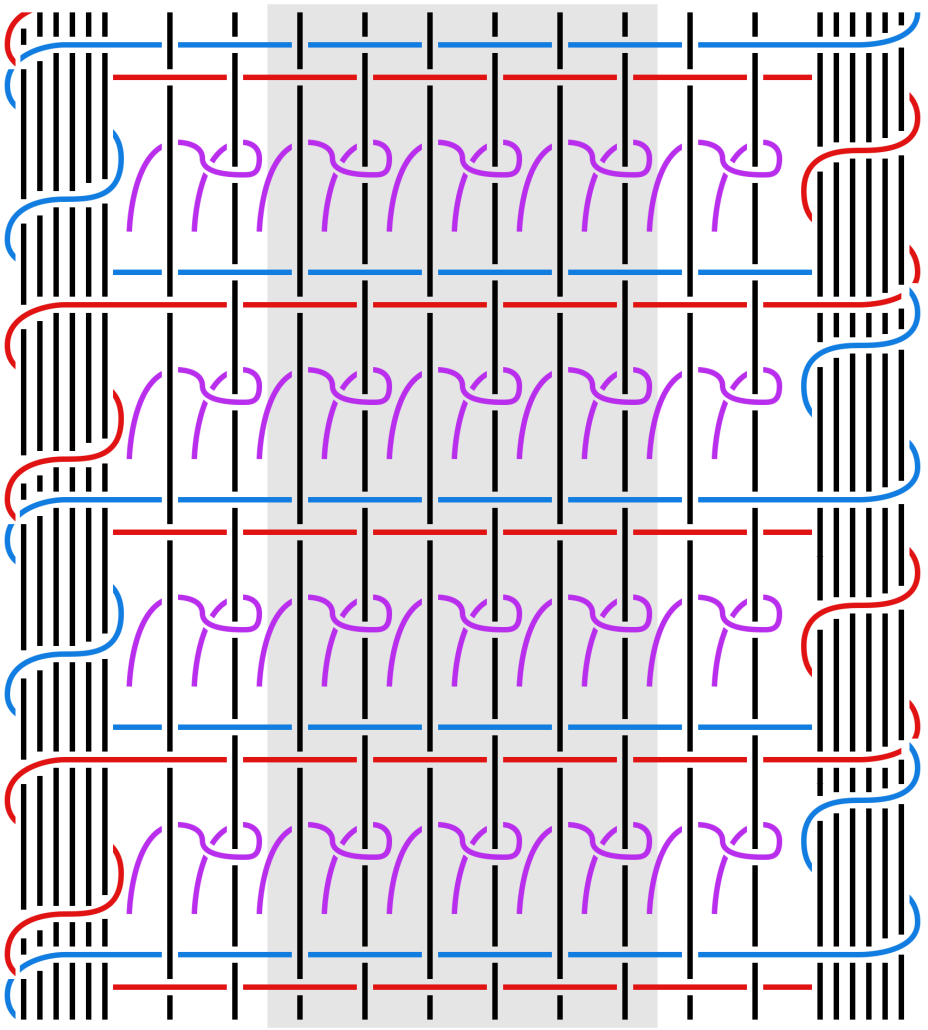
Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



Notes:

- alternate rows of knots are tall/thick (asymmetric knots), or short/narrow (wrap knots)
- in photos, wrap knots sometimes get ‘swallowed’ by weft and can be hard to see
- although part of the same catalogue entry as MU-AS-17, the two groups are structurally different suggesting different original pieces

MU-AS-10 Figure B.45



Attribution: Maymana, Faryab Province, Afghanistan
Woven 415 – 640 CE
Location: Al-Sabah Collection (LNS 62 R a-b)
Kuwait City, Kuwait

Total Unit Size (l x w): 1.800 x 0.975 meters
Frag. A: 1.800 x 0.975 m
Frag. B: 0.288 x 0.243 m

Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Reg.

Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: 6:1
Binding-Weft Overlap: C

Notes:

- knots at edges have extra-long pile, presumably to cover the binding and create a fringed effect
- binding not added at regular intervals; picks added as necessary to keep level with knotting

MU-AS-11 **Figure B.46**

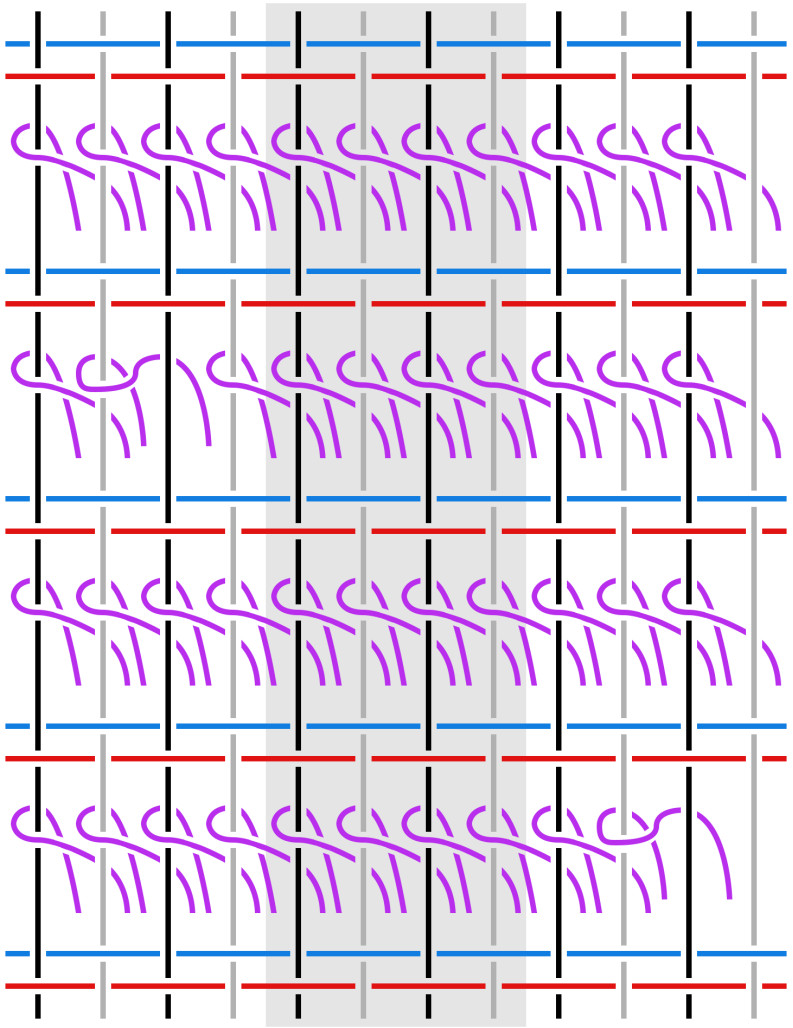
Attribution: Samangan Province, Afghanistan
Woven 535 – 680 CE
Location: Al-Sabah Collection (LNS 48 R a-e)
Kuwait City, Kuwait

Total Unit Size (l x w): 1.664 x 0.757 meters
Frag. A: 1.080 x 0.700 m
Frag. B: 0.390 x 0.400 m
Frag. C: 0.230 x 0.520 m
Frag. D: 0.250 x 0.160 m
Frag. E: 0.270 x 0.160 m

Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C; D
Knot Spacing: -1
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



Notes:

- Knot Spacing of 0 occasionally; no apparent pattern and not frequent; possibly a way to smooth design?

MU-AS-12 Figure B.47

Attribution: Samangan Province, Afghanistan
Woven 332 – 430 CE
Location: Al-Sabah Collection (LNS 74 R)
Kuwait City, Kuwait

Total Fragment Size (l x w): 0.930 x 1.070 meters

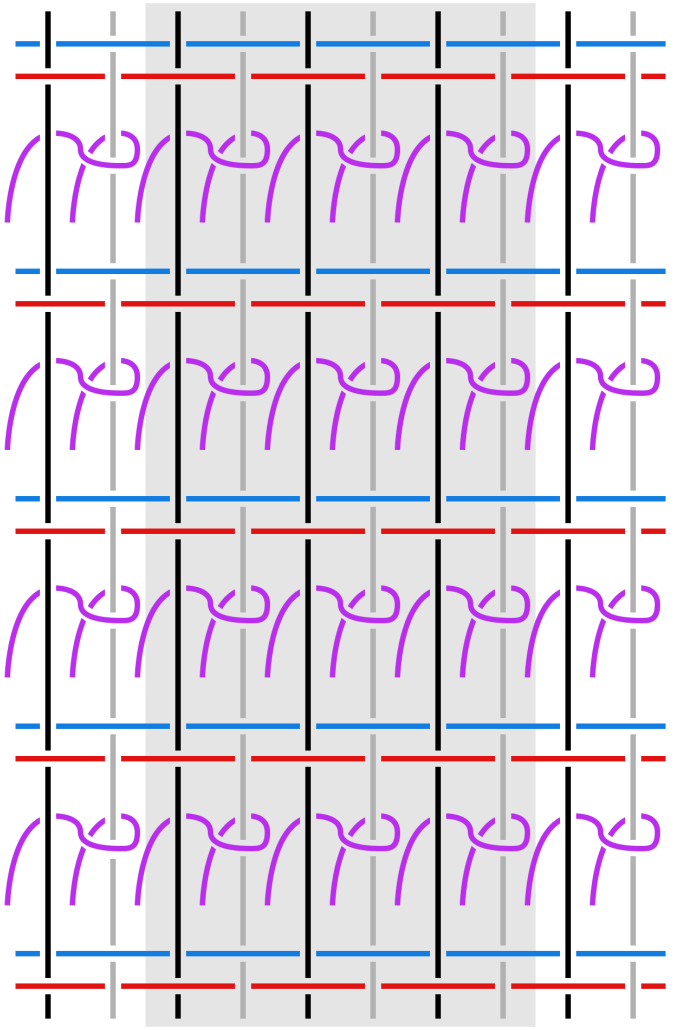
Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- warps very close together, making very tall and narrow knots



MU-AS-13 Figure B.48

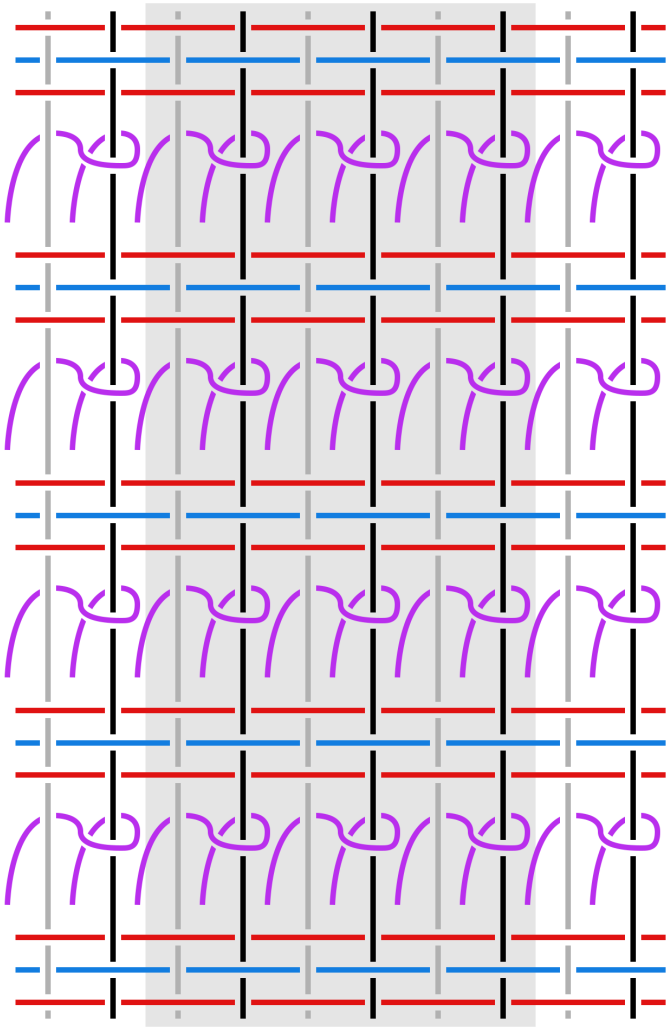
Attribution: Herat, Afghanistan
Woven 17th century CE
Location: Al-Sabah Collection (LNS 44 R)
Kuwait City, Kuwait

Total Fragment Size (l x w): 1.850 x 1.390 meters

Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: B
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 3
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



MU-AS-14 Figure B.49

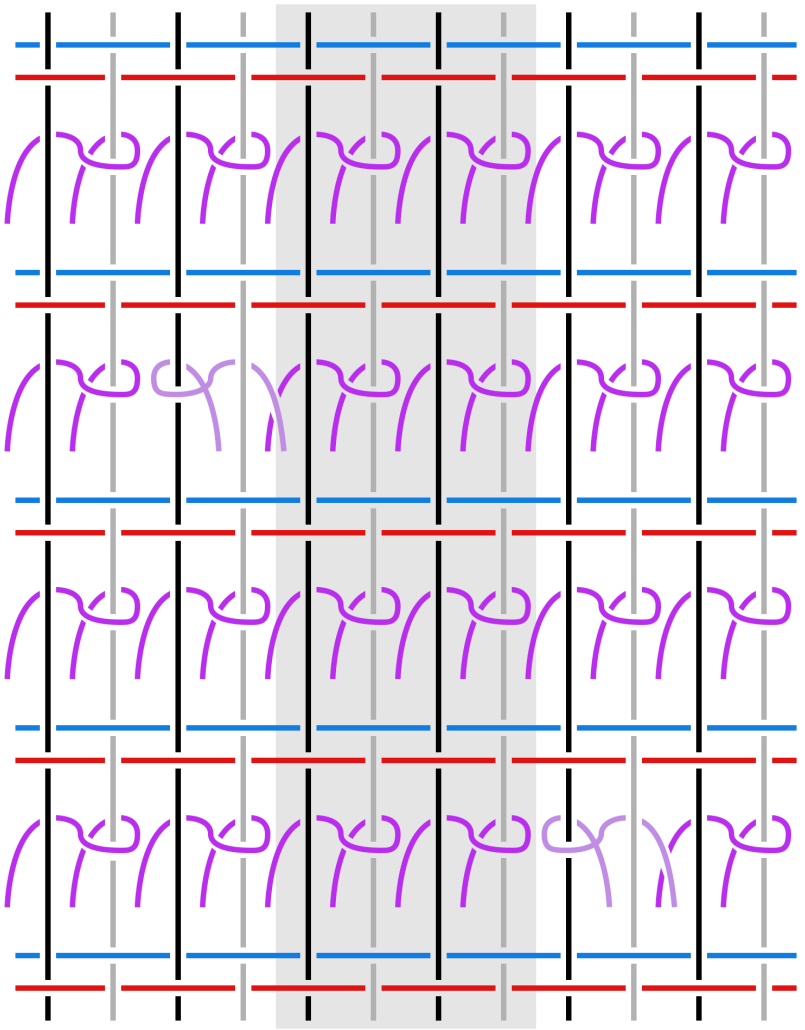
Attribution: Samangan Province, Afghanistan
Woven 280 – 340 CE
Location: Al-Sabah Collection (LNS 73 R)
Kuwait City, Kuwait

Total Fragment Size (l x w): 0.980 x 0.860 meters

Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: II
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



Notes:

- some random knots are right-opening; no apparent pattern and not frequent
- warps very close together, making very tall and narrow knots

MU-AS-16 **Figure B.50**

Attribution: Samangan Province, Afghanistan
Woven 500 – 699 CE
Location: Al-Sabah Collection (LNS 61 R b)
Kuwait City, Kuwait

Total Fragment Size (l x w): 0.175 x 0.155 meters

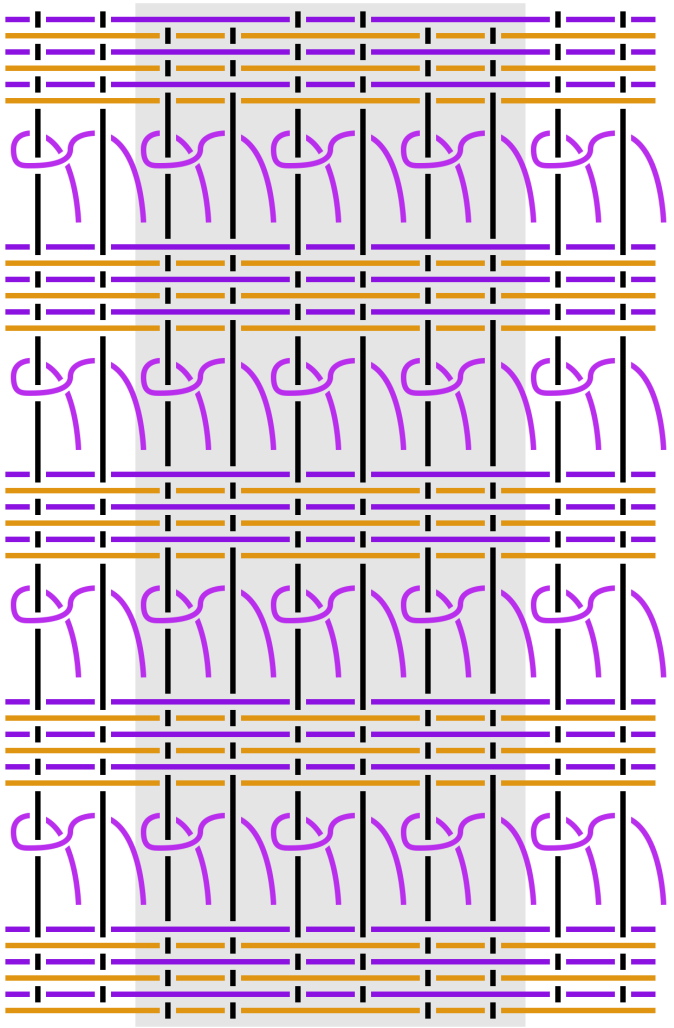
Knot Type: AS
Knot Direction: R
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: G; H
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 6*
Weft Shot Weave: Tabby
Weft Weave Size: 2/2
Weft Offset Pattern: Regular

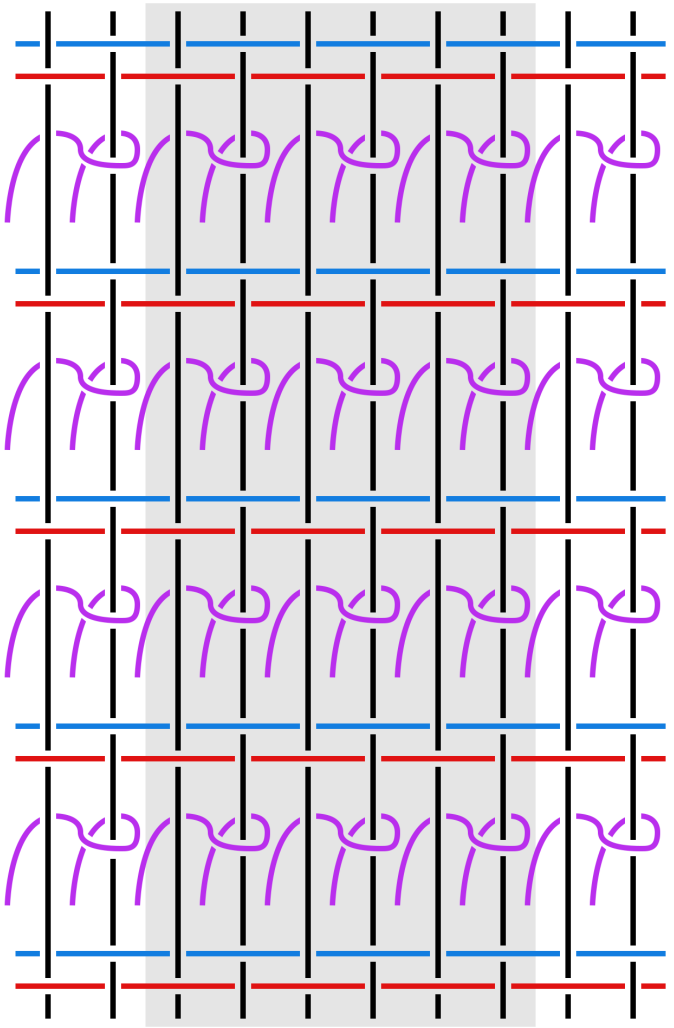
Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- usually 6 picks per weft shot, but occasional shots with 3-8
- warps very close together, making very tall and narrow knots



MU-AS-17ef **Figure B.51**



Attribution: Samangan Province, Afghanistan
Woven 220 – 410 CE*
Location: Al-Sabah Collection (LNS 47 R e-f)
Kuwait City, Kuwait

Total Unit Size (l x w): 0.370 x 0.282 meters
Frag. E: 0.370 x 0.265 m Frag. F: 0.085 x 0.080 m

Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

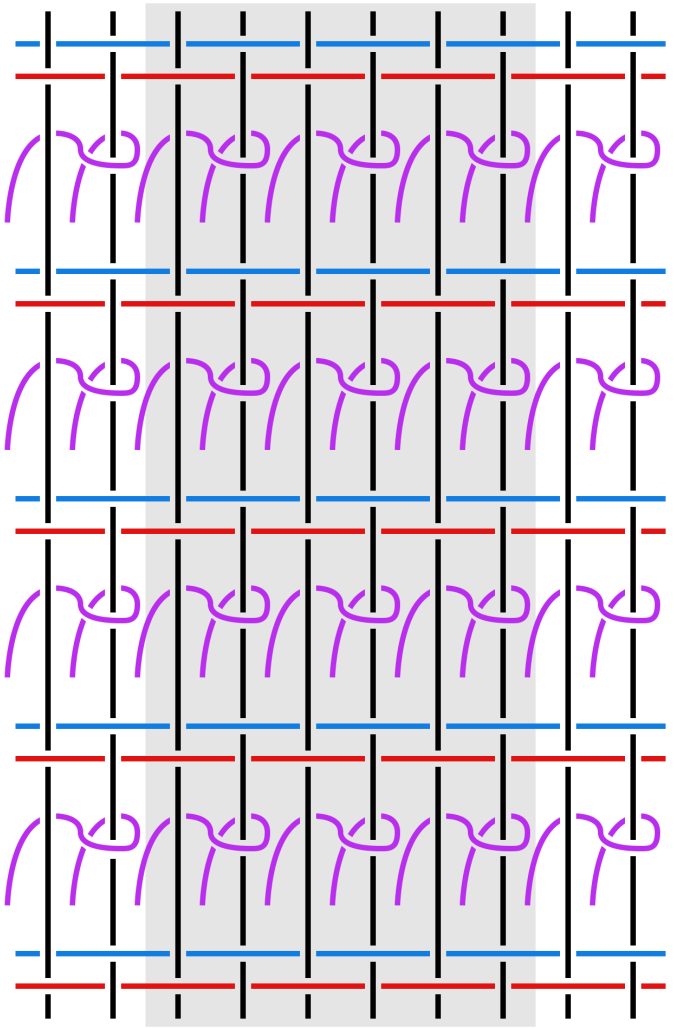
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- although part of the same catalogue entry as MU-AS-9 and MU-AS-18, the three groups are structurally/ materially different, suggesting different original pieces
- *only pieces LNS 47 R a (MU-AS-9a) and LNS 47 R h (MU-AS-18) were carbon-dated

MU-AS-17g **Figure B.52**



Attribution: Samangan Province, Afghanistan
Woven 220 – 410 CE*
Location: Al-Sabah Collection (LNS 47 R g)
Kuwait City, Kuwait

Total Fragment Size (l x w): 0.195 x 0.170 meters

Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- although part of the same catalogue entry as MU-AS-9 and MU-AS-18, the three groups are structurally/materially different, suggesting different original pieces
- *only pieces LNS 47 R a (MU-AS-9a) and LNS 47 R h (MU-AS-18) were carbon-dated

MU-AS-18 Figure B.53

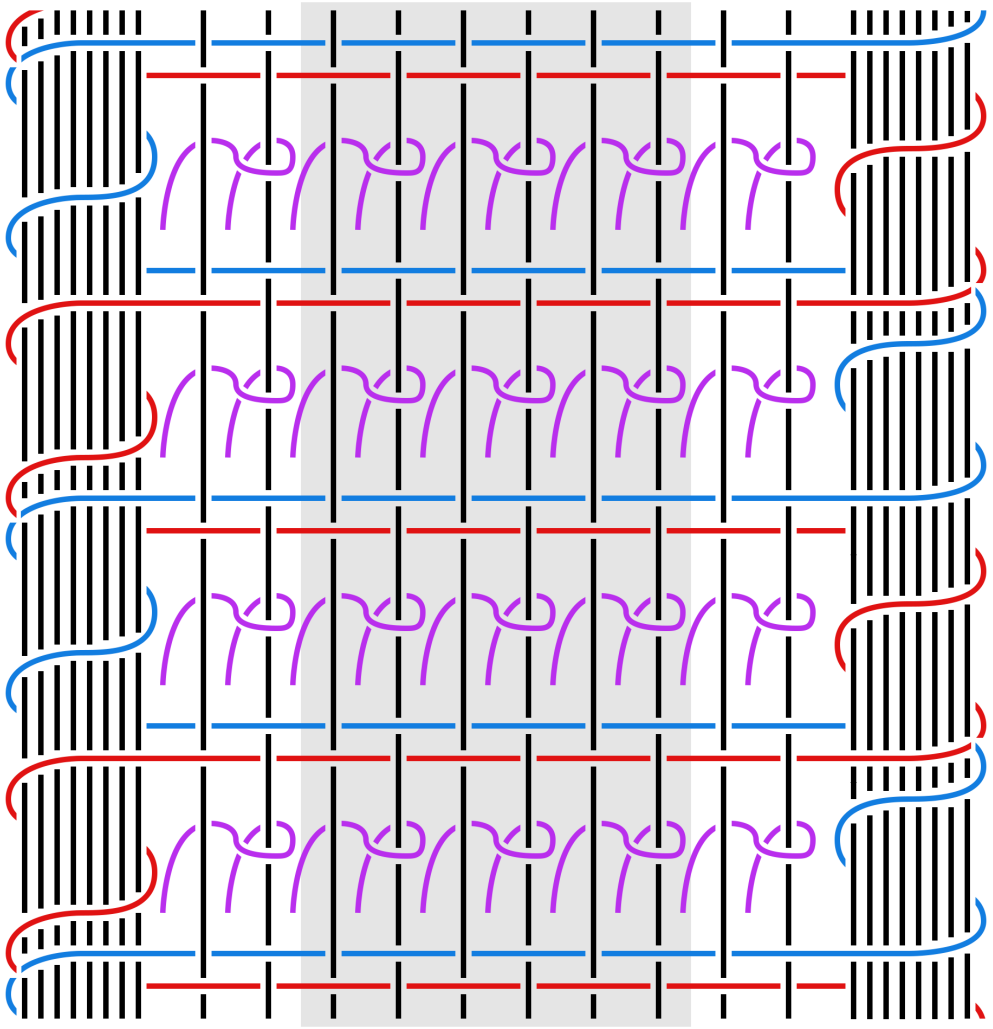
Attribution: Samangan Province, Afghanistan
Woven 114 – 348 CE
Location: Al-Sabah Collection (LNS 47 R h)
Kuwait City, Kuwait

Total Fragment Size (l x w): 0.165 x 0.180 meters

Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

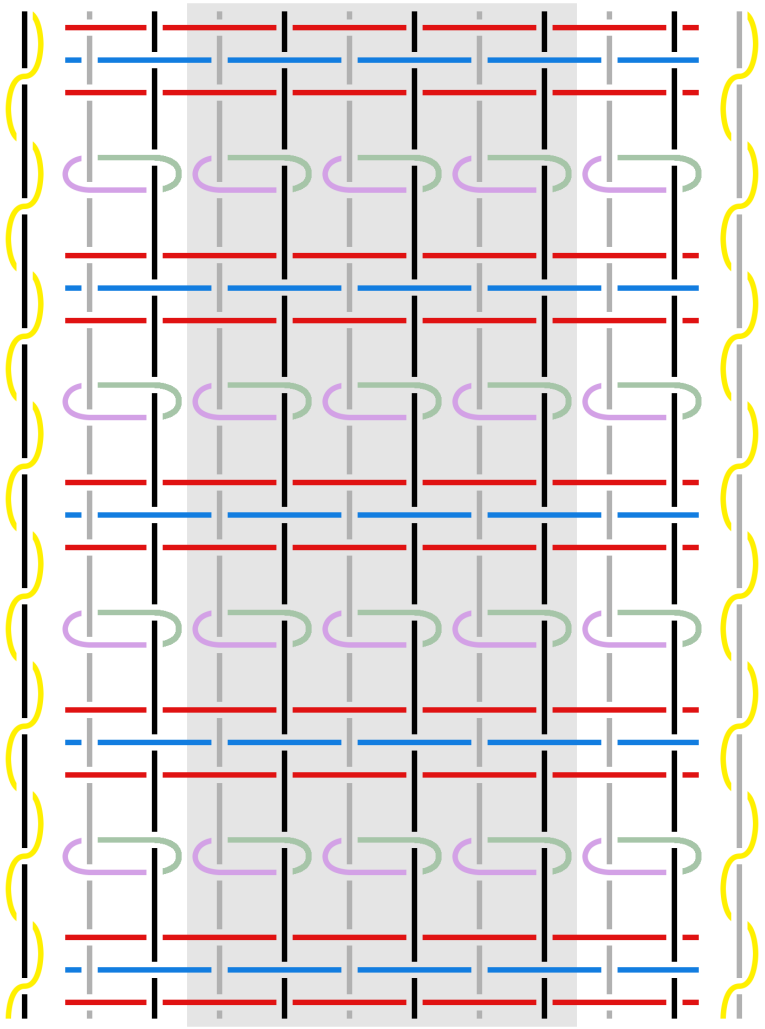
Binding Weave Pattern: Wrap
Binding Warps: 8:1
Binding-Weft Overlap: C



Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting
- although part of the same catalogue entry as MU-AS-9 and MU-AS-17, the three groups are structurally/ materially different, suggesting different original pieces

MU-CH-1 Figure B.54



Attribution: Khotan, Xinjiang, China
Woven c. 1800 CE
Location: Private Collection (Christie's Lot 213)

Total Fragment Size (l x w): 1.510 x 0.990 meters

Knot Type: ?
Knot Direction: ?
Knot Variants: ?
Knot-Warp Pattern: III
Knot Weft Pattern: B
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 3
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: ?:1
Binding-Weft Overlap: S

Notes:

- do not know how many warps are bundled in each side binding
- binding not added at regular intervals; picks added as necessary to keep level with knotting

MU-CH-2 Figure B.55

Attribution: Tarim Basin, Xinjiang, China
Woven late 18th century CE
Location: Private Collection (Christie's Lot 214)

Total Fragment Size (l x w): 1.750 x 0.980 meters

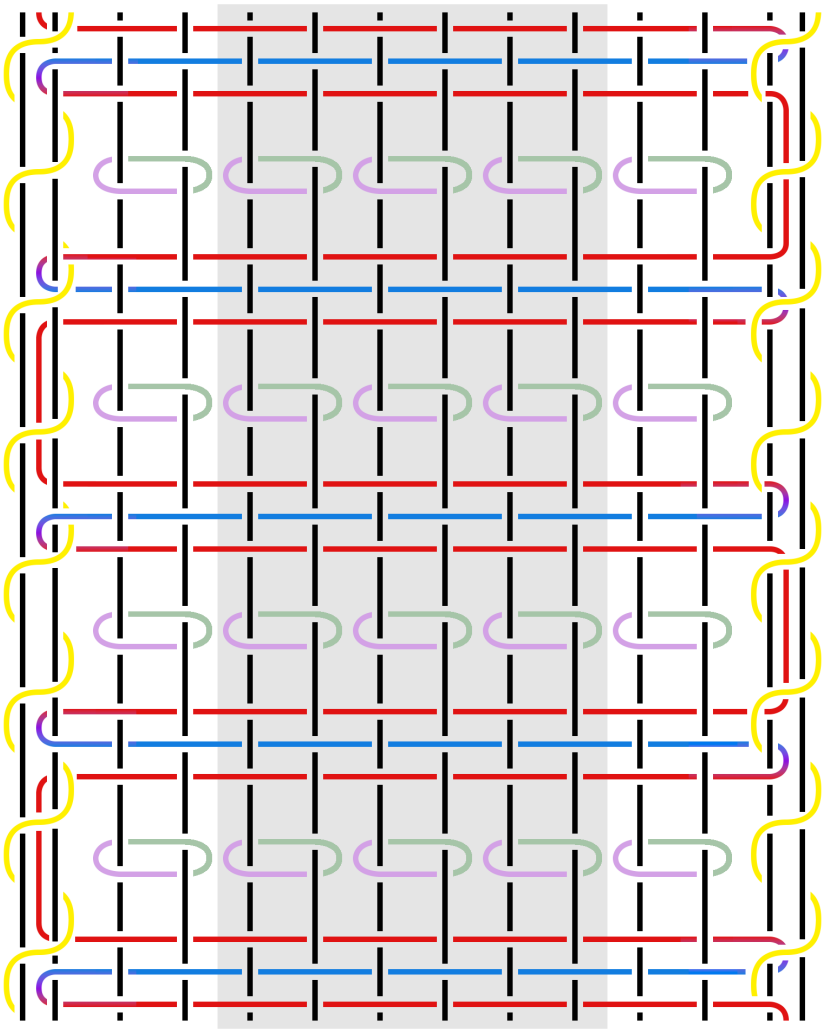
Knot Type: ?
Knot Direction: ?
Knot Variants: ?
Knot-Warp Pattern: I
Knot Weft Pattern: B
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 3
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

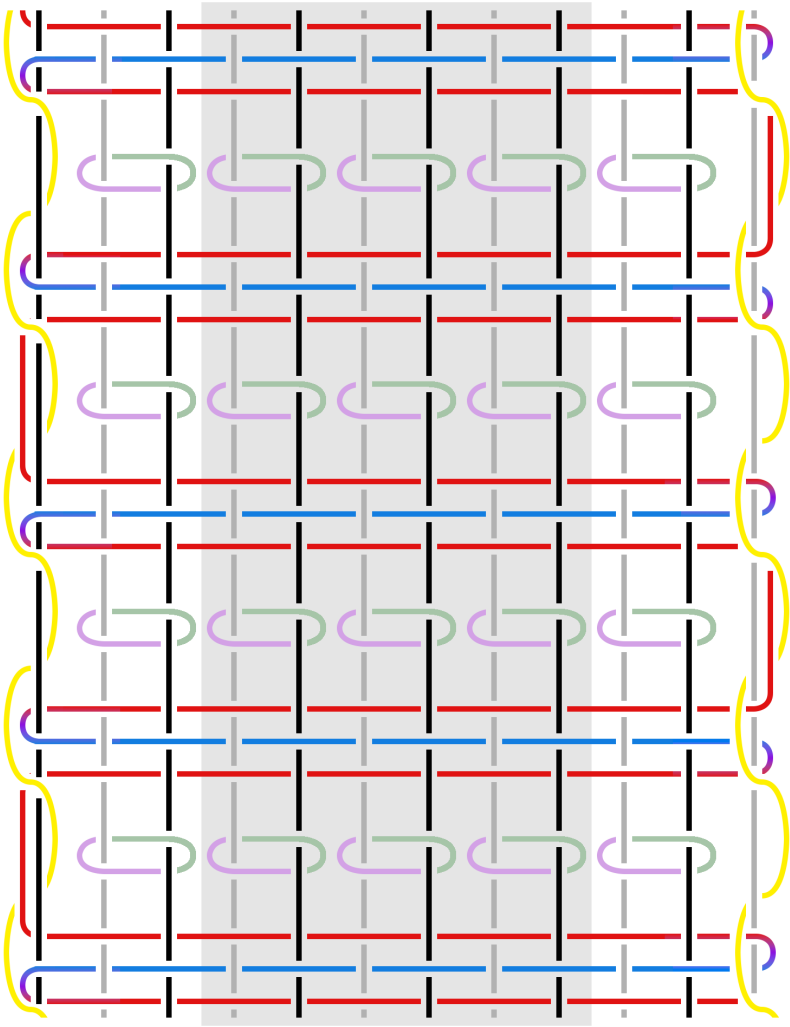
Binding Weave Pattern: Wrap
Binding Warps: 2:1
Binding-Weft Overlap: S

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting



MU-CH-3 Figure B.56



Attribution: East Turkestan
Woven late 18th century CE
Location: Private Collection (Christie's Lot 216)

Total Fragment Size (l x w): 3.490 x 1.840 meters

Knot Type: ?
Knot Direction: ?
Knot Variants: ?
Knot-Warp Pattern: III
Knot Weft Pattern: B
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 3
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: 2:1
Binding-Weft Overlap: S

Notes:

- Christie's provenance given as "East Turkestan", likely referring to Xinjiang, China
- binding not added at regular intervals; picks added as necessary to keep level with knotting

MU-CH-4 Figure B.57

Attribution: Western Turkey
Woven late 17th century CE
Location: Private Collection (Christie's Lot 229)

Total Fragment Size (l x w): 1.660 x 1.250 meters

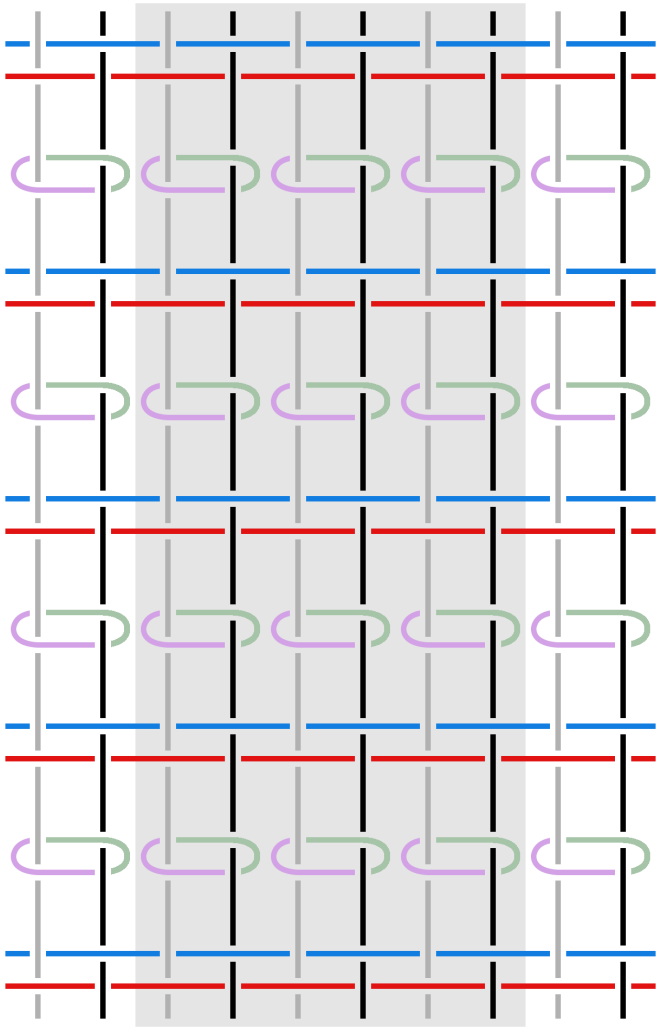
Knot Type: ?
Knot Direction: ?
Knot Variants: ?
Knot-Warp Pattern: III
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- original binding does not survive; current binding is 20th century restoration



MU-CH-5 Figure B.58

Attribution: Beijing, China
Woven early 17th century CE
Location: Private Collection (Christie's Lot 271)

Total Fragment Size (l x w): 1.780 x 1.070 meters

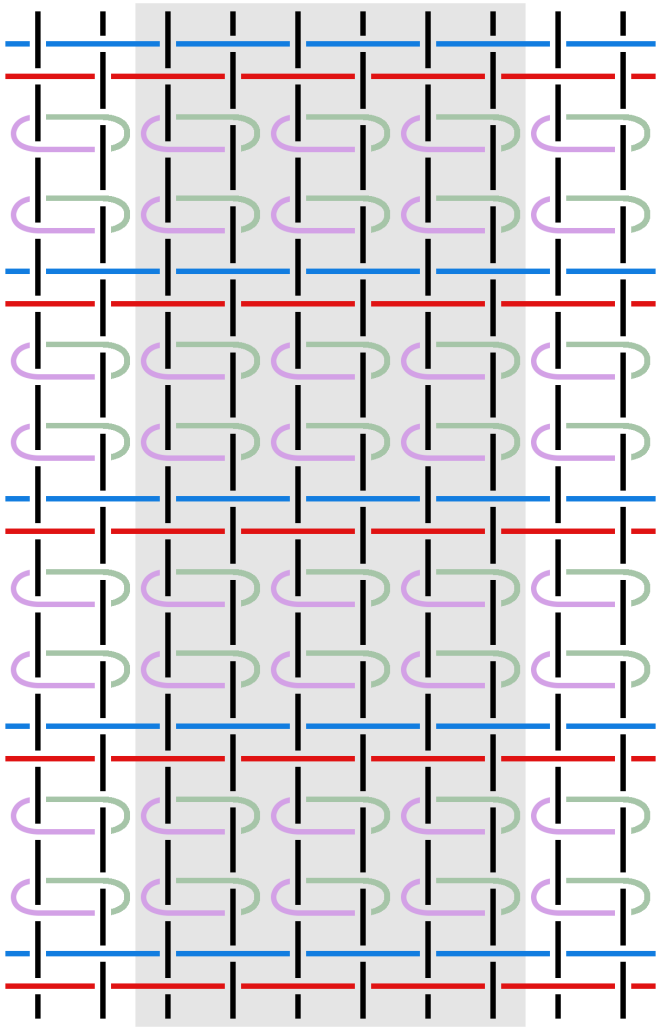
Knot Type: ?
Knot Direction: ?
Knot Variants: ?
Knot-Warp Pattern: I
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- original binding does not survive; current binding is 20th century restoration



MU-CH-6 Figure B.59

Attribution: Northern China
Woven 1662 – 1722 CE
Location: Private Collection (Christie's Lot 272)

Total Fragment Size (l x w): 1.330 x 3.120 meters

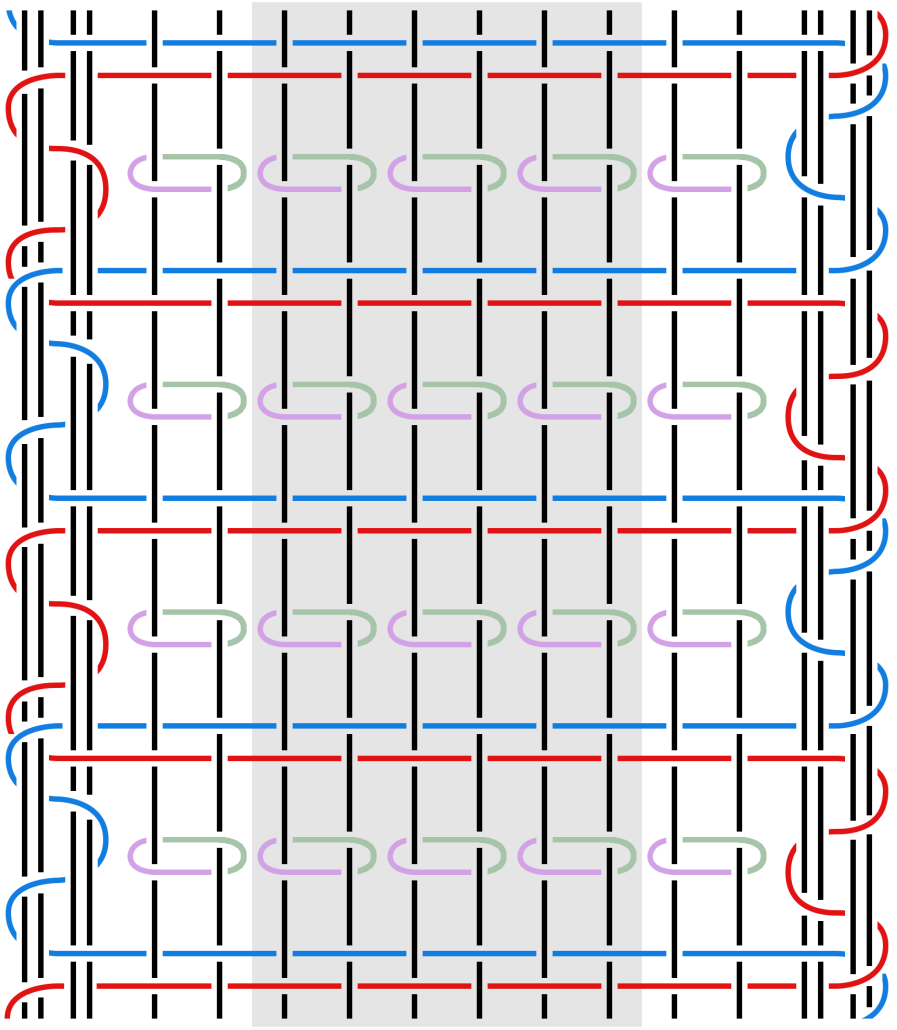
Knot Type: ?
Knot Direction: ?
Knot Variants: ?
Knot-Warp Pattern: I
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Tabby
Binding Warps: 4:2
Binding-Weft Overlap: C

Notes:

- binding not added at regular intervals; picks added as necessary to keep level with knotting



MU-CH-7 Figure B.60

Attribution: Northern China
Woven 18th century CE
Location: Private Collection (Christie's Lot 273)

Total Fragment Size (l x w): 2.290 x 3.590 meters

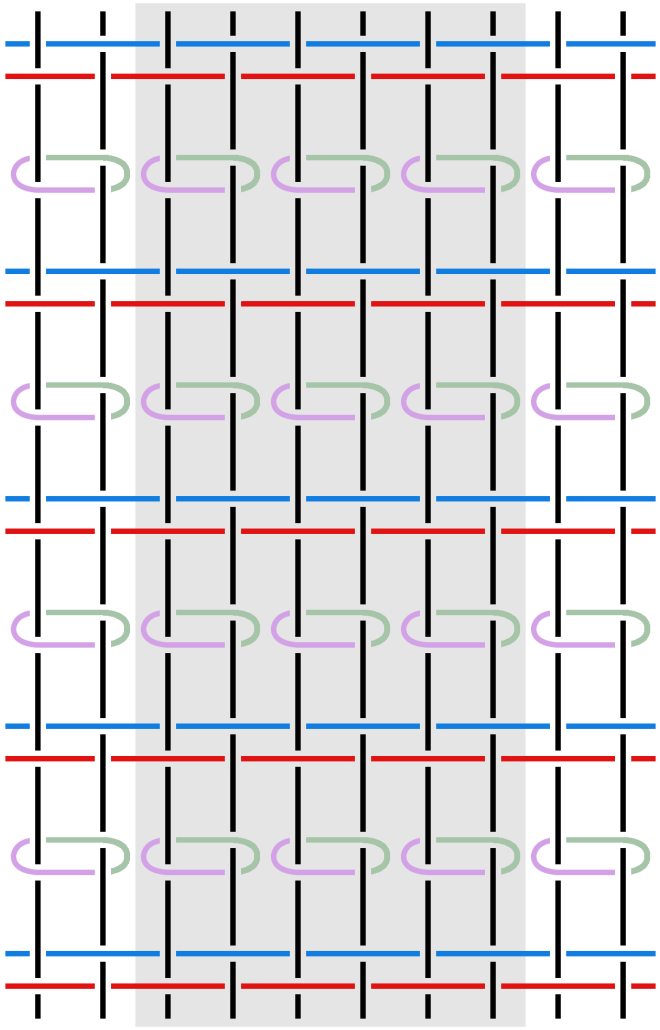
Knot Type: ?
Knot Direction: ?
Knot Variants: ?
Knot-Warp Pattern: I
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- original binding does not survive; current binding is 20th century restoration



MU-DY-1a **Figure B.61**

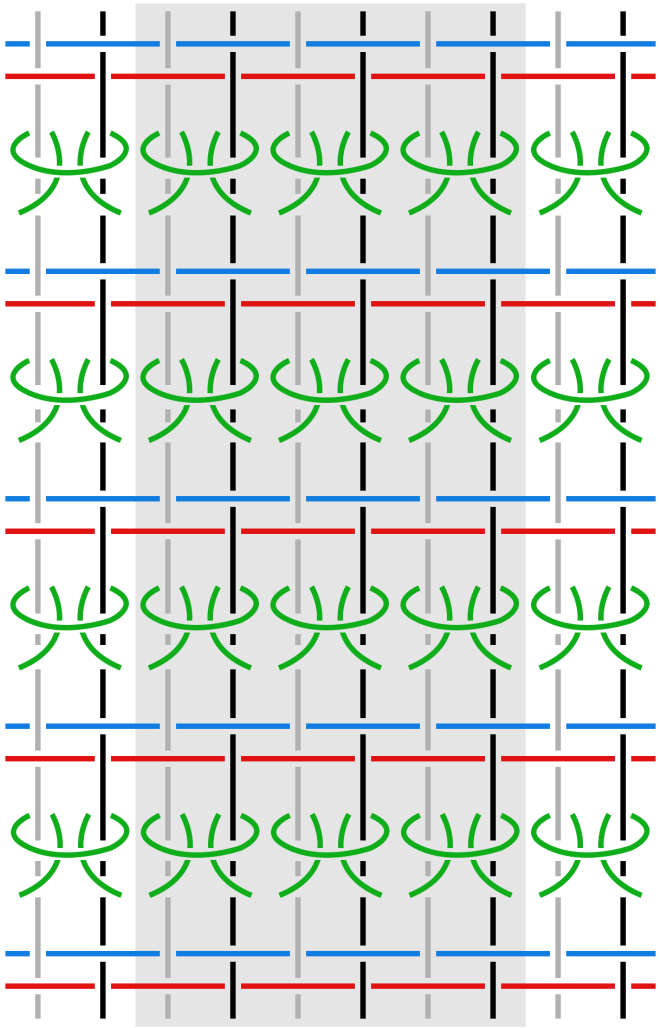
Attribution: Ushak, Turkey
Woven 16th century CE
Location: de Young Museum (1986.90a)
San Francisco, California, USA

Total Fragment Size (l x w): 0.322 x 0.454 meters

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



MU-DY-1b **Figure B.62**

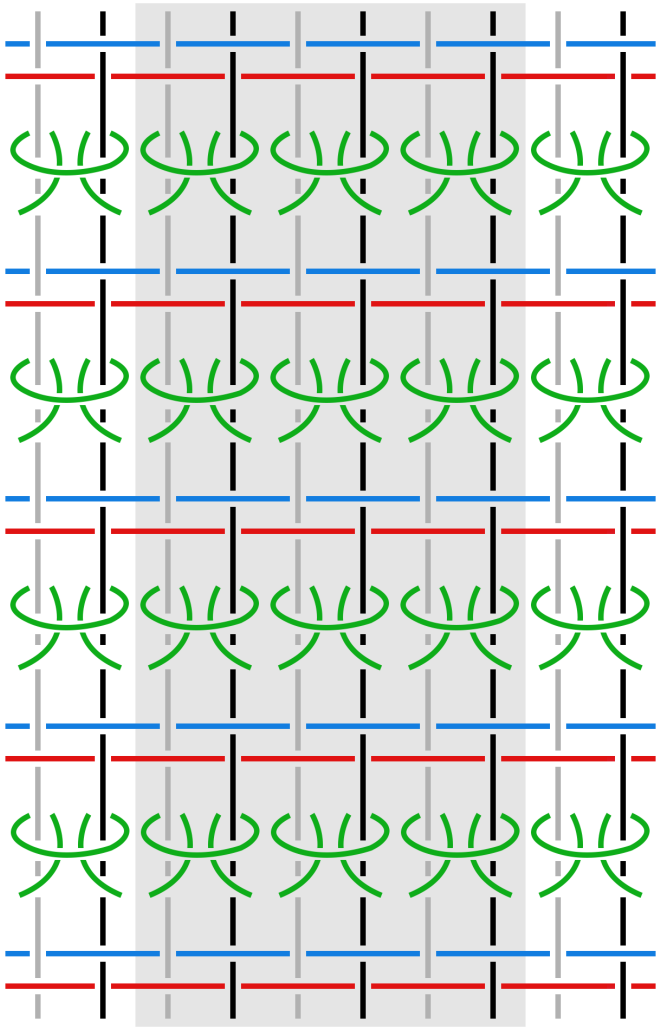
Attribution: Ushak, Turkey
Woven 16th century CE
Location: de Young Museum (1986.90b)
San Francisco, California, USA

Total Fragment Size (l x w): 0.489 x 0.303 meters

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



MU-DY-1c **Figure B.63**

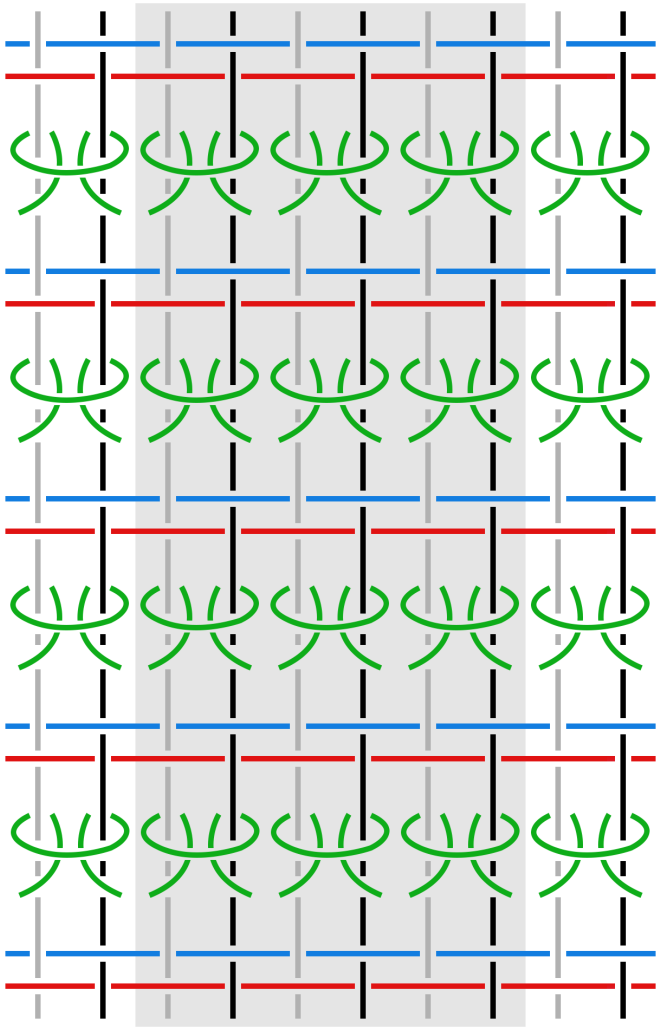
Attribution: Ushak, Turkey
Woven 16th century CE
Location: de Young Museum (1986.90c)
San Francisco, California, USA

Total Fragment Size (l x w): 0.539 x 0.455 meters

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



MU-DY-1d **Figure B.64**

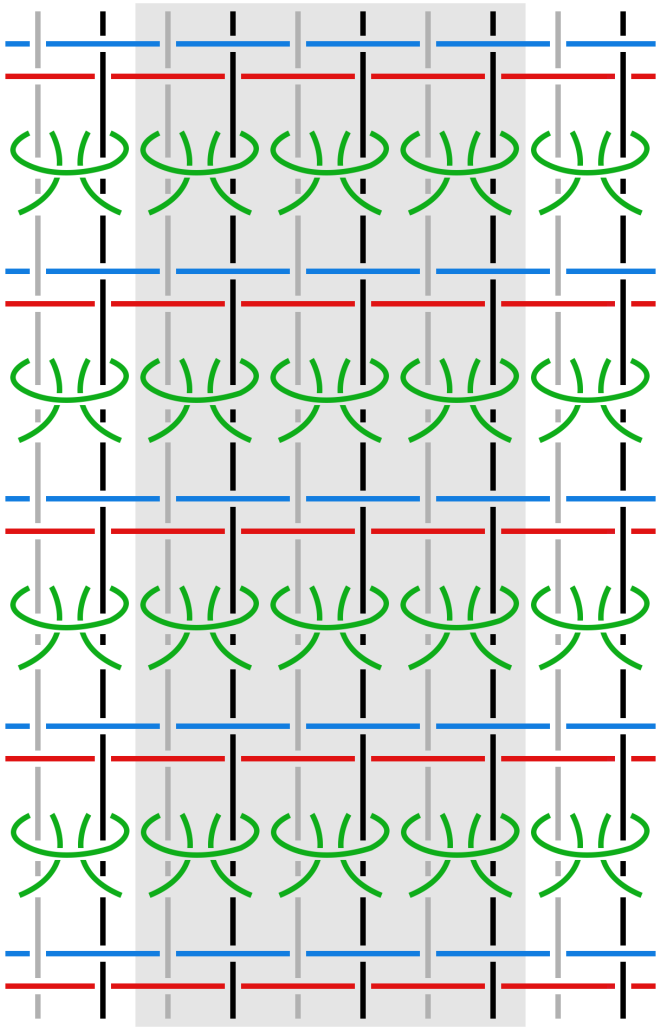
Attribution: Ushak, Turkey
Woven 16th century CE
Location: de Young Museum (1986.90d)
San Francisco, California, USA

Total Fragment Size (l x w): 0.361 x 0.158 meters

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



MU-DY-2a **Figure B.65**

Attribution: Central Asia or West China
Woven 418 – 602 CE
Location: de Young Museum (2019.84.1a)
San Francisco, California, USA

Total Fragment Size (l x w): 0.604 x 0.581 meters

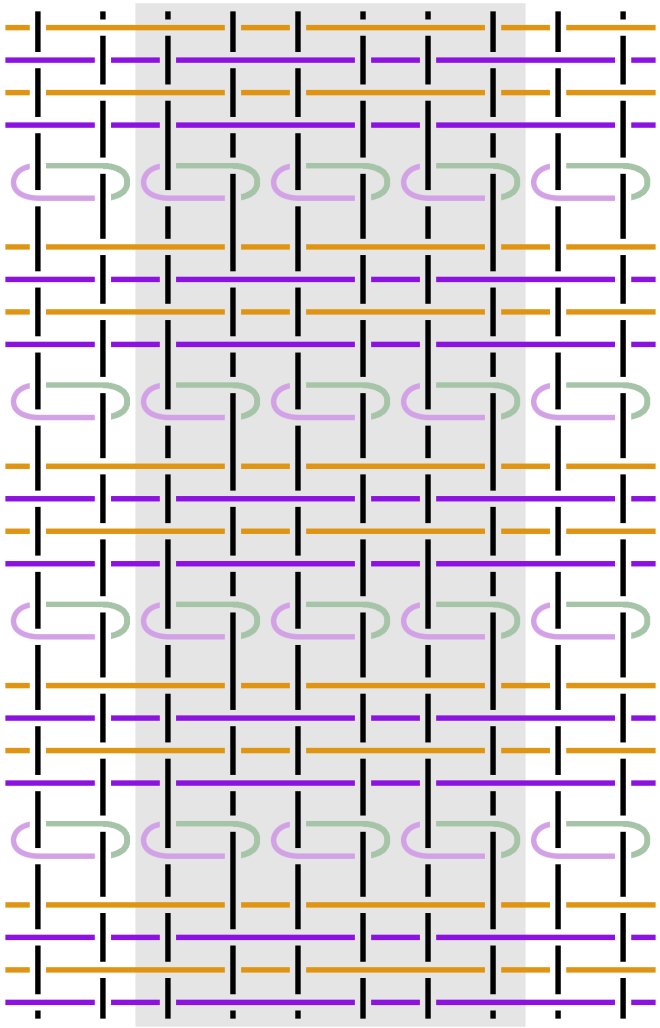
Knot Type: ?
Knot Direction: ?
Knot Variants: ?
Knot-Warp Pattern: I
Knot Weft Pattern: C; D
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 4*
Weft Shot Weave: Tabby
Weft Weave Size: 2/2
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- usually 4 picks per weft shot, but occasionally 3-5



MU-DY-2b Figure B.66

Attribution: Central Asia or West China
Woven 418 – 602 CE
Location: de Young Museum (2019.84.1b)
San Francisco, California, USA

Total Fragment Size (l x w): 0.372 x 0.368 meters

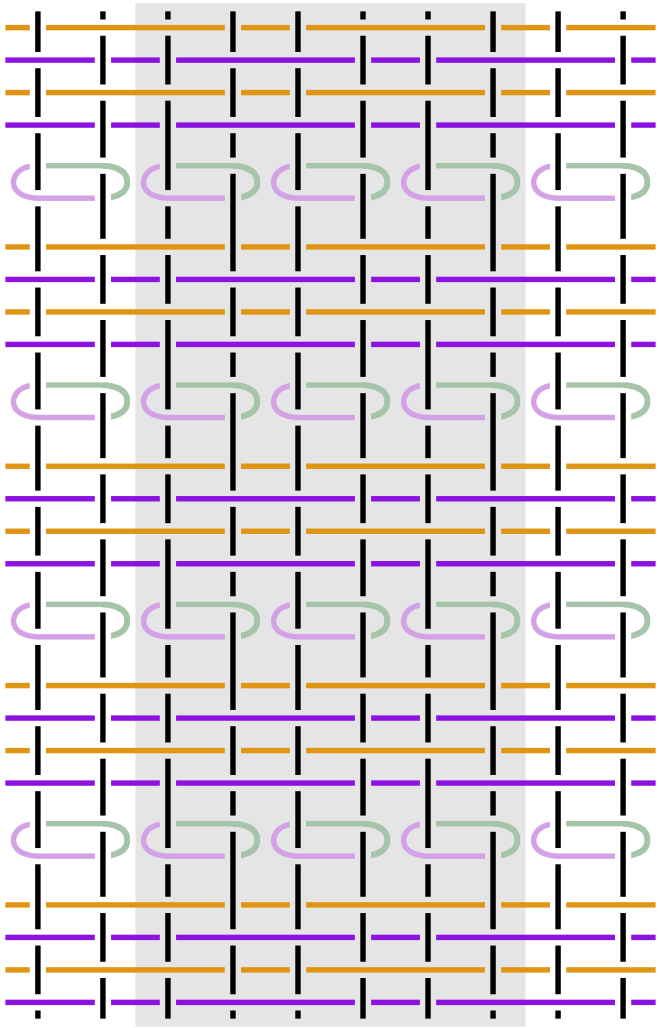
Knot Type: ?
Knot Direction: ?
Knot Variants: ?
Knot-Warp Pattern: I
Knot Weft Pattern: C; D
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 4*
Weft Shot Weave: Tabby
Weft Weave Size: 2/2
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- usually 4 picks per weft shot, but occasionally 3-5



MU-DY-2c **Figure B.67**

Attribution: Central Asia or West China
Woven 418 – 602 CE
Location: de Young Museum (2019.84.1c)
San Francisco, California, USA

Total Fragment Size (l x w): 0.311 x 0.136 meters

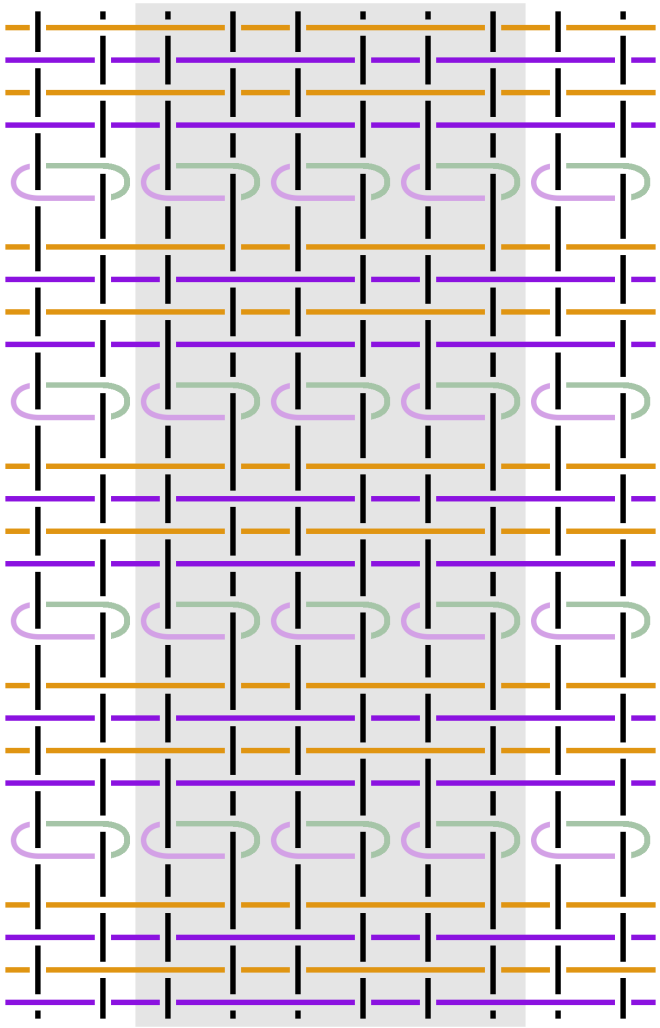
Knot Type: ?
Knot Direction: ?
Knot Variants: ?
Knot-Warp Pattern: I
Knot Weft Pattern: C; D
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 4*
Weft Shot Weave: Tabby
Weft Weave Size: 2/2
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- usually 4 picks per weft shot, but occasionally 3-5



MU-IN-1 Figure B.68

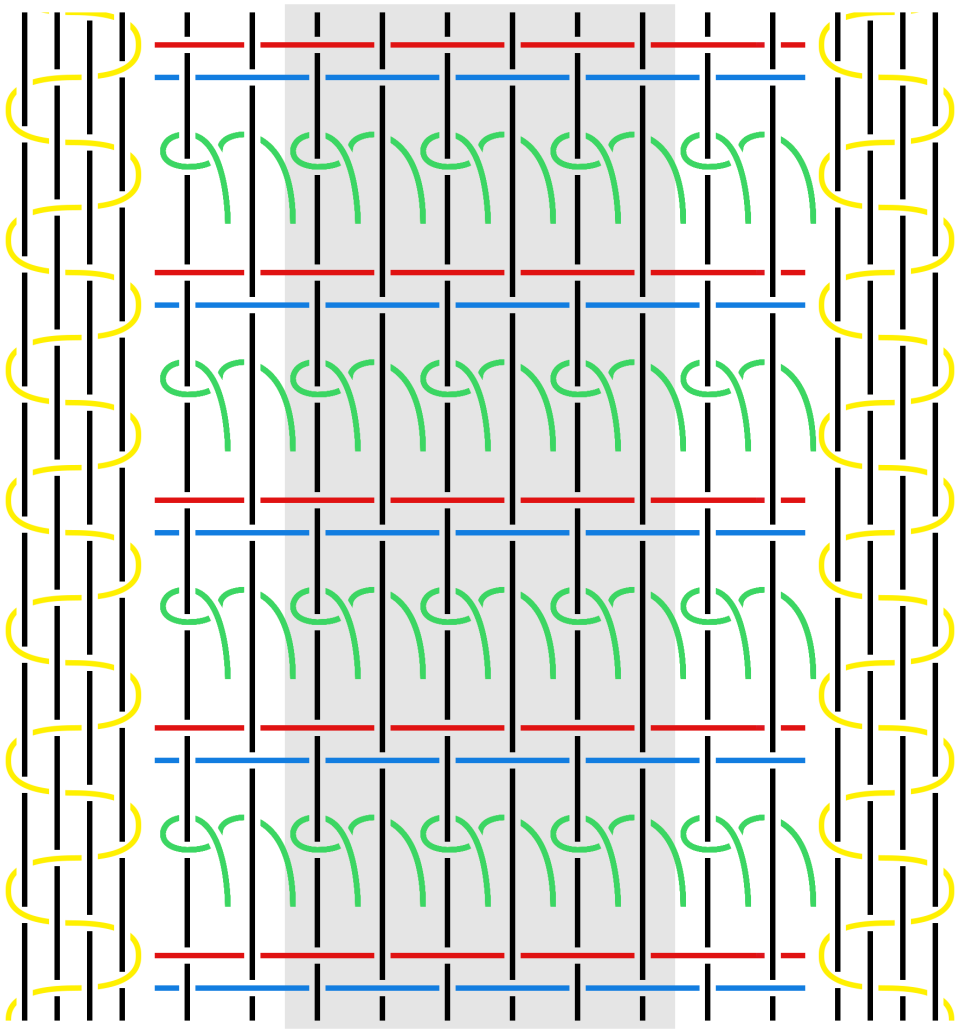
Attribution: Torbat-e Heydarieh, Khorasan, Iran
Woven c. 1875 CE
Location: Indianapolis Museum of Art at Newfields (1996.25); Indianapolis, Indiana, USA

Total Size (l x w): 1.930 x 1.118 meters

Knot Type: AS
Knot Direction: R
Knot Variants: Y
Knot-Warp Pattern: I
Knot Weft Pattern: D
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Tabby
Binding Warps: ?:4
Binding-Weft Overlap: ?



Notes:

- not clear whether the weft yarns are continuous with the binding wrap
- do not know how many warps are bundled in each side binding
- binding not added at regular intervals; picks added as necessary to keep level with knotting

MU-IN-2 Figure B.69

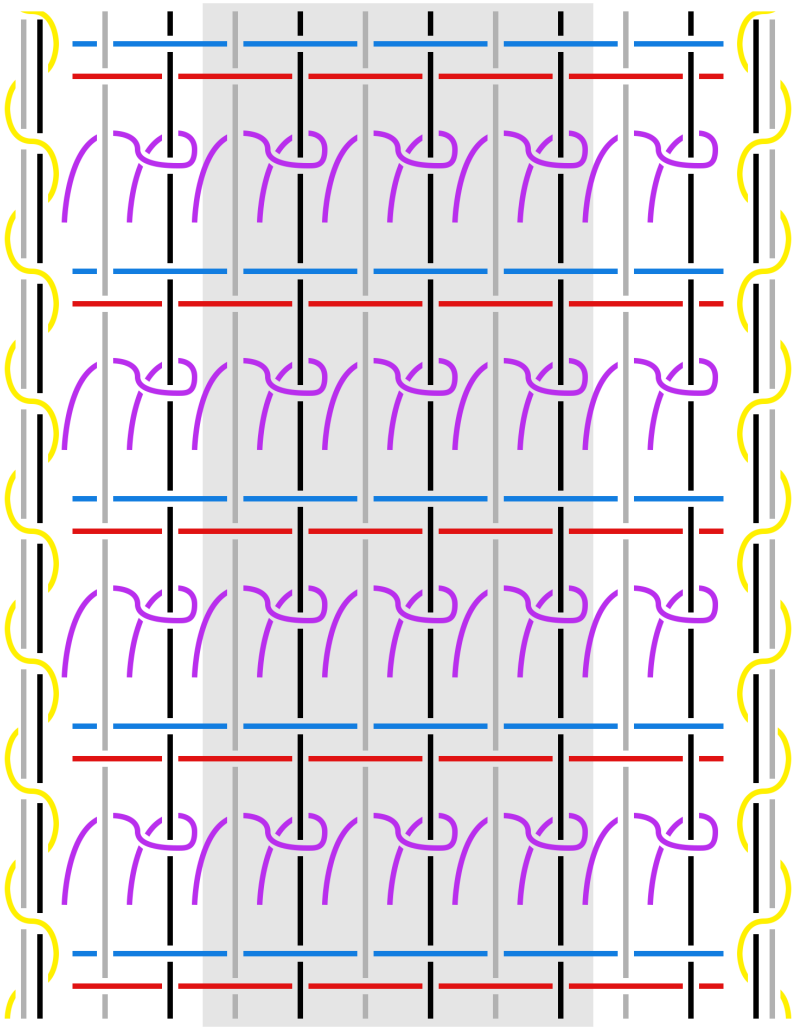
Attribution: Qaen, Khorasan, Iran
Woven late 19th century CE
Location: Indianapolis Museum of Art at Newfields (1996.65)
Indianapolis, Indiana, USA

Total Size (l x w): 1.727 x 0.940 meters

Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Tabby
Binding Warps: 2:1
Binding-Weft Overlap: ?



Notes:

- not clear whether the weft yarns are continuous with the binding wrap
- binding not added at regular intervals; picks added as necessary to keep level with knotting

MU-IN-3 Figure B.70

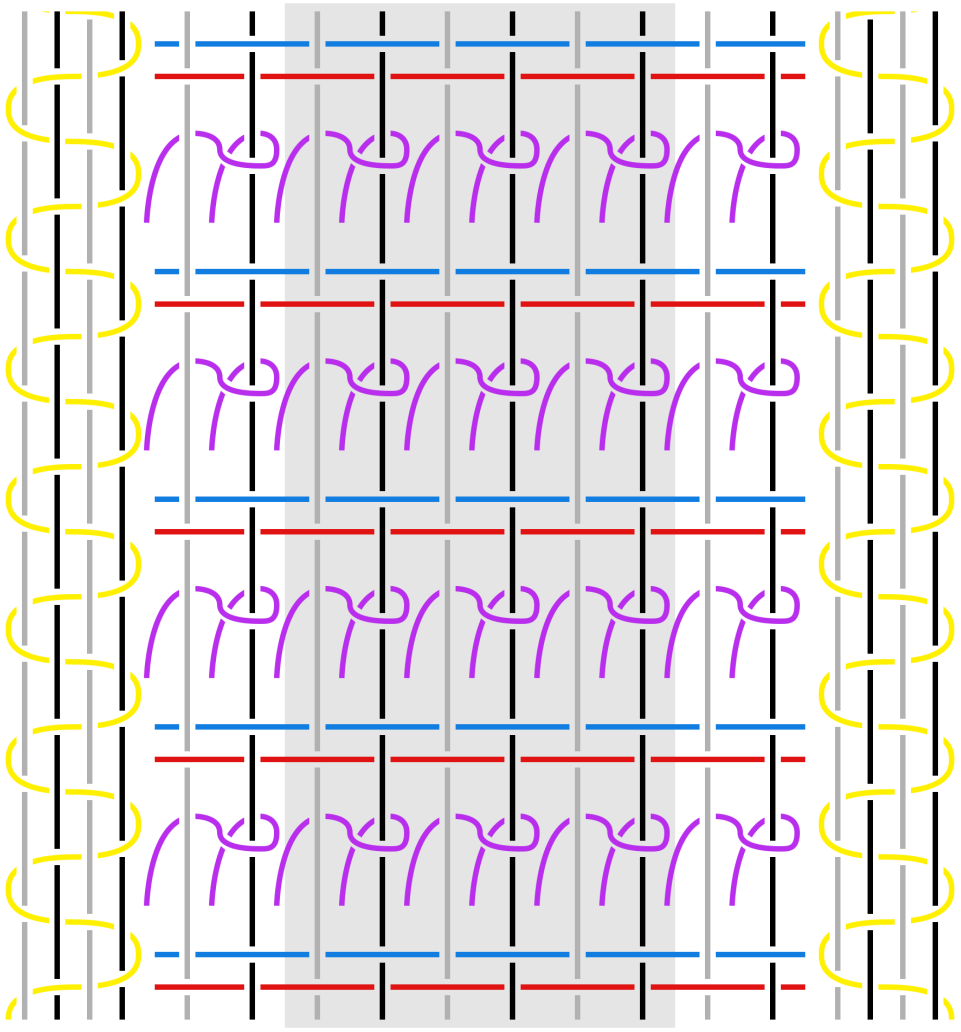
Attribution: Torbat-e Heydarieh, Khorasan, Iran
Woven c. 1870 CE
Location: Indianapolis Museum of Art at Newfields (1996.22); Indianapolis, Indiana, USA

Total Size (l x w): 1.676 x 0.991 meters

Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

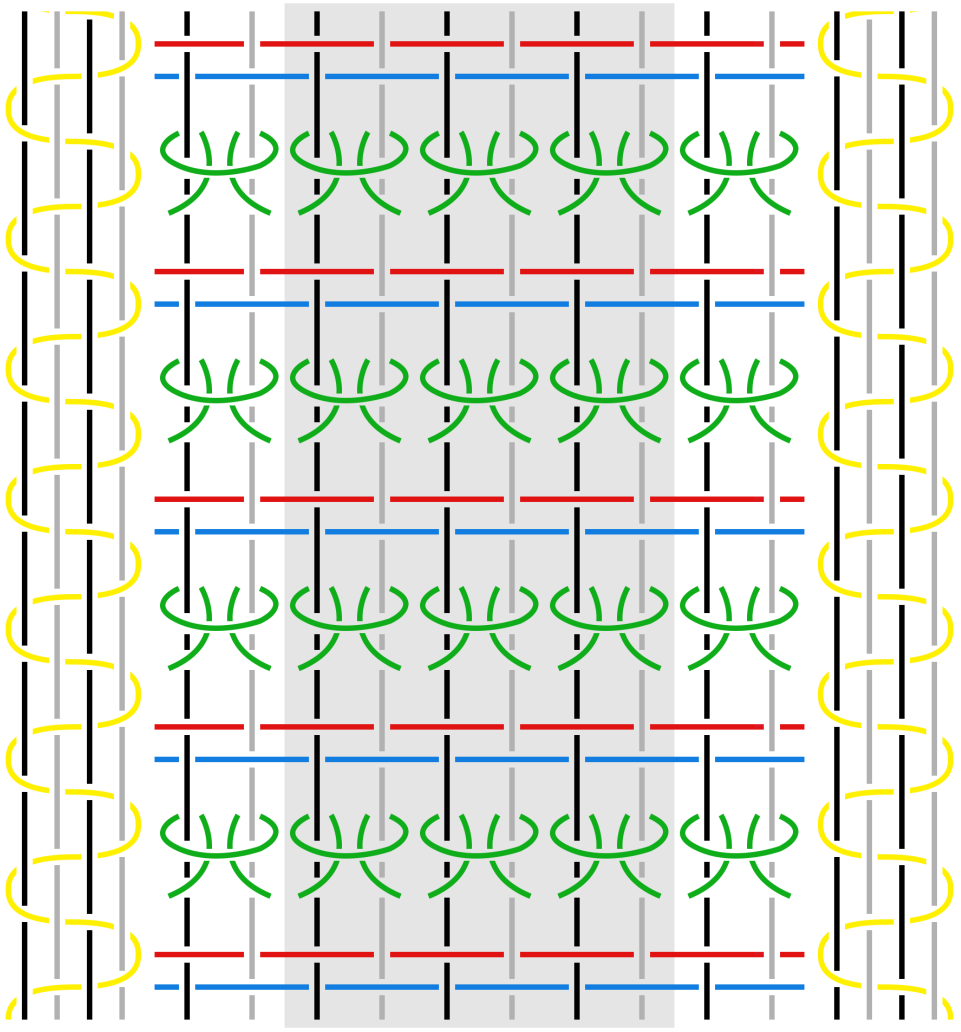
Binding Weave Pattern: Tabby
Binding Warps: ?:4
Binding-Weft Overlap: ?



Notes:

- not clear whether the weft yarns are continuous with the binding wrap
- do not know how many warps are bundled in each side binding
- binding not added at regular intervals; picks added as necessary to keep level with knotting

MU-IN-4 Figure B.71



Attribution: Qaen, Khorasan, Iran
Woven late 19th century CE
Location: Indianapolis Museum of Art at Newfields (1996.63); Indianapolis, Indiana, USA

Total Size (l x w): 1.600 x 0.889 meters

Knot Type: SY
Knot Variants: N
Knot Weft Pattern: D
Knot Spacing: 0
Knot-Row Offset: 0

Knot Direction: (NA)
Knot-Warp Pattern: II

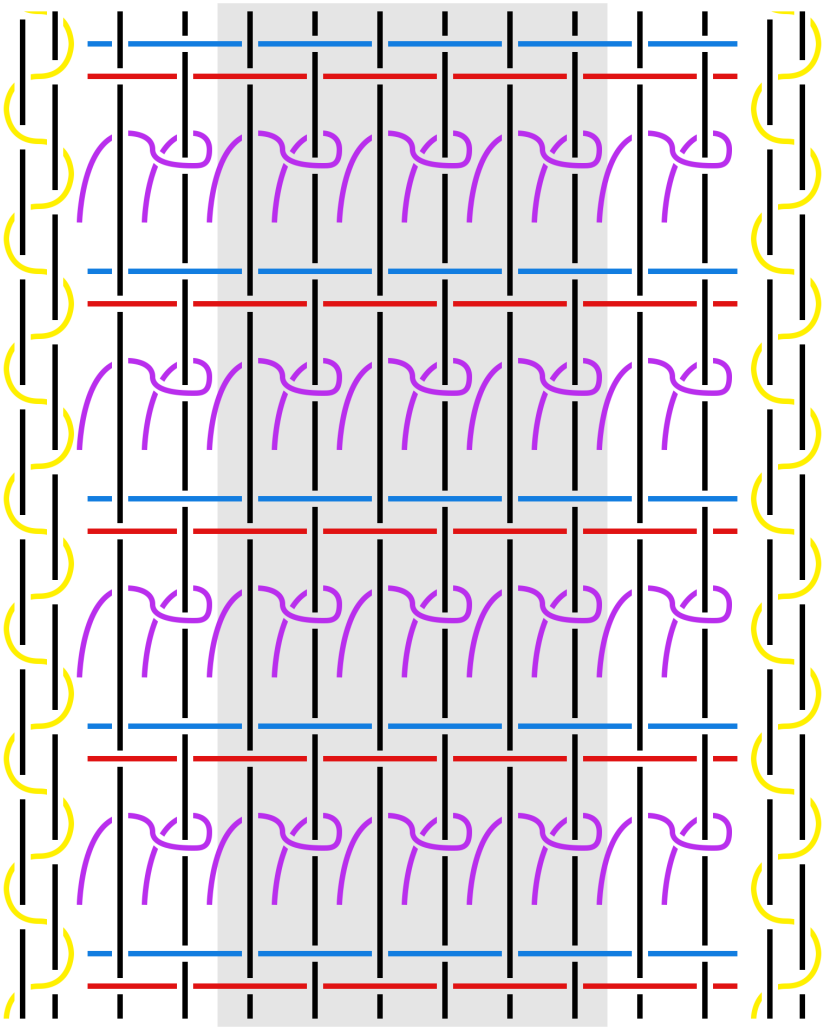
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Tabby
Binding Warps: ?:4
Binding-Weft Overlap: ?

Notes:

- museum documents describe knots as “Turkish knot pointing to the right”
- not clear whether the weft yarns are continuous with the binding wrap
- do not know how many warps are bundled in each side binding
- binding not added at regular intervals; picks added as necessary to keep level with knotting

MU-IN-5 Figure B.72



Attribution: Torbat-e Heydarieh, Khorasan, Iran
Woven c. 1875 CE
Location: Indianapolis Museum of Art at Newfields (1996.28)
Indianapolis, Indiana, USA

Total Size (l x w): 1.524 x 0.965 meters

Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

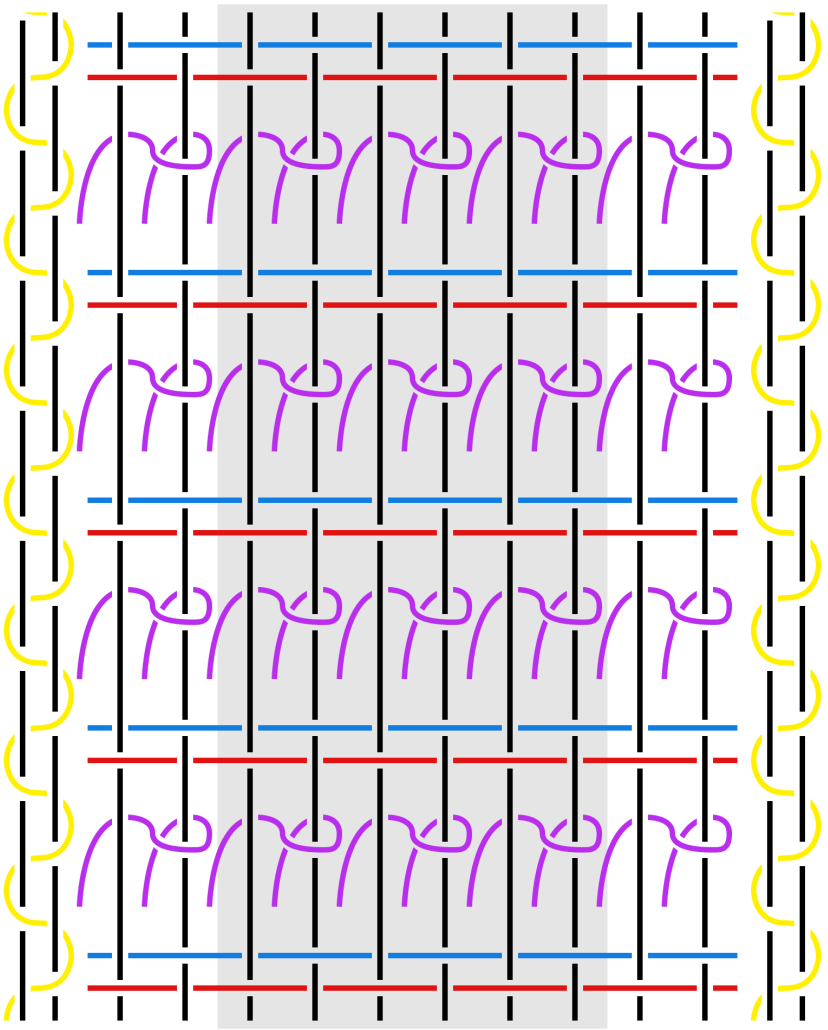
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Tabby
Binding Warps: ?:2
Binding-Weft Overlap: ?

Notes:

- not clear whether the weft yarns are continuous with the binding wrap
- do not know how many warps are bundled in each side binding
- binding not added at regular intervals; picks added as necessary to keep level with knotting

MU-IN-6 Figure B.73



Attribution: Torbat-e Heydarieh, Khorasan, Iran
Woven mid-19th century CE
Location: Indianapolis Museum of Art at Newfields (1996.21)
Indianapolis, Indiana, USA

Total Size (l x w): 1.448 x 1.016 meters

Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

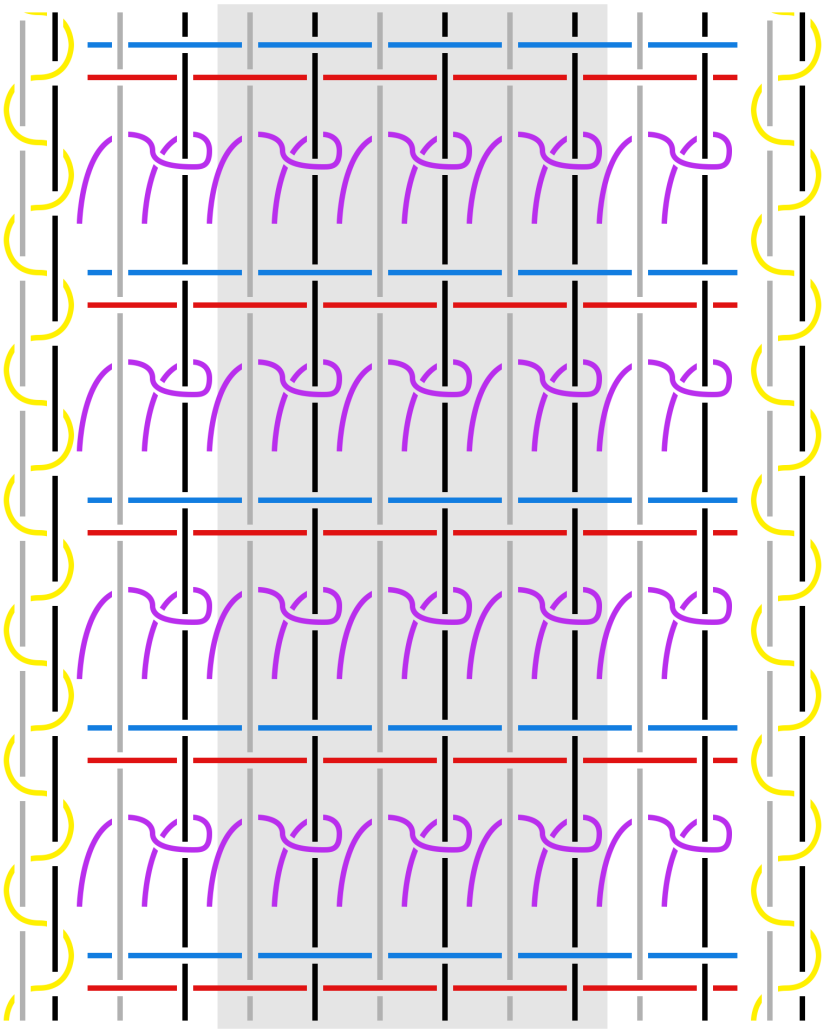
Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Tabby
Binding Warps: ?:2
Binding-Weft Overlap: ?

Notes:

- not clear whether the weft yarns are continuous with the binding wrap
- do not know how many warps are bundled in each side binding
- binding not added at regular intervals; picks added as necessary to keep level with knotting

MU-IN-7 Figure B.74



Attribution: Torbat-e Heydarieh, Khorasan, Iran
Woven late 19th century CE
Location: Indianapolis Museum of Art at Newfields (1996.30)
Indianapolis, Indiana, USA

Total Size (l x w): 1.295 x 0.711 meters

Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Tabby
Binding Warps: ?:2
Binding-Weft Overlap: ?

Notes:

- not clear whether the weft yarns are continuous with the binding wrap
- do not know how many warps are bundled in each side binding
- binding not added at regular intervals; picks added as necessary to keep level with knotting

MU-SO-1 Figure B.75

Attribution: Ushak, Turkey
Woven 17th century CE
Location: Private Collection (Sotheby's Lot 156)

Total Size (l x w): 1.790 x 1.190 meters

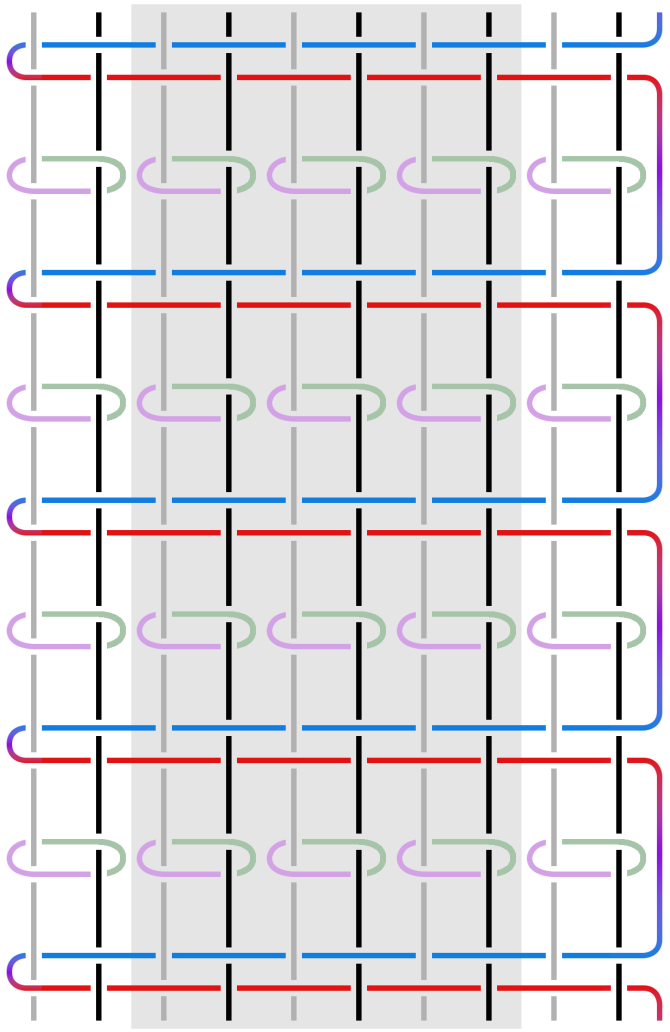
Knot Type: ?
Knot Direction: ?
Knot Variants: ?
Knot-Warp Pattern: III
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

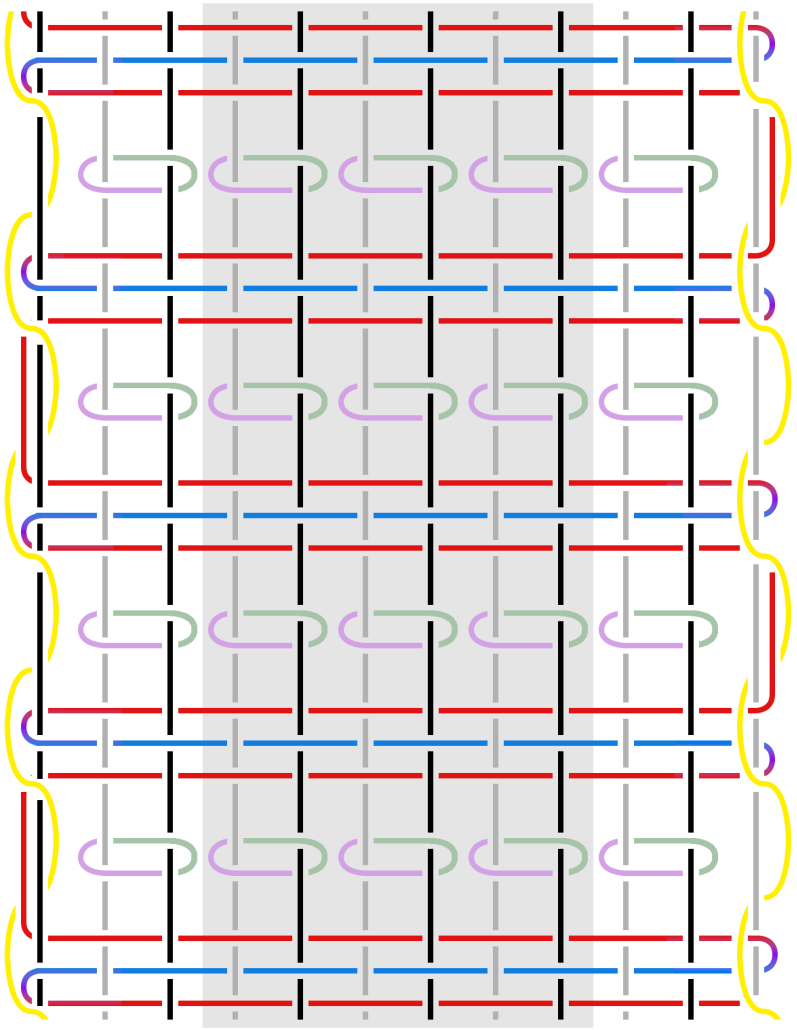
Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- original binding does not survive; current binding is 20th century restoration



MU-SO-2 Figure B.76



Attribution: East Turkestan
Woven 19th century CE
Location: Private Collection (Sotheby's Lot 159)

Total Size (l x w): 1.290 x 0.950 meters

Knot Type: ?
Knot Direction: ?
Knot Variants: ?
Knot-Warp Pattern: III
Knot Weft Pattern: B
Knot Spacing: 0
Knot-Row Offset: 0

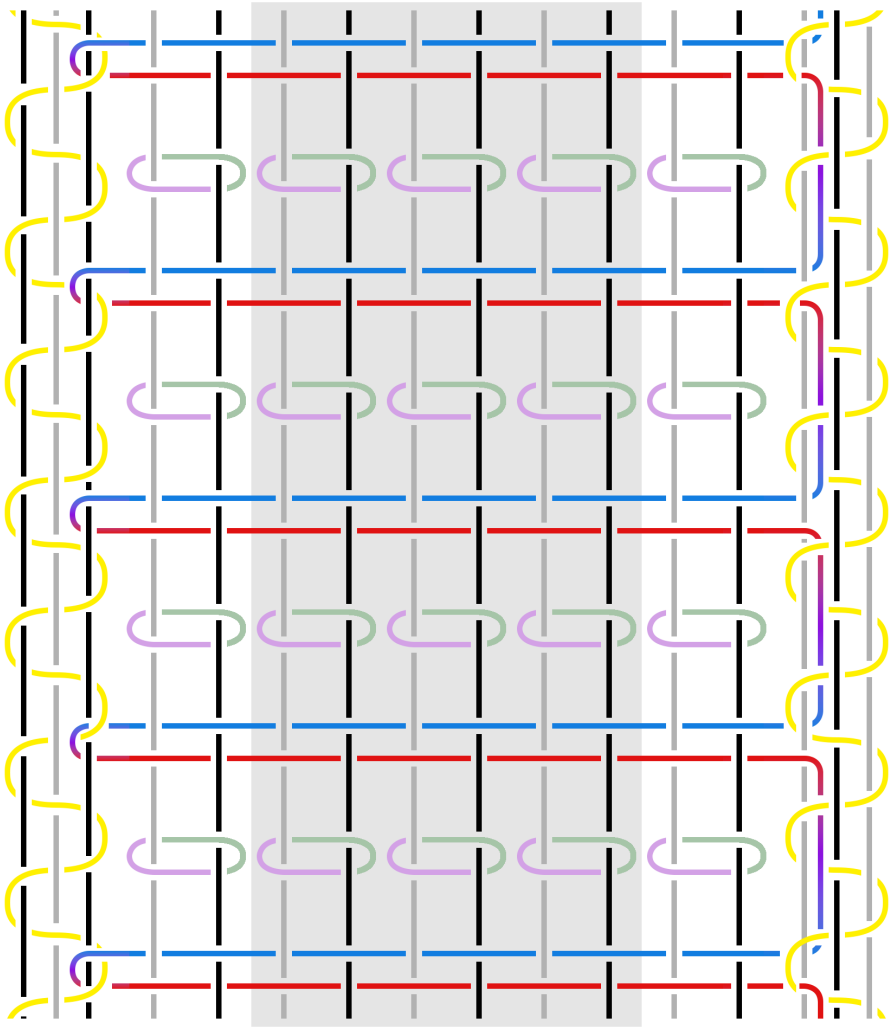
Weft Shot Pick Count: 3
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Wrap
Binding Warps: ?:1
Binding-Weft Overlap: S

Notes:

- Sotheby's provenance given as "East Turkestan", likely referring to Xinjiang, China
- do not know how many warps are bundled in each side binding
- binding not added at regular intervals; picks added as necessary to keep level with knotting

MU-SO-3 Figure B.77



Attribution: Ushak, Turkey
Woven 17th century CE
Location: Private Collection (Sotheby's Lot 157)

Total Size (l x w): 2.870 x 2.050 meters

Knot Type: ?
Knot Direction: ?
Knot Variants: ?
Knot-Warp Pattern: III
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: Tabby
Binding Warps: ?:3
Binding-Weft Overlap: S

Notes:

- do not know how many warps are bundled in each side binding
- binding not added at regular intervals; picks added as necessary to keep level with knotting

MU-SO-4 Figure B.78

Attribution: Isfahan, Iran
Woven 17th century CE
Location: Private Collection (Sotheby's Lot 158)

Total Size (l x w): 2.020 x 1.370 meters

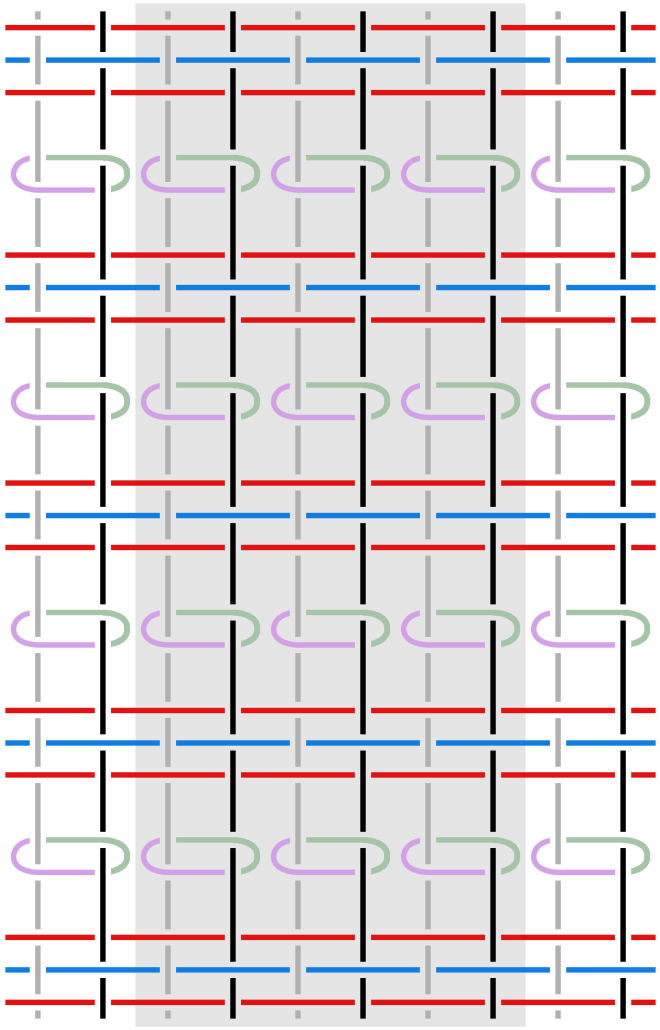
Knot Type: ?
Knot Direction: ?
Knot Variants: ?
Knot-Warp Pattern: III
Knot Weft Pattern: B
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 3
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- original binding does not survive; current binding is 20th century restoration



MU-VA-1 **Figure B.79**

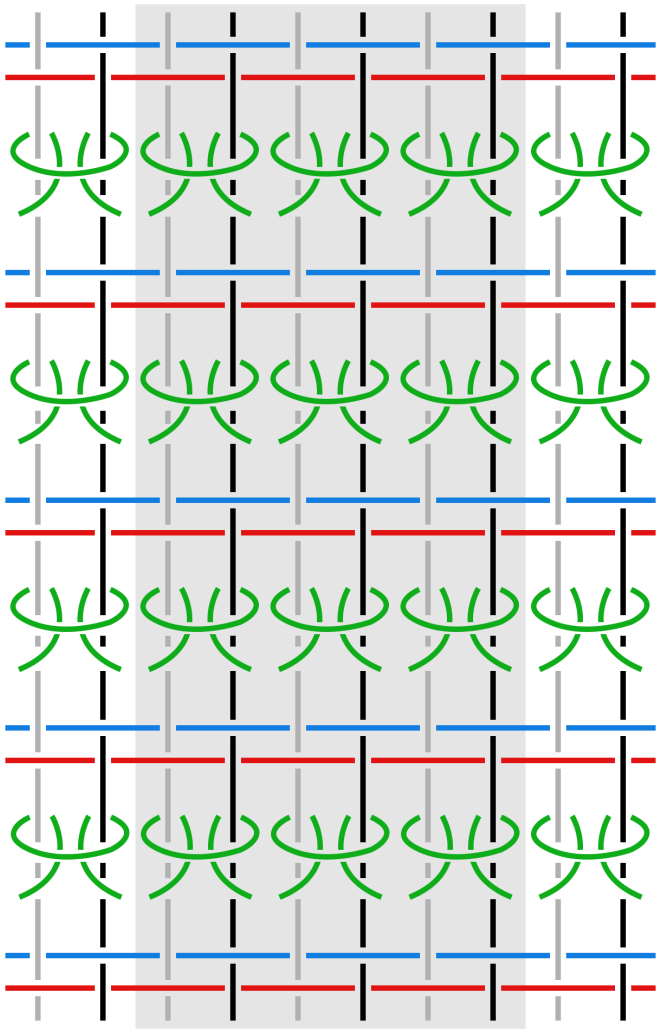
Attribution: Turkey
Woven 17th century CE
Location: Victoria & Albert Museum (859-1902)
London, UK

Total Fragment Size (l x w): 0.740 x 0.180 meters

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: C
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 2
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



MU-VA-2 Figure B.80

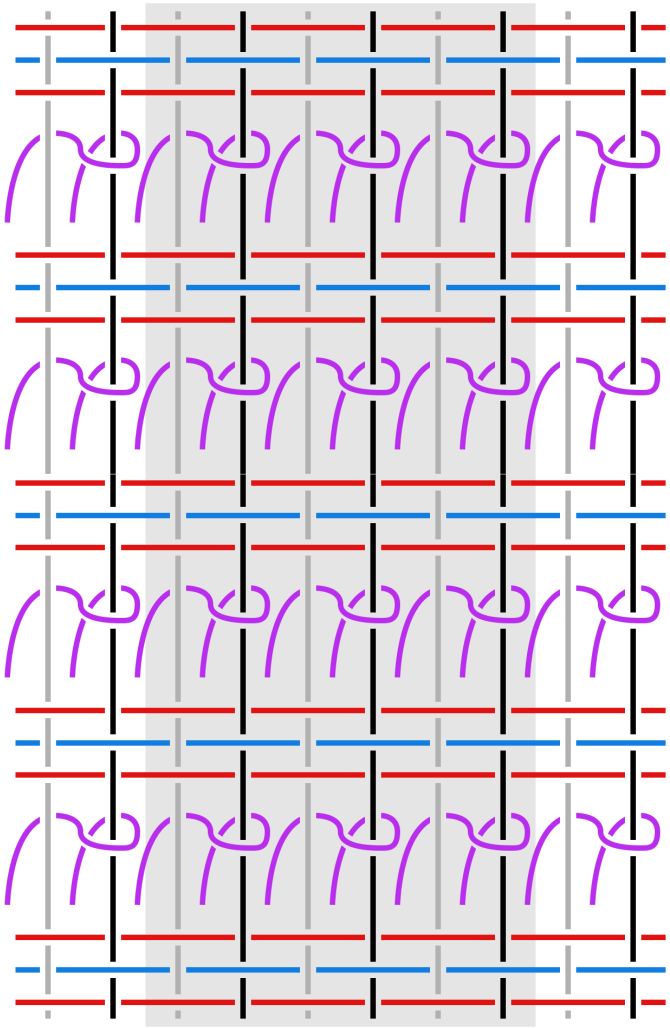
Attribution: Tabriz, Iran
Woven early 16th century CE
Location: Victoria & Albert Museum (T.30-1956)
London, UK

Total Fragment Size (l x w): 0.980 x 0.600 meters

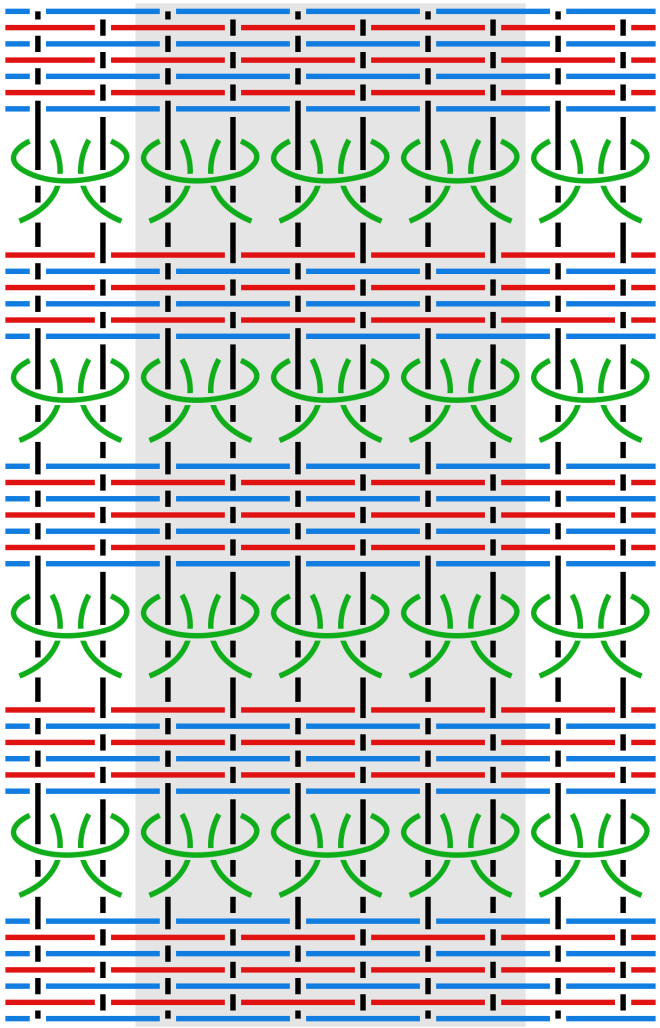
Knot Type: AS
Knot Direction: L
Knot Variants: N
Knot-Warp Pattern: III
Knot Weft Pattern: B
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 3
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Regular

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?



MU-VA-3 **Figure B.81**



Attribution: Loulan, Xinjiang, China
Woven 150 BCE – 60 CE
Location: Victoria & Albert Museum (LOAN:STEIN.536)
London, UK

Total Fragment Size (l x w): 0.160 x 0.180 meters

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: A; D
Knot Spacing: 0
Knot-Row Offset: 0

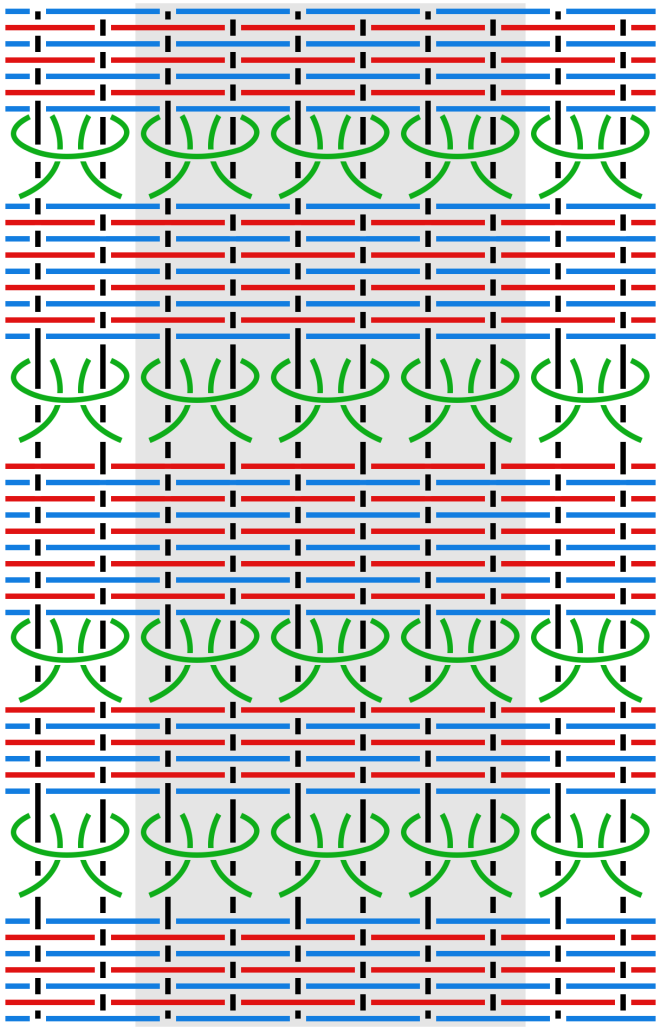
Weft Shot Pick Count: 6:7
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Alternate

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- pick count reliably alternates between 6 and 7, although there are occasional instances of 5 or 8

MU-VA-4 Figure B.82



Attribution: Loulan, Xinjiang, China
Woven 150 BCE – 60 CE
Location: Victoria & Albert Museum (LOAN:STEIN.647)
London, UK

Total Fragment Size (l x w): 0.130 x 0.130 meters

Knot Type: SY
Knot Direction: (NA)
Knot Variants: N
Knot-Warp Pattern: I
Knot Weft Pattern: A; D
Knot Spacing: 0
Knot-Row Offset: 0

Weft Shot Pick Count: 7*
Weft Shot Weave: Tabby
Weft Weave Size: 1/1
Weft Offset Pattern: Random

Binding Weave Pattern: ?
Binding Warps: ?
Binding-Weft Overlap: ?

Notes:

- number of picks per weft shot appears to be random, from 6-10 per shot; average of 7.5 from all weft shots remaining in fragment

Appendix C. Production Characteristics

This section contains the complete table of carpet characteristics documented in this study for both the ethnographic and historic samples. It lists the full structural-technological dataset, including the variables which were excluded from the analysis for being non-differentiating. It also includes metadata on production data and carpet origin.

Production start/end dates give the estimate date range for historic carpets. Length and width measurements are given in meters, and areas in square meters. The knot density is given in knots per square centimeter.

Current locations are represented with the following abbreviations. Blank cells (marked with a dash) indicate unknown whereabouts.

ASC-KC: Al-Sabah Collection, Kuwait City, Kuwait
DYM-SF: De Young Museum, San Francisco, California, USA
HLATC-UW: Helen Louise Allen Textile Collection, University of Wisconsin-Madison, USA
IMA-I: Indianapolis Museum of Art at Newfields, Indianapolis, Indiana, USA
VAM-L: Victoria & Albert Museum, London, United Kingdom

Priv. Coll.: Private Collection

Carpet ID	Extended ID	Current Location	Survey #	Production Start	Production End	Total Dim: Right Warp (m)	Total Dim: Left Warp (m)	Total Height (m)
KZ-OT-1	KZ-OT-1	HLATC-UW	15	2021	2021	0.695	0.705	0.700
KZ-OT-2	KZ-OT-2	Priv. Coll.	15	2021	2021	0.665	0.682	0.674
KZ-OT-3	KZ-OT-3	Priv. Coll.	15	2021	2021	-	-	0.686
KZ-SH-1	KZ-SH-1	Priv. Coll.	14	2021	2021	0.894	0.899	0.897
KZ-SH-2	KZ-SH-2	Priv. Coll.	14	2021	2021	0.435	0.433	0.434
TK-MA-1	TK-MA-1	Priv. Coll.	16	2021	2021	0.987	0.981	0.984
TK-MA-2	TK-MA-2	HLATC-UW	16	2021	2021	1.045	1.045	1.045
TK-MA-3	TK-MA-3	Priv. Coll.	16	2021	2021	1.055	1.062	1.059
TK-MA-4	TK-MA-4	Priv. Coll.	16	2021	2021	1.006	1.004	1.005
TK-MA-5	TK-MA-5	Priv. Coll.	16	2021	2021	1.038	1.037	1.038
TK-MA-6	TK-MA-6	Priv. Coll.	16	2021	2021	1.022	1.013	1.018
TK-MA-7	TK-MA-7	Priv. Coll.	16	2021	2021	0.985	1.001	0.993
TK-MA-8	TK-MA-8	Priv. Coll.	16	2021	2021	1.031	1.024	1.028
TK-MA-9	TK-MA-9	Priv. Coll.	16	2021	2021	1.038	1.055	1.047
UZ-KH-1	UZ-KH-1	Priv. Coll.	6	2021	2021	1.152	1.116	1.134

Carpet ID	Extended ID	Current Location	Survey #	Production Start	Production End	Total Dim: Right Warp (m)	Total Dim: Left Warp (m)	Total Height (m)
UZ-KH-2	UZ-KH-2	Priv. Coll.	6	2021	2021	1.267	1.270	1.269
UZ-KH-3	UZ-KH-3	Priv. Coll.	11	2021	2021	1.263	1.267	1.265
UZ-KH-4	UZ-KH-4	Priv. Coll.	11	2021	2021	1.172	1.173	1.173
UZ-KH-5	UZ-KH-5	HLATC-UW	12	2021	2021	1.118	1.185	1.152
UZ-KH-6	UZ-KH-6	Priv. Coll.	12	2021	2021	1.124	1.131	1.128
UZ-KH-7	UZ-KH-7	Priv. Coll.	13	2021	2021	1.174	1.149	1.162
UZ-KH-8	UZ-KH-8	Priv. Coll.	13	2021	2021	1.140	1.142	1.141
UZ-KH-9	UZ-KH-9	-	7	2021	2021	1.700	-	1.700
UZ-KH-10	UZ-KH-10	-	7	2021	2021	2.000	-	2.000
UZ-KH-11	UZ-KH-11	-	8/9	2021	2021	1.900	-	1.900
UZ-KH-12	UZ-KH-12	-	8	2021	2021	1.800	-	1.800
UZ-KH-13	UZ-KH-13	-	9	2021	2021	1.240	-	1.240
UZ-SK-1	UZ-SK-1	-	1	2021	2021	1.800	-	1.800
UZ-SK-2	UZ-SK-2	-	2	2021	2021	1.550	-	1.550
UZ-SK-3	UZ-SK-3	-	4	2021	2021	2.040	-	2.040

Carpet ID	Extended ID	Current Location	Survey #	Production Start	Production End	Total Dim: Right Warp (m)	Total Dim: Left Warp (m)	Total Height (m)
MU-AS-1	MU-AS-1	ASC-KC	None	380	540	-	-	-
MU-AS-2a	MU-AS-2a	ASC-KC	None	1010	1160	-	-	-
MU-AS-2b	MU-AS-2b	ASC-KC	None	1010	1160	-	-	-
MU-AS-3	MU-AS-3	ASC-KC	None	378	598	-	-	-
MU-AS-4a	MU-AS-4a	ASC-KC	None	543	638	-	-	-
MU-AS-4b	MU-AS-4b	ASC-KC	None	543	638	-	-	-
MU-AS-4c	MU-AS-4c	ASC-KC	None	543	638	-	-	-
MU-AS-5	MU-AS-5	ASC-KC	None	540	585	-	-	-
MU-AS-6	MU-AS-6	ASC-KC	None	1150	1260	-	-	-
MU-AS-7	MU-AS-7	ASC-KC	None	130	270	-	-	-
MU-AS-8	MU-AS-8c	ASC-KC	None	565	655	-	-	-
MU-AS-8	MU-AS-8d	ASC-KC	None	565	655	-	-	-
MU-AS-8	MU-AS-8e	ASC-KC	None	565	655	-	-	-
MU-AS-8	MU-AS-8f	ASC-KC	None	565	655	-	-	-
MU-AS-9ab	MU-AS-9a	ASC-KC	None	220	410	-	-	-
MU-AS-9ab	MU-AS-9b	ASC-KC	None	220	410	-	-	-

Carpet ID	Extended ID	Current Location	Survey #	Production Start	Production End	Total Dim: Right Warp (m)	Total Dim: Left Warp (m)	Total Height (m)
MU-AS-9c	MU-AS-9c	ASC-KC	None	220	410	-	-	-
MU-AS-9d	MU-AS-9d	ASC-KC	None	220	410	-	-	-
MU-AS-10	MU-AS-10a	ASC-KC	None	415	640	-	-	-
MU-AS-10	MU-AS-10b	ASC-KC	None	415	640	-	-	-
MU-AS-11	MU-AS-11a	ASC-KC	None	535	680	-	-	-
MU-AS-11	MU-AS-11b	ASC-KC	None	535	680	-	-	-
MU-AS-11	MU-AS-11c	ASC-KC	None	535	680	-	-	-
MU-AS-11	MU-AS-11d	ASC-KC	None	535	680	-	-	-
MU-AS-11	MU-AS-11e	ASC-KC	None	535	680	-	-	-
MU-AS-12	MU-AS-12	ASC-KC	None	332	430	-	-	-
MU-AS-13	MU-AS-13	ASC-KC	None	1600	1699	-	-	-
MU-AS-14	MU-AS-14	ASC-KC	None	280	340	-	-	-
MU-AS-16	MU-AS-16	ASC-KC	None	500	699	-	-	-
MU-AS-17ef	MU-AS-17e	ASC-KC	None	220	410	-	-	-
MU-AS-17ef	MU-AS-17f	ASC-KC	None	220	410	-	-	-

Carpet ID	Extended ID	Current Location	Survey #	Production Start	Production End	Total Dim: Right Warp (m)	Total Dim: Left Warp (m)	Total Height (m)
MU-AS-17g	MU-AS-17g	ASC-KC	None	220	410	-	-	-
MU-AS-18	MU-AS-18	ASC-KC	None	114	348	-	-	-
MU-CH-1	MU-CH-1	-	None	1800	1800	1.510	-	1.510
MU-CH-2	MU-CH-2	-	None	1750	1800	1.750	-	1.750
MU-CH-3	MU-CH-3	-	None	1750	1800	3.490	-	3.490
MU-CH-4	MU-CH-4	-	None	1650	1700	1.660	-	1.660
MU-CH-5	MU-CH-5	-	None	1600	1650	1.780	-	1.780
MU-CH-6	MU-CH-6	-	None	1662	1722	1.330	-	1.330
MU-CH-7	MU-CH-7	-	None	1700	1799	2.290	-	2.290
MU-DY-1a	MU-DY-1a	DYM-SF	None	1500	1599	-	-	-
MU-DY-1b	MU-DY-1b	DYM-SF	None	1500	1599	-	-	-
MU-DY-1c	MU-DY-1c	DYM-SF	None	1500	1599	-	-	-
MU-DY-1d	MU-DY-1d	DYM-SF	None	1500	1599	-	-	-
MU-DY-2a	MU-DY-2a	DYM-SF	None	418	602	-	-	-
MU-DY-2b	MU-DY-2b	DYM-SF	None	418	602	-	-	-

Carpet ID	Extended ID	Current Location	Survey #	Production Start	Production End	Total Dim: Right Warp (m)	Total Dim: Left Warp (m)	Total Height (m)
MU-DY-2c	MU-DY-2c	DYM-SF	None	418	602	-	-	-
MU-IN-1	MU-IN-1	IMA-I	None	1875	1875	1.930	-	1.930
MU-IN-2	MU-IN-2	IMA-I	None	1850	1900	1.727	-	1.727
MU-IN-3	MU-IN-3	IMA-I	None	1870	1870	1.676	-	1.676
MU-IN-4	MU-IN-4	IMA-I	None	1850	1900	1.600	-	1.600
MU-IN-5	MU-IN-5	IMA-I	None	1875	1875	1.524	-	1.524
MU-IN-6	MU-IN-6	IMA-I	None	1825	1875	1.448	-	1.448
MU-IN-7	MU-IN-7	IMA-I	None	1850	1900	1.295	-	1.295
MU-SO-1	MU-SO-1	-	None	1600	1699	1.790	-	1.790
MU-SO-2	MU-SO-2	-	None	1800	1899	1.290	-	1.290
MU-SO-3	MU-SO-3	-	None	1600	1699	2.870	-	2.870
MU-SO-4	MU-SO-4	-	None	1600	1699	2.020	-	2.020
MU-VA-1	MU-VA-1	VAM-L	None	1600	1699	-	-	-
MU-VA-2	MU-VA-2	VAM-L	None	1500	1550	-	-	-
MU-VA-3	MU-VA-3	VAM-L	None	-150	60	-	-	-
MU-VA-4	MU-VA-4	VAM-L	None	-150	60	-	-	-

Carpet ID	Total Dim: Top Weft (m)	Total Dim: Bottom Weft (m)	Total Width (m)	Total Dim: Area (m2)	Knotted Dim: Right Warp (m)	Knotted Dim: Left Warp (m)	Knotted Height (m)	Knotted Dim: Top Weft (m)
KZ-OT-1	0.459	0.495	0.477	0.334	0.667	0.678	0.673	0.450
KZ-OT-2	0.457	0.514	0.486	0.327	0.623	0.636	0.630	0.449
KZ-OT-3	-	-	0.481	0.330	-	-	-	-
KZ-SH-1	0.401	0.444	0.423	0.379	0.868	0.849	0.859	0.400
KZ-SH-2	0.412	0.410	0.411	0.178	0.409	0.408	0.409	0.402
TK-MA-1	0.468	0.493	0.481	0.473	0.953	0.957	0.955	0.460
TK-MA-2	0.521	0.530	0.526	0.549	0.994	1.000	0.997	0.513
TK-MA-3	0.507	0.526	0.517	0.547	1.022	1.044	1.033	0.499
TK-MA-4	0.508	0.528	0.518	0.521	0.951	0.945	0.948	0.499
TK-MA-5	0.511	0.530	0.521	0.540	0.983	0.981	0.982	0.503
TK-MA-6	0.507	0.517	0.512	0.521	0.976	0.977	0.977	0.494
TK-MA-7	0.545	0.551	0.548	0.544	0.938	0.937	0.938	0.531
TK-MA-8	0.539	0.535	0.537	0.552	0.985	0.980	0.983	0.528
TK-MA-9	0.526	0.537	0.532	0.556	0.996	1.002	0.999	0.512
UZ-KH-1	0.801	0.799	0.800	0.907	1.111	1.110	1.111	0.784

Carpet ID	Total Dim: Top Weft (m)	Total Dim: Bottom Weft (m)	Total Width (m)	Total Dim: Area (m2)	Knotted Dim: Right Warp (m)	Knotted Dim: Left Warp (m)	Knotted Height (m)	Knotted Dim: Top Weft (m)
UZ-KH-2	0.807	0.793	0.800	1.015	1.224	1.229	1.227	0.791
UZ-KH-3	0.826	0.810	0.818	1.035	1.239	1.239	1.239	0.808
UZ-KH-4	0.817	0.812	0.815	0.955	1.141	1.141	1.141	0.796
UZ-KH-5	0.797	0.804	0.801	0.922	1.166	1.167	1.167	0.781
UZ-KH-6	0.815	0.803	0.809	0.912	1.104	1.106	1.105	0.795
UZ-KH-7	0.806	0.798	0.802	0.932	1.138	1.120	1.129	0.789
UZ-KH-8	0.819	0.814	0.817	0.932	1.113	1.114	1.114	0.801
UZ-KH-9	1.000	-	1.000	1.700	-	-	-	-
UZ-KH-10	1.200	-	1.200	2.400	-	-	-	-
UZ-KH-11	1.210	-	1.210	2.299	-	-	-	-
UZ-KH-12	0.790	-	0.790	1.422	-	-	-	-
UZ-KH-13	2.500	-	2.500	3.100	-	-	-	-
UZ-SK-1	1.200	-	1.200	2.160	-	-	-	-
UZ-SK-2	1.150	-	1.150	1.783	-	-	-	-
UZ-SK-3	1.500	-	1.500	3.060	-	-	-	-

Carpet ID	Total Dim: Top Weft (m)	Total Dim: Bottom Weft (m)	Total Width (m)	Total Dim: Area (m2)	Knotted Dim: Right Warp (m)	Knotted Dim: Left Warp (m)	Knotted Height (m)	Knotted Dim: Top Weft (m)
MU-AS-1	-	-	-	-	0.410	-	0.410	0.550
MU-AS-2a	-	-	-	-	0.390	-	0.390	0.240
MU-AS-2b	-	-	-	-	0.120	-	0.120	0.140
MU-AS-3	-	-	-	-	0.880	-	0.880	0.290
MU-AS-4a	-	-	-	-	0.515	-	0.515	0.490
MU-AS-4b	-	-	-	-	0.130	-	0.130	0.130
MU-AS-4c	-	-	-	-	0.130	-	0.130	0.110
MU-AS-5	-	-	-	-	0.180	-	0.180	0.220
MU-AS-6	-	-	-	-	0.255	-	0.255	0.105
MU-AS-7	-	-	-	-	1.140	-	1.140	0.330
MU-AS-8	-	-	-	-	0.340	-	0.340	0.345
MU-AS-8	-	-	-	-	0.425	-	0.425	0.270
MU-AS-8	-	-	-	-	0.175	-	0.175	0.120
MU-AS-8	-	-	-	-	0.820	-	0.820	0.610
MU-AS-9ab	-	-	-	-	1.415	-	1.415	0.620
MU-AS-9ab	-	-	-	-	0.565	-	0.565	0.400

Carpet ID	Total Dim: Top Weft (m)	Total Dim: Bottom Weft (m)	Total Width (m)	Total Dim: Area (m2)	Knotted Dim: Right Warp (m)	Knotted Dim: Left Warp (m)	Knotted Height (m)	Knotted Dim: Top Weft (m)
MU-AS-9c	-	-	-	-	0.380	-	0.380	0.260
MU-AS-9d	-	-	-	-	0.915	-	0.915	0.250
MU-AS-10	-	-	-	-	1.800	-	1.800	0.975
MU-AS-10	-	-	-	-	0.288	-	0.288	0.243
MU-AS-11	-	-	-	-	1.080	-	1.080	0.700
MU-AS-11	-	-	-	-	0.390	-	0.390	0.400
MU-AS-11	-	-	-	-	0.230	-	0.230	0.520
MU-AS-11	-	-	-	-	0.250	-	0.250	0.160
MU-AS-11	-	-	-	-	0.270	-	0.270	0.160
MU-AS-12	-	-	-	-	0.930	-	0.930	1.070
MU-AS-13	-	-	-	-	1.850	-	1.850	1.390
MU-AS-14	-	-	-	-	0.980	-	0.980	0.860
MU-AS-16	-	-	-	-	0.175	-	0.175	0.155
MU-AS-17ef	-	-	-	-	0.370	-	0.370	0.265
MU-AS-17ef	-	-	-	-	0.085	-	0.085	0.080

Carpet ID	Total Dim: Top Weft (m)	Total Dim: Bottom Weft (m)	Total Width (m)	Total Dim: Area (m2)	Knotted Dim: Right Warp (m)	Knotted Dim: Left Warp (m)	Knotted Height (m)	Knotted Dim: Top Weft (m)
MU-AS-17g	-	-	-	-	0.195	-	0.195	0.170
MU-AS-18	-	-	-	-	0.165	-	0.165	0.180
MU-CH-1	0.990	-	0.990	1.495	-	-	-	-
MU-CH-2	0.980	-	0.980	1.715	-	-	-	-
MU-CH-3	1.840	-	1.840	6.422	-	-	-	-
MU-CH-4	1.250	-	1.250	2.075	-	-	-	-
MU-CH-5	1.070	-	1.070	1.905	-	-	-	-
MU-CH-6	3.120	-	3.120	4.150	-	-	-	-
MU-CH-7	3.590	-	3.590	8.221	-	-	-	-
MU-DY-1a	-	-	-	-	0.322	-	0.322	0.454
MU-DY-1b	-	-	-	-	0.489	-	0.489	0.303
MU-DY-1c	-	-	-	-	0.539	-	0.539	0.455
MU-DY-1d	-	-	-	-	0.361	-	0.361	0.158
MU-DY-2a	-	-	-	-	0.604	-	0.604	0.581
MU-DY-2b	-	-	-	-	0.372	-	0.372	0.368

Carpet ID	Total Dim: Top Weft (m)	Total Dim: Bottom Weft (m)	Total Width (m)	Total Dim: Area (m2)	Knotted Dim: Right Warp (m)	Knotted Dim: Left Warp (m)	Knotted Height (m)	Knotted Dim: Top Weft (m)
MU-DY-2c	-	-	-	-	0.311	-	0.311	0.136
MU-IN-1	1.118	-	1.118	2.158	-	-	-	-
MU-IN-2	0.940	-	0.940	1.623	-	-	-	-
MU-IN-3	0.991	-	0.991	1.661	-	-	-	-
MU-IN-4	0.889	-	0.889	1.422	-	-	-	-
MU-IN-5	0.965	-	0.965	1.471	-	-	-	-
MU-IN-6	1.016	-	1.016	1.471	-	-	-	-
MU-IN-7	0.711	-	0.711	0.921	-	-	-	-
MU-SO-1	1.190	-	1.190	2.130	-	-	-	-
MU-SO-2	0.950	-	0.950	1.226	-	-	-	-
MU-SO-3	2.050	-	2.050	5.884	-	-	-	-
MU-SO-4	1.370	-	1.370	2.767	-	-	-	-
MU-VA-1	-	-	-	-	0.740	-	0.740	0.180
MU-VA-2	-	-	-	-	0.980	-	0.980	0.600
MU-VA-3	-	-	-	-	0.160	-	0.160	0.180
MU-VA-4	-	-	-	-	0.310	-	0.310	0.130

Carpet ID	Knotted Dim: Bottom Weft (m)	Knotted Width (m)	Knotted Dimensions: Area (m2)	Total Knots	Knot Density (k/cm2)	Warp Material	Weft Material	Pile Material
KZ-OT-1	0.479	0.465	0.312	29467	9.43	Cotton	Cotton-Synth	Wool
KZ-OT-2	0.496	0.473	0.297	29733	10.00	Cotton	Cotton-Synth	Wool
KZ-OT-3	-	-	-	44800	13.58	Cotton	Cotton-Synth	Wool
KZ-SH-1	0.443	0.422	0.362	42667	11.79	Wool	Wool	Wool
KZ-SH-2	0.397	0.400	0.163	27600	16.91	Cotton	Wool	Wool
TK-MA-1	0.483	0.472	0.450	116800	25.94	Wool	Wool	Wool
TK-MA-2	0.518	0.516	0.514	137200	26.70	Wool	Wool	Wool
TK-MA-3	0.515	0.507	0.524	93467	17.85	Wool	Wool	Wool
TK-MA-4	0.508	0.504	0.477	107333	22.49	Wool	Wool	Wool
TK-MA-5	0.509	0.506	0.497	88800	17.87	Wool	Wool	Wool
TK-MA-6	0.505	0.500	0.488	94533	19.38	Wool	Wool	Wool
TK-MA-7	0.533	0.532	0.499	83067	16.66	Wool	Wool	Wool
TK-MA-8	0.522	0.525	0.516	110533	21.43	Wool	Wool	Wool
TK-MA-9	0.520	0.516	0.515	118933	23.07	Wool	Wool	Wool
UZ-KH-1	0.784	0.784	0.871	39200	4.50	Cotton	Wool	Synth

Carpet ID	Knotted Dim: Bottom Weft (m)	Knotted Width (m)	Knotted Dimensions: Area (m2)	Total Knots	Knot Density (k/cm2)	Warp Material	Weft Material	Pile Material
UZ-KH-2	0.780	0.786	0.963	44133	4.58	Cotton	Wool	Synth
UZ-KH-3	0.795	0.802	0.993	41733	4.20	Cotton	Wool	Synth
UZ-KH-4	0.797	0.797	0.909	46400	5.11	Cotton	Wool	Synth
UZ-KH-5	0.782	0.782	0.912	41733	4.58	Cotton	Wool	Synth
UZ-KH-6	0.783	0.789	0.872	38667	4.44	Cotton	Wool	Synth
UZ-KH-7	0.781	0.785	0.886	36800	4.15	Cotton	Wool	Synth
UZ-KH-8	0.794	0.798	0.888	40933	4.61	Cotton	Wool	Synth
UZ-KH-9	-	-	-	246267	14.49	Silk	Silk	Silk
UZ-KH-10	-	-	-	553467	23.06	Silk	Silk	Silk
UZ-KH-11	-	-	-	1016267	44.20	Silk	Silk	Silk
UZ-KH-12	-	-	-	293867	20.67	Silk	Silk	Silk
UZ-KH-13	-	-	-	522267	16.85	Silk	Silk	Silk
UZ-SK-1	-	-	-	460267	21.31	Silk	Silk	Silk
UZ-SK-2	-	-	-	521733	29.27	Silk	Silk	Silk
UZ-SK-3	-	-	-	706400	23.08	Silk	Silk	Silk

Carpet ID	Knotted Dim: Bottom Weft (m)	Knotted Width (m)	Knotted Dimensions: Area (m2)	Total Knots	Knot Density (k/cm2)	Warp Material	Weft Material	Pile Material
MU-AS-1	-	0.550	0.226	NA	3.56	Wool	Wool	Wool
MU-AS-2a	-	0.240	0.094	NA	31.36	Wool	Wool	Wool
MU-AS-2b	-	0.140	0.017	NA	25.92	Wool	Wool	Wool
MU-AS-3	-	0.290	0.255	NA	4.89	Wool	Wool	Wool
MU-AS-4a	-	0.490	0.252	NA	4.89	Wool	Wool	Wool
MU-AS-4b	-	0.130	0.017	NA	3.64	Wool	Wool	Wool
MU-AS-4c	-	0.110	0.014	NA	6.75	Wool	Wool	Wool
MU-AS-5	-	0.220	0.040	NA	4.22	Wool	Wool	Wool
MU-AS-6	-	0.105	0.027	NA	6.22	Wool	Wool	Wool
MU-AS-7	-	0.330	0.376	NA	7.68	Wool	Wool	Wool
MU-AS-8	-	0.345	0.117	NA	0.84	Wool	Wool	Wool
MU-AS-8	-	0.270	0.115	NA	0.84	Wool	Wool	Wool
MU-AS-8	-	0.120	0.021	NA	0.84	Wool	Wool	Wool
MU-AS-8	-	0.610	0.500	NA	0.84	Wool	Wool	Wool
MU-AS-9ab	-	0.620	0.877	NA	2.778	Wool	Wool	Wool
MU-AS-9ab	-	0.400	0.226	NA	2.778	Wool	Wool	Wool

Carpet ID	Knotted Dim: Bottom Weft (m)	Knotted Width (m)	Knotted Dimensions: Area (m2)	Total Knots	Knot Density (k/cm2)	Warp Material	Weft Material	Pile Material
MU-AS-9c	-	0.260	0.099	NA	1.50	Wool	Wool	Wool
MU-AS-9d	-	0.250	0.229	NA	2.25	Wool	Wool	Wool
MU-AS-10	-	0.975	1.755	NA	5.000	Wool	Wool	Wool
MU-AS-10	-	0.243	0.070	NA	5.000	Wool	Wool	Wool
MU-AS-11	-	0.700	0.756	NA	1.440	Wool	Wool	Wool
MU-AS-11	-	0.400	0.156	NA	1.440	Wool	Wool	Wool
MU-AS-11	-	0.520	0.120	NA	1.440	Wool	Wool	Wool
MU-AS-11	-	0.160	0.040	NA	1.440	Wool	Wool	Wool
MU-AS-11	-	0.160	0.043	NA	1.440	Wool	Wool	Wool
MU-AS-12	-	1.070	0.995	NA	2.19	Wool	Wool	Wool
MU-AS-13	-	1.390	2.572	NA	24.00	Cotton	Cotton	Wool
MU-AS-14	-	0.860	0.843	NA	3.94	Wool	Wool	Wool
MU-AS-16	-	0.155	0.027	NA	2.90	Wool	Wool	Wool
MU-AS-17ef	-	0.265	0.098	NA	3.750	Wool	Wool	Wool
MU-AS-17ef	-	0.080	0.007	NA	3.750	Wool	Wool	Wool

Carpet ID	Knotted Dim: Bottom Weft (m)	Knotted Width (m)	Knotted Dimensions: Area (m2)	Total Knots	Knot Density (k/cm2)	Warp Material	Weft Material	Pile Material
MU-AS-17g	-	0.170	0.033	NA	4.50	Wool	Wool	Wool
MU-AS-18	-	0.180	0.030	NA	4.72	Wool	Wool	Wool
MU-CH-1	-	-	-	98933	6.62	-	-	-
MU-CH-2	-	-	-	97867	5.71	-	-	-
MU-CH-3	-	-	-	406800	6.33	-	-	-
MU-CH-4	-	-	-	198667	9.57	-	-	-
MU-CH-5	-	-	-	41200	2.16	-	-	-
MU-CH-6	-	-	-	188000	4.53	-	-	-
MU-CH-7	-	-	-	236667	2.88	-	-	-
MU-DY-1a	-	0.454	0.146	NA	19.76	Wool	Wool	Wool
MU-DY-1b	-	0.303	0.148	NA	23.76	Wool	Wool	Wool
MU-DY-1c	-	0.455	0.245	NA	23.78	Wool	Wool	Wool
MU-DY-1d	-	0.158	0.057	NA	22.04	Wool	Wool	Wool
MU-DY-2a	-	0.581	0.351	NA	1.75	Wool	Wool	Wool
MU-DY-2b	-	0.368	0.137	NA	1.28	Wool	Wool	Wool

Carpet ID	Knotted Dim: Bottom Weft (m)	Knotted Width (m)	Knotted Dimensions: Area (m2)	Total Knots	Knot Density (k/cm2)	Warp Material	Weft Material	Pile Material
MU-DY-2c	-	0.136	0.042	NA	2.00	Wool	Wool	Wool
MU-IN-1	-	-	-	126000	5.84	Wool	Wool	Wool
MU-IN-2	-	-	-	45600	2.81	Wool	Wool	Wool
MU-IN-3	-	-	-	62133	3.74	Wool	Wool	Wool
MU-IN-4	-	-	-	96800	6.81	Wool	Wool	Wool
MU-IN-5	-	-	-	75333	5.12	Wool	Wool	Wool
MU-IN-6	-	-	-	59733	4.06	Wool	Wool	Wool
MU-IN-7	-	-	-	49600	5.39	Wool	Wool	Wool; Silk
MU-SO-1	-	-	-	141200	6.63	-	-	-
MU-SO-2	-	-	-	56267	4.59	-	-	-
MU-SO-3	-	-	-	260667	4.43	-	-	-
MU-SO-4	-	-	-	460133	16.63	-	-	-
MU-VA-1	-	0.180	0.133	NA	12.24	Wool	Wool	Wool
MU-VA-2	-	0.600	0.588	NA	30.22	Wool	Cotton	Wool
MU-VA-3	-	0.180	0.029	NA	4.80	Wool	Wool	Wool
MU-VA-4	-	0.130	0.040	NA	3.64	Wool	Wool	Wool

Carpet ID	Loom Orientation	Warping System	Warp Bar Spacing: Bottom	Warp Bar Spacing: Top	Tension Rods: Top	Tension Rods: Bottom	Shed Rods	Single-Shed Heddles
KZ-OT-1	Vertical	Belt	N	N	1	1	1	1
KZ-OT-2	Vertical	Belt	N	N	1	1	1	1
KZ-OT-3	Vertical	Belt	N	N	1	1	1	1
KZ-SH-1	Vertical	Belt	N	N	0	0	1	1
KZ-SH-2	Vertical	Belt	N	N	0	0	1	1
TK-MA-1	Vertical	Belt	N	N	0	1	0	0
TK-MA-2	Vertical	Belt	N	N	0	1	0	0
TK-MA-3	Vertical	Belt	N	N	0	1	0	0
TK-MA-4	Vertical	Belt	N	N	0	1	0	0
TK-MA-5	Vertical	Belt	N	N	0	1	0	0
TK-MA-6	Vertical	Belt	N	N	0	1	0	0
TK-MA-7	Vertical	Belt	N	N	0	1	0	0
TK-MA-8	Vertical	Belt	N	N	0	1	0	0
TK-MA-9	Vertical	Belt	N	N	0	1	0	0
UZ-KH-1	Vertical	Belt	N	N	0	1	0	0

Carpet ID	Loom Orientation	Warping System	Warp Bar Spacing: Bottom	Warp Bar Spacing: Top	Tension Rods: Top	Tension Rods: Bottom	Shed Rods	Single-Shed Heddles
UZ-KH-2	Vertical	Belt	N	N	0	1	0	0
UZ-KH-3	Vertical	Belt	N	N	0	1	0	0
UZ-KH-4	Vertical	Belt	N	N	0	1	0	0
UZ-KH-5	Vertical	Belt	N	N	0	1	0	0
UZ-KH-6	Vertical	Belt	N	N	0	1	0	0
UZ-KH-7	Vertical	Belt	N	N	0	1	0	0
UZ-KH-8	Vertical	Belt	N	N	0	1	0	0
UZ-KH-9	Vertical	Belt	N	N	0	0	0	0
UZ-KH-10	Vertical	Belt	N	N	0	0	0	0
UZ-KH-11	Vertical	Belt	N	N	0	1	0	0
UZ-KH-12	Vertical	Belt	N	N	0	1	0	0
UZ-KH-13	Vertical	Belt	N	N	0	1	0	0
UZ-SK-1	Vertical	Belt	N	N	0	0	1	1
UZ-SK-2	Vertical	Belt	N	N	0	0	1	1
UZ-SK-3	Vertical	Belt	N	N	0	0	1	1

Carpet ID	Loom Orientation	Warping System	Warp Bar Spacing: Bottom	Warp Bar Spacing: Top	Tension Rods: Top	Tension Rods: Bottom	Shed Rods	Single-Shed Heddles
MU-AS-1	-	-	-	-	-	-	-	-
MU-AS-2a	-	-	-	-	-	-	-	-
MU-AS-2b	-	-	-	-	-	-	-	-
MU-AS-3	-	-	-	-	-	-	-	-
MU-AS-4a	-	-	-	-	-	-	-	-
MU-AS-4b	-	-	-	-	-	-	-	-
MU-AS-4c	-	-	-	-	-	-	-	-
MU-AS-5	-	-	-	-	-	-	-	-
MU-AS-6	-	-	-	-	-	-	-	-
MU-AS-7	-	-	-	-	-	-	-	-
MU-AS-8	-	-	-	-	-	-	-	-
MU-AS-8	-	-	-	-	-	-	-	-
MU-AS-8	-	-	-	-	-	-	-	-
MU-AS-8	-	-	-	-	-	-	-	-
MU-AS-9ab	-	-	-	-	-	-	-	-
MU-AS-9ab	-	-	-	-	-	-	-	-

Carpet ID	Loom Orientation	Warping System	Warp Bar Spacing: Bottom	Warp Bar Spacing: Top	Tension Rods: Top	Tension Rods: Bottom	Shed Rods	Single-Shed Heddles
MU-AS-9c	-	-	-	-	-	-	-	-
MU-AS-9d	-	-	-	-	-	-	-	-
MU-AS-10	-	-	-	-	-	-	-	-
MU-AS-10	-	-	-	-	-	-	-	-
MU-AS-11	-	-	-	-	-	-	-	-
MU-AS-11	-	-	-	-	-	-	-	-
MU-AS-11	-	-	-	-	-	-	-	-
MU-AS-11	-	-	-	-	-	-	-	-
MU-AS-11	-	-	-	-	-	-	-	-
MU-AS-12	-	-	-	-	-	-	-	-
MU-AS-13	-	-	-	-	-	-	-	-
MU-AS-14	-	-	-	-	-	-	-	-
MU-AS-16	-	-	-	-	-	-	-	-
MU-AS-17ef	-	-	-	-	-	-	-	-
MU-AS-17ef	-	-	-	-	-	-	-	-

Carpet ID	Loom Orientation	Warping System	Warp Bar Spacing: Bottom	Warp Bar Spacing: Top	Tension Rods: Top	Tension Rods: Bottom	Shed Rods	Single-Shed Heddles
MU-AS-17g	-	-	-	-	-	-	-	-
MU-AS-18	-	-	-	-	-	-	-	-
MU-CH-1	-	-	-	-	-	-	-	-
MU-CH-2	-	-	-	-	-	-	-	-
MU-CH-3	-	-	-	-	-	-	-	-
MU-CH-4	-	-	-	-	-	-	-	-
MU-CH-5	-	-	-	-	-	-	-	-
MU-CH-6	-	-	-	-	-	-	-	-
MU-CH-7	-	-	-	-	-	-	-	-
MU-DY-1a	-	-	-	-	-	-	-	-
MU-DY-1b	-	-	-	-	-	-	-	-
MU-DY-1c	-	-	-	-	-	-	-	-
MU-DY-1d	-	-	-	-	-	-	-	-
MU-DY-2a	-	-	-	-	-	-	-	-
MU-DY-2b	-	-	-	-	-	-	-	-

Carpet ID	Loom Orientation	Warping System	Warp Bar Spacing: Bottom	Warp Bar Spacing: Top	Tension Rods: Top	Tension Rods: Bottom	Shed Rods	Single-Shed Heddles
MU-DY-2c	-	-	-	-	-	-	-	-
MU-IN-1	-	-	-	-	-	-	-	-
MU-IN-2	-	-	-	-	-	-	-	-
MU-IN-3	-	-	-	-	-	-	-	-
MU-IN-4	-	-	-	-	-	-	-	-
MU-IN-5	-	-	-	-	-	-	-	-
MU-IN-6	-	-	-	-	-	-	-	-
MU-IN-7	-	-	-	-	-	-	-	-
MU-SO-1	-	-	-	-	-	-	-	-
MU-SO-2	-	-	-	-	-	-	-	-
MU-SO-3	-	-	-	-	-	-	-	-
MU-SO-4	-	-	-	-	-	-	-	-
MU-VA-1	-	-	-	-	-	-	-	-
MU-VA-2	-	-	-	-	-	-	-	-
MU-VA-3	-	-	-	-	-	-	-	-
MU-VA-4	-	-	-	-	-	-	-	-

Carpet ID	Double-Shed Heddles	Selvedge Picks: Bottom	Selvedge Strands: Bottom	Selvedge Weave: Bottom	Selvedge Picks: Top	Selvedge Strands: Top	Selvedge Weave: Top	Knot Type
KZ-OT-1	0	10	1	1/1	15	2	1/1	SY
KZ-OT-2	0	12	1	1/1	19	1	1/1	SY
KZ-OT-3	0	-	-	-	-	-	-	SY
KZ-SH-1	0	12	1	1/1	9	1	1/1	SY
KZ-SH-2	0	10	1	1/1	7	1	1/1	AS
TK-MA-1	1	8	1	1/1	10	1	1/1	AS
TK-MA-2	1	16	1	1/1	16	1	1/1	AS
TK-MA-3	1	13	1	1/1	13	1	1/1	AS
TK-MA-4	1	15	1	1/1	16	1	1/1	AS
TK-MA-5	1	21	1	1/1	15	1	1/1	AS
TK-MA-6	1	21	1	1/1	18	1	1/1	AS
TK-MA-7	1	17	1	1/1	13	1	1/1	AS
TK-MA-8	1	15	1	1/1	17	1	1/1	AS
TK-MA-9	1	14	1	1/1	17	1	1/1	AS
UZ-KH-1	1	12	4	1/1	14	4	1/1	AS

Carpet ID	Double-Shed Heddles	Selvedge Picks: Bottom	Selvedge Strands: Bottom	Selvedge Weave: Bottom	Selvedge Picks: Top	Selvedge Strands: Top	Selvedge Weave: Top	Knot Type
UZ-KH-2	1	12	4	1/1	8	4	1/1	AS
UZ-KH-3	1	6	2	1/1	6	4	1/1	AS
UZ-KH-4	1	9	4	1/1	8	4	1/1	AS
UZ-KH-5	1	4	4	1/1	6	4	1/1	AS
UZ-KH-6	1	5	2	1/1	4	2	1/1	AS
UZ-KH-7	1	7	4	1/1	8	4	1/1	AS
UZ-KH-8	1	9	2	1/1	8	2	1/1	AS
UZ-KH-9	1	20*	1	1/1	-	-	-	SY
UZ-KH-10	1	32*	1	1/1	-	-	-	SY
UZ-KH-11	1	40*	1	1/1	-	-	-	SY
UZ-KH-12	1	26*	1	1/1	-	-	-	SY
UZ-KH-13	1	28*	1	1/1	-	-	-	SY
UZ-SK-1	0	-	-	1/1	-	-	-	SY
UZ-SK-2	0	18*	1	1/1	-	-	-	SY
UZ-SK-3	0	20*	1	1/1	-	-	-	SY

Carpet ID	Double-Shed Heddles	Selvedge Picks: Bottom	Selvedge Strands: Bottom	Selvedge Weave: Bottom	Selvedge Picks: Top	Selvedge Strands: Top	Selvedge Weave: Top	Knot Type
MU-AS-1	-	6*	2*	1/1	match	match	match	WR
MU-AS-2a	-	-	-	-	-	-	-	WR
MU-AS-2b	-	-	-	-	-	-	-	WR
MU-AS-3	-	-	-	-	-	-	-	WR
MU-AS-4a	-	-	-	-	-	-	-	AS
MU-AS-4b	-	-	-	-	-	-	-	AS
MU-AS-4c	-	-	-	-	-	-	-	AS
MU-AS-5	-	-	-	-	-	-	-	WR
MU-AS-6	-	-	-	-	-	-	-	SY
MU-AS-7	-	-	-	-	-	-	-	AS
MU-AS-8	-	-	-	-	-	-	-	AS
MU-AS-8	-	-	-	-	-	-	-	AS
MU-AS-8	-	-	-	-	-	-	-	AS
MU-AS-8	-	-	-	-	-	-	-	AS
MU-AS-9ab	-	-	-	-	-	-	-	AS; WR
MU-AS-9ab	-	-	-	-	-	-	-	AS; WR

Carpet ID	Double-Shed Heddles	Selvedge Picks: Bottom	Selvedge Strands: Bottom	Selvedge Weave: Bottom	Selvedge Picks: Top	Selvedge Strands: Top	Selvedge Weave: Top	Knot Type
MU-AS-9c	-	-	-	-	-	-	-	AS; WR
MU-AS-9d	-	-	-	-	-	-	-	AS; WR
MU-AS-10	-	-	6	1/1	-	match	match	AS
MU-AS-10	-	-	6	1/1	-	match	match	AS
MU-AS-11	-	-	-	-	-	-	-	AS
MU-AS-11	-	-	-	-	-	-	-	AS
MU-AS-11	-	7	3	1/1	match	match	match	AS
MU-AS-11	-	-	-	-	-	-	-	AS
MU-AS-11	-	-	-	-	-	-	-	AS
MU-AS-12	-	-	-	-	-	-	-	AS
MU-AS-13	-	-	-	-	-	-	-	AS
MU-AS-14	-	-	-	-	-	-	-	AS
MU-AS-16	-	-	-	-	-	-	-	AS
MU-AS-17ef	-	-	-	-	-	-	-	AS
MU-AS-17ef	-	-	-	-	-	-	-	AS

Carpet ID	Double-Shed Heddles	Selvedge Picks: Bottom	Selvedge Strands: Bottom	Selvedge Weave: Bottom	Selvedge Picks: Top	Selvedge Strands: Top	Selvedge Weave: Top	Knot Type
MU-AS-17g	-	-	-	-	-	-	-	AS
MU-AS-18	-	-	-	-	-	-	-	AS
MU-CH-1	-	-	-	-	-	-	-	-
MU-CH-2	-	-	-	-	-	-	-	-
MU-CH-3	-	2	-	1/1	4	-	1/1	-
MU-CH-4	-	-	-	-	-	-	-	-
MU-CH-5	-	-	-	-	-	-	-	-
MU-CH-6	-	-	-	-	-	-	-	-
MU-CH-7	-	-	-	-	-	-	-	-
MU-DY-1a	-	-	-	-	-	-	-	SY
MU-DY-1b	-	-	-	-	-	-	-	SY
MU-DY-1c	-	-	-	-	-	-	-	SY
MU-DY-1d	-	-	-	-	-	-	-	SY
MU-DY-2a	-	-	-	-	-	-	-	-
MU-DY-2b	-	-	-	-	-	-	-	-

Carpet ID	Double-Shed Heddles	Selvedge Picks: Bottom	Selvedge Strands: Bottom	Selvedge Weave: Bottom	Selvedge Picks: Top	Selvedge Strands: Top	Selvedge Weave: Top	Knot Type
MU-DY-2c	-	-	-	-	-	-	-	-
MU-IN-1	-	-	-	1/1	-	-	1/1	AS
MU-IN-2	-	-	-	1/1	-	-	1/1	AS
MU-IN-3	-	-	-	1/1	-	-	1/1	AS
MU-IN-4	-	-	-	1/1	-	-	1/1	SY
MU-IN-5	-	-	-	1/1	-	-	1/1	AS
MU-IN-6	-	-	-	1/1	-	-	1/1	AS
MU-IN-7	-	-	-	1/1	-	-	1/1	AS
MU-SO-1	-	38*	-	1/1	64*	-	1/1	-
MU-SO-2	-	18*	-	1/1	10*	-	1/1	-
MU-SO-3	-	0*	-	-	0*	-	-	-
MU-SO-4	-	0*	-	-	0*	-	-	-
MU-VA-1	-	-	-	-	-	-	-	SY
MU-VA-2	-	-	-	-	-	-	-	AS
MU-VA-3	-	-	-	-	-	-	-	SY
MU-VA-4	-	-	-	-	-	-	-	SY

Carpet ID	Knot Direction	Knot Variants	Strands per Knot	Knot-Warp Pattern	Knot-Weft Pattern	Knot Spacing	Knot-Row Offset	Knotting Shed Position
KZ-OT-1	None	N	2	I	C; D	0	0	Closed
KZ-OT-2	None	N	2	I	C; D	0	0	Closed
KZ-OT-3	None	N	2	I	C; D	0	0	Closed
KZ-SH-1	None	N	2.5	I	C; D	0	0	Closed
KZ-SH-2	R	N	2	II	C	0	0	Closed
TK-MA-1	R	N	2	II	D	0	0	Partial
TK-MA-2	R	N	2	II	D	0	0	Partial
TK-MA-3	R	N	2	II	D	0	0	Partial
TK-MA-4	R	N	2	II	D	0	0	Partial
TK-MA-5	R	N	2	II	D	0	0	Partial
TK-MA-6	R	N	2	II	D	0	0	Partial
TK-MA-7	R	N	2	II	D	0	0	Partial
TK-MA-8	R	N	1	II	D	0	0	Partial
TK-MA-9	R	N	2	II	D	0	0	Partial
UZ-KH-1	R	N	4	II	A; D	0	0	Partial

Carpet ID	Knot Direction	Knot Variants	Strands per Knot	Knot-Warp Pattern	Knot-Weft Pattern	Knot Spacing	Knot-Row Offset	Knotting Shed Position
UZ-KH-2	R	N	2	II	A; D	0	0	Partial
UZ-KH-3	R	N	4	II	A; D	0	0	Partial
UZ-KH-4	R	N	4	II	A; D	0	0	Partial
UZ-KH-5	R	N	4	II	A; D	0	0	Partial
UZ-KH-6	R	N	2	II	A; D	0	0	Partial
UZ-KH-7	R	N	4	II	A; D	0	0	Partial
UZ-KH-8	R	N	2	II	A; D	0	0	Partial
UZ-KH-9	None	N	1	III	A; D	0	0	Open
UZ-KH-10	None	N	1	III	A; D	0	0	Open
UZ-KH-11	None	N	1	III	A; D	0	0	Open
UZ-KH-12	None	N	1	III	A; D	0	0	Open
UZ-KH-13	None	N	1	III	A; D	0	0	Open
UZ-SK-1	None	N	1	III	A	0	0	Partial
UZ-SK-2	None	N	1	III	A	0	0	Partial
UZ-SK-3	None	N	1	III	A	0	0	Partial

Carpet ID	Knot Direction	Knot Variants	Strands per Knot	Knot-Warp Pattern	Knot-Weft Pattern	Knot Spacing	Knot-Row Offset	Knotting Shed Position
MU-AS-1	-	N	2	I	C	1	1	-
MU-AS-2a	-	N	2.5	I	C; D	0	0	-
MU-AS-2b	-	N	2	I	C; D	0	0	-
MU-AS-3	Z	N	1	I	C; D	0; 1	0	-
MU-AS-4a	L	N	4	II	C	0	0	-
MU-AS-4b	L	N	4	II	C	0	0	-
MU-AS-4c	L	N	4	II	C	0	0	-
MU-AS-5	S	N	4	I	C; D	0	0	-
MU-AS-6	None	N	3	I	Q; R; L; J	0	1	-
MU-AS-7	L	N	3.5	II	C	0	0	-
MU-AS-8	R	N	5	I	D	0	1	-
MU-AS-8	R	N	5	I	D	0	1	-
MU-AS-8	R	N	5	I	D	0	1	-
MU-AS-8	R	N	5	I	D	0	1	-
MU-AS-9ab	L; Z	N	3	I	C; D	0; 1	0	-
MU-AS-9ab	L; Z	N	3	I	C; D	0; 1	0	-

Carpet ID	Knot Direction	Knot Variants	Strands per Knot	Knot-Warp Pattern	Knot-Weft Pattern	Knot Spacing	Knot-Row Offset	Knotting Shed Position
MU-AS-9c	L; Z	N	3	I	C; D	0; 1	0	-
MU-AS-9d	L; Z	N	3	I	C; D	0; 1	0	-
MU-AS-10	L	N	3	I	C	0	0	-
MU-AS-10	L	N	3	I	C	0	0	-
MU-AS-11	R	N	3	I	C; D	-1	0	-
MU-AS-11	R	N	3	I	C; D	-1	0	-
MU-AS-11	R	N	3	I	C; D	-1	0	-
MU-AS-11	R	N	3	I	C; D	-1	0	-
MU-AS-11	R	N	3	I	C; D	-1	0	-
MU-AS-12	L	N	2	II	C	0	0	-
MU-AS-13	L	N	2	III	B	0	0	-
MU-AS-14	L	N	2.5	II	C	0	0	-
MU-AS-16	R	N	4	I	G; H	0	0	-
MU-AS-17ef	L	N	3	I	C	0	0	-
MU-AS-17ef	L	N	3	I	C	0	0	-

Carpet ID	Knot Direction	Knot Variants	Strands per Knot	Knot-Warp Pattern	Knot-Weft Pattern	Knot Spacing	Knot-Row Offset	Knotting Shed Position
MU-AS-17g	L	N	3	I	C	0	0	-
MU-AS-18	L	N	3	I	C	0	0	-
MU-CH-1	-	-	-	III	B	0	0	-
MU-CH-2	-	-	-	I	B	0	0	-
MU-CH-3	-	-	-	III	B	0	0	-
MU-CH-4	-	-	-	III	C	0	0	-
MU-CH-5	-	-	-	I	C	0	0	-
MU-CH-6	-	-	-	I	C	0	0	-
MU-CH-7	-	-	-	I	C	0	0	-
MU-DY-1a	None	N	-	III	C	0	0	-
MU-DY-1b	None	N	-	III	C	0	0	-
MU-DY-1c	None	N	-	III	C	0	0	-
MU-DY-1d	None	N	-	III	C	0	0	-
MU-DY-2a	-	-	-	I	C; D	0	0	-
MU-DY-2b	-	-	-	I	C; D	0	0	-

Carpet ID	Knot Direction	Knot Variants	Strands per Knot	Knot-Warp Pattern	Knot-Weft Pattern	Knot Spacing	Knot-Row Offset	Knotting Shed Position
MU-DY-2c	-	-	-	I	C; D	0	0	-
MU-IN-1	R	Y	-	I	D	0	0	-
MU-IN-2	L	N	-	III	C	0	0	-
MU-IN-3	L	N	-	III	C	0	0	-
MU-IN-4	None	N	-	II	D	0	0	-
MU-IN-5	L	N	-	I	C	0	0	-
MU-IN-6	L	N	-	I	C	0	0	-
MU-IN-7	L	N	-	III	C	0	0	-
MU-SO-1	-	-	-	III	C	0	0	-
MU-SO-2	-	-	-	III	B	0	0	-
MU-SO-3	-	-	-	III	C	0	0	-
MU-SO-4	-	-	-	III	B	0	0	-
MU-VA-1	None	N	-	III	C	0	0	-
MU-VA-2	L	N	-	III	B	0	0	-
MU-VA-3	None	N	-	I	A; D	0	0	-
MU-VA-4	None	N	-	I	A; D	0	0	-

Carpet ID	Knotting Order	Cartoon Use	Weft Rows	Weft Shot Pick Count	Weft Shot Weave	Weft Weave Size	Weft Offset Pattern	Weft Addition Rate
KZ-OT-1	D/R-L	Continuous	N	1	Tabby	1/1	Alternate	Continuous
KZ-OT-2	D/R-L	Continuous	N	1	Tabby	1/1	Alternate	Continuous
KZ-OT-3	D/R-L	Continuous	N	1	Tabby	1/1	Alternate	Continuous
KZ-SH-1	Pattern	Sporadic	Y	1	Tabby	1/1	Alternate	Continuous
KZ-SH-2	Pattern	Sporadic	Y	2	Tabby	1/1	Regular	Continuous
TK-MA-1	Color	Sporadic	N	2	Tabby	1/1	Regular	Continuous
TK-MA-2	Color	Sporadic	N	2	Tabby	1/1	Regular	Continuous
TK-MA-3	Color	Sporadic	N	2	Tabby	1/1	Regular	Continuous
TK-MA-4	Color	Sporadic	N	2	Tabby	1/1	Regular	Continuous
TK-MA-5	Color	Sporadic	N	2	Tabby	1/1	Regular	Continuous
TK-MA-6	Color	Sporadic	N	2	Tabby	1/1	Regular	Continuous
TK-MA-7	Color	Sporadic	N	2	Tabby	1/1	Regular	Continuous
TK-MA-8	Color	Sporadic	N	2	Tabby	1/1	Regular	Continuous
TK-MA-9	Color	Sporadic	N	2	Tabby	1/1	Regular	Continuous
UZ-KH-1	Color	None	Y	1:2	Tabby	1/1	Alternate	Continuous

Carpet ID	Knotting Order	Cartoon Use	Weft Rows	Weft Shot Pick Count	Weft Shot Weave	Weft Weave Size	Weft Offset Pattern	Weft Addition Rate
UZ-KH-2	Color	None	Y	1:2	Tabby	1/1	Alternate	Continuous
UZ-KH-3	Color	None	Y	1:2	Tabby	1/1	Alternate	Continuous
UZ-KH-4	D/R-L	None	Y	1:2	Tabby	1/1	Alternate	Continuous
UZ-KH-5	Color	Continuous	Y	1:2	Tabby	1/1	Alternate	Continuous
UZ-KH-6	Color	None	Y	1:2	Tabby	1/1	Alternate	Continuous
UZ-KH-7	D/R-L	None	Y	1:2	Tabby	1/1	Alternate	Continuous
UZ-KH-8	D/R-L	None	Y	1:2	Tabby	1/1	Alternate	Continuous
UZ-KH-9	Color	Sporadic	N	1:2	Tabby	1/1	Alternate	Continuous
UZ-KH-10	Color	Sporadic	N	1:2	Tabby	1/1	Alternate	Continuous
UZ-KH-11	Color	Continuous	N	1:2	Tabby	1/1	Alternate	Continuous
UZ-KH-12	Color	Continuous	N	1:2	Tabby	1/1	Alternate	Continuous
UZ-KH-13	Pattern	Continuous	N	1:2	Tabby	1/1	Alternate	Continuous
UZ-SK-1	Color	Sporadic	N	1	Tabby	1/1	Regular	Continuous
UZ-SK-2	Color	Sporadic	N	1	Tabby	1/1	Regular	Continuous
UZ-SK-3	Pattern	Sporadic	N	1	Tabby	1/1	Regular	Broken

Carpet ID	Knotting Order	Cartoon Use	Weft Rows	Weft Shot Pick Count	Weft Shot Weave	Weft Weave Size	Weft Offset Pattern	Weft Addition Rate
MU-AS-1	-	-	Y	1	Tabby	1/1	Alternate	-
MU-AS-2a	-	-	N	3	Tabby	1/1	Alternate	-
MU-AS-2b	-	-	N	3	Tabby	1/1	Alternate	-
MU-AS-3	-	-	Y	1	Tabby	1/1	Alternate	-
MU-AS-4a	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-4b	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-4c	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-5	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-6	-	-	Y	4	Twill	3/1; 1/3	Regular	-
MU-AS-7	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-8	-	-	Y	1	Tabby	1/1	Alternate	-
MU-AS-8	-	-	Y	1	Tabby	1/1	Alternate	-
MU-AS-8	-	-	Y	1	Tabby	1/1	Alternate	-
MU-AS-8	-	-	Y	1	Tabby	1/1	Alternate	-
MU-AS-9ab	-	-	Y	1	Tabby	1/1	Alternate	-
MU-AS-9ab	-	-	Y	1	Tabby	1/1	Alternate	-

Carpet ID	Knotting Order	Cartoon Use	Weft Rows	Weft Shot Pick Count	Weft Shot Weave	Weft Weave Size	Weft Offset Pattern	Weft Addition Rate
MU-AS-9c	-	-	Y	1	Tabby	1/1	Alternate	-
MU-AS-9d	-	-	Y	1	Tabby	1/1	Alternate	-
MU-AS-10	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-10	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-11	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-11	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-11	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-11	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-11	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-12	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-13	-	-	Y	3	Tabby	1/1	Regular	-
MU-AS-14	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-16	-	-	Y	6*	Tabby	2/2	Regular	-
MU-AS-17ef	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-17ef	-	-	Y	2	Tabby	1/1	Regular	-

Carpet ID	Knotting Order	Cartoon Use	Weft Rows	Weft Shot Pick Count	Weft Shot Weave	Weft Weave Size	Weft Offset Pattern	Weft Addition Rate
MU-AS-17g	-	-	Y	2	Tabby	1/1	Regular	-
MU-AS-18	-	-	Y	2	Tabby	1/1	Regular	-
MU-CH-1	-	-	Y	3	Tabby	1/1	Regular	-
MU-CH-2	-	-	Y	3	Tabby	1/1	Regular	-
MU-CH-3	-	-	Y	3	Tabby	1/1	Regular	-
MU-CH-4	-	-	Y	2	Tabby	1/1	Regular	-
MU-CH-5	-	-	Y	2	Tabby	1/1	Regular	-
MU-CH-6	-	-	Y	2	Tabby	1/1	Regular	-
MU-CH-7	-	-	Y	2	Tabby	1/1	Regular	-
MU-DY-1a	-	-	Y	2	Tabby	1/1	Regular	-
MU-DY-1b	-	-	Y	2	Tabby	1/1	Regular	-
MU-DY-1c	-	-	Y	2	Tabby	1/1	Regular	-
MU-DY-1d	-	-	Y	2	Tabby	1/1	Regular	-
MU-DY-2a	-	-	Y	4*	Tabby	2/2	Regular	-
MU-DY-2b	-	-	Y	4*	Tabby	2/2	Regular	-

Carpet ID	Knotting Order	Cartoon Use	Weft Rows	Weft Shot Pick Count	Weft Shot Weave	Weft Weave Size	Weft Offset Pattern	Weft Addition Rate
MU-DY-2c	-	-	Y	4*	Tabby	2/2	Regular	-
MU-IN-1	-	-	Y	2	Tabby	1/1	Regular	-
MU-IN-2	-	-	Y	2	Tabby	1/1	Regular	-
MU-IN-3	-	-	N	2	Tabby	1/1	Regular	-
MU-IN-4	-	-	Y	2	Tabby	1/1	Regular	-
MU-IN-5	-	-	Y	2	Tabby	1/1	Regular	-
MU-IN-6	-	-	Y	2	Tabby	1/1	Regular	-
MU-IN-7	-	-	Y	2	Tabby	1/1	Regular	-
MU-SO-1	-	-	Y	2	Tabby	1/1	Regular	-
MU-SO-2	-	-	Y	3	Tabby	1/1	Regular	-
MU-SO-3	-	-	Y	2	Tabby	1/1	Regular	-
MU-SO-4	-	-	Y	3	Tabby	1/1	Regular	-
MU-VA-1	-	-	Y	2	Tabby	1/1	Regular	-
MU-VA-2	-	-	Y	3	Tabby	1/1	Regular	-
MU-VA-3	-	-	Y	6:7	Tabby	1/1	Alternate	-
MU-VA-4	-	-	Y	7*	Tabby	1/1	Random	-

Carpet ID	Binding Weave Pattern	Binding Warps	Binding-Weft Overlap	Knife Type	Cutting Direction	Scissor Type	Trim Frequency	Hook
KZ-OT-1	Tabby	2:2	S	Straight	N-S	Standard	1	Y
KZ-OT-2	Tabby	2:2	S	Straight	N-S	Standard	1	Y
KZ-OT-3	Tabby	2:2	S	Straight	N-S	Standard	1	Y
KZ-SH-1	Tabby	2:2	S	Curve	NE-SW	Standard	1	N
KZ-SH-2	Tabby	2:2	S	Curve	NE-SW	Standard	1	N
TK-MA-1	Wrap	4:1	S	Curve	N-S	Standard	2	N
TK-MA-2	Wrap	4:1	S	Curve	NE-SW	Standard	2	N
TK-MA-3	Wrap	4:1	S	Curve	N-S	Standard	2	N
TK-MA-4	Wrap	4:1	S	Curve	N-S	Standard	2	N
TK-MA-5	Wrap	4:1	S	Curve	NE-SW	Standard	2	N
TK-MA-6	Wrap	4:1	S	Curve	NE-SW	Standard	2	N
TK-MA-7	Wrap	4:1	S	Curve	N-S	Standard	2	N
TK-MA-8	Wrap	4:1	S	Curve	NE-SW	Standard	2	N
TK-MA-9	Wrap	4:1	S	Curve	NE-SW	Standard	2	N
UZ-KH-1	Tabby	6:2	S	Curve	NE-SW	Standard	1	N

Carpet ID	Binding Weave Pattern	Binding Warps	Binding-Weft Overlap	Knife Type	Cutting Direction	Scissor Type	Trim Frequency	Hook
UZ-KH-2	Tabby	6:2	S	Curve	NE-SW	Standard	1	N
UZ-KH-3	Tabby	6:2	S	Curve	NE-SW	Offset	2	N
UZ-KH-4	Tabby	6:2	S	Curve	NE-SW	Offset	2	N
UZ-KH-5	Tabby	10:2	S	Curve	N-S	Offset	1	N
UZ-KH-6	Tabby	10:2	S	Curve	N-S	Offset	1	N
UZ-KH-7	Tabby	6:2	S	Curve	N-S	Offset	2	N
UZ-KH-8	Tabby	10:2	S	Curve	N-S	Offset	2	N
UZ-KH-9	Tabby	6:3	S	Straight	N-S	Offset	1	Y
UZ-KH-10	Tabby	6:3	S	Straight	N-S	Offset	1	Y
UZ-KH-11	Tabby	6:3	S	Straight	-/N-S	Offset	1	Y
UZ-KH-12	Tabby	6:3	S	Straight	N-S	Offset	1	Y
UZ-KH-13	Tabby	6:3	S	Straight	N-S	Offset	1	Y
UZ-SK-1	Tabby	8:4	S	Straight	N-S	Offset	2	Y
UZ-SK-2	Tabby	8:4	S	Straight	N-S	Offset	2	Y
UZ-SK-3	Tabby	8:4	S	Straight	NE-SW	Offset	2	Y

Carpet ID	Binding Weave Pattern	Binding Warps	Binding-Weft Overlap	Knife Type	Cutting Direction	Scissor Type	Trim Frequency	Hook
MU-AS-1	Wrap	-	-	-	-	-	-	-
MU-AS-2a	-	-	-	-	-	-	-	-
MU-AS-2b	-	-	-	-	-	-	-	-
MU-AS-3	-	-	-	-	-	-	-	-
MU-AS-4a		3:1	C	-	-	-	-	-
MU-AS-4b	Wrap	3:1	C	-	-	-	-	-
MU-AS-4c	Wrap	3:1	C	-	-	-	-	-
MU-AS-5	-	-	-	-	-	-	-	-
MU-AS-6	-	-	-	-	-	-	-	-
MU-AS-7	-	-	-	-	-	-	-	-
MU-AS-8	-	-	-	-	-	-	-	-
MU-AS-8	-	-	-	-	-	-	-	-
MU-AS-8	-	-	-	-	-	-	-	-
MU-AS-8	-	-	-	-	-	-	-	-
MU-AS-9ab	-	-	-	-	-	-	-	-
MU-AS-9ab	-	-	-	-	-	-	-	-

Carpet ID	Binding Weave Pattern	Binding Warps	Binding-Weft Overlap	Knife Type	Cutting Direction	Scissor Type	Trim Frequency	Hook
MU-AS-9c	-	-	-	-	-	-	-	-
MU-AS-9d	-	-	-	-	-	-	-	-
MU-AS-10	Wrap	6:1	C	-	-	-	-	-
MU-AS-10	Wrap	6:1	C	-	-	-	-	-
MU-AS-11	-	-	-	-	-	-	-	-
MU-AS-11	-	-	-	-	-	-	-	-
MU-AS-11	-	-	-	-	-	-	-	-
MU-AS-11	-	-	-	-	-	-	-	-
MU-AS-11	-	-	-	-	-	-	-	-
MU-AS-12	-	-	-	-	-	-	-	-
MU-AS-13	-	-	-	-	-	-	-	-
MU-AS-14	-	-	-	-	-	-	-	-
MU-AS-16	-	-	-	-	-	-	-	-
MU-AS-17ef	-	-	-	-	-	-	-	-
MU-AS-17ef	-	-	-	-	-	-	-	-

Carpet ID	Binding Weave Pattern	Binding Warps	Binding-Weft Overlap	Knife Type	Cutting Direction	Scissor Type	Trim Frequency	Hook
MU-AS-17g	-	-	-	-	-	-	-	-
MU-AS-18	Wrap	8:1	C	-	-	-	-	-
MU-CH-1	Wrap	?:1	S	-	-	-	-	-
MU-CH-2	Wrap	2:1	S	-	-	-	-	-
MU-CH-3	Wrap	1:1	S	-	-	-	-	-
MU-CH-4	-	-	-	-	-	-	-	-
MU-CH-5	-	-	-	-	-	-	-	-
MU-CH-6	Tabby	4:2	C	-	-	-	-	-
MU-CH-7	-	-	-	-	-	-	-	-
MU-DY-1a	-	-	-	-	-	-	-	-
MU-DY-1b	-	-	-	-	-	-	-	-
MU-DY-1c	-	-	-	-	-	-	-	-
MU-DY-1d	-	-	-	-	-	-	-	-
MU-DY-2a	-	-	-	-	-	-	-	-
MU-DY-2b	-	-	-	-	-	-	-	-

Carpet ID	Binding Weave Pattern	Binding Warps	Binding-Weft Overlap	Knife Type	Cutting Direction	Scissor Type	Trim Frequency	Hook
MU-DY-2c	-	-	-	-	-	-	-	-
MU-IN-1	Tabby	?:4	-	-	-	-	-	-
MU-IN-2	Wrap	2:1	-	-	-	-	-	-
MU-IN-3	Tabby	?:4	-	-	-	-	-	-
MU-IN-4	Tabby	?:4	-	-	-	-	-	-
MU-IN-5	Tabby	?:2	-	-	-	-	-	-
MU-IN-6	Tabby	?:2	-	-	-	-	-	-
MU-IN-7	Tabby	?:2	-	-	-	-	-	-
MU-SO-1	-	-	S	-	-	-	-	-
MU-SO-2	Wrap	?:1	S	-	-	-	-	-
MU-SO-3	Tabby	?:3	S	-	-	-	-	-
MU-SO-4	-	-	-	-	-	-	-	-
MU-VA-1	-	-	-	-	-	-	-	-
MU-VA-2	-	-	-	-	-	-	-	-
MU-VA-3	-	-	-	-	-	-	-	-
MU-VA-4	-	-	-	-	-	-	-	-

Carpet ID	Beater Type	Weaver	Pseudonym	Number of Weavers	Weaving Position	Handedness	Oversight	Experience
KZ-OT-1	Comb	Sholpan Zhycinbek	Kate	1	None	R	None	10
KZ-OT-2	Comb	Sholpan Zhycinbek	Kate	1	None	R	None	10
KZ-OT-3	Comb	Sholpan Zhycinbek	Kate	1	None	R	None	10
KZ-SH-1	Comb	Madina Ahmetova	Margaret	1	None	R	None	9
KZ-SH-2	Comb	Kulyash Aidarbekova	Teri	1	None	R	None	20+
TK-MA-1	Comb	Anonymous C	Christina	1	None	R	PS	1
TK-MA-2	Comb	Anonymous A	Anna	1	None	R	PS	2
TK-MA-3	Comb	Anonymous B	Barbara	1	None	R	PS	8
TK-MA-4	Comb	Anonymous B	Barbara	1	None	R	PS	8
TK-MA-5	Comb	Anonymous A	Anna	1	None	R	PS	2
TK-MA-6	Comb	Anonymous A	Anna	1	None	R	PS	2
TK-MA-7	Comb	Anonymous C	Christina	1	None	R	PS	1
TK-MA-8	Comb	Anonymous E	Eleanora	1	None	R	PS	6
TK-MA-9	Comb	Anonymous D	Dorothy	1	None	R	PS	9
UZ-KH-1	Comb	Durdiposhsha Omonova	Ginny	1	None	R	None	48

Carpet ID	Beater Type	Weaver	Pseudonym	Number of Weavers	Weaving Position	Handedness	Oversight	Experience
UZ-KH-2	Comb	Durdiposhsha Omonova	Ginny	1	None	R	None	48
UZ-KH-3	Comb	Mehribon Haitova	Monica	1	None	R	None	20+
UZ-KH-4	Comb	Mehribon Haitova	Monica	1	None	R	None	20+
UZ-KH-5	Comb	Dilbar Omonova	Jennifer	1	None	R	None	30
UZ-KH-6	Comb	Dilbar Omonova	Jennifer	1	None	R	None	30
UZ-KH-7	Comb	Anonymous F	Stephanie	1	None	R	None	30
UZ-KH-8	Comb	Anonymous F	Stephanie	1	None	R	None	30
UZ-KH-9	Comb	Halima Matyaqubova	Janina	1	None	R	PR	3
UZ-KH-10	Comb	Halima Matyaqubova	Janina	1	None	R	PR	3
UZ-KH-11	Comb	M. Qurbonova / N. Aminova	Alexandra / Jean	2	Consistent	R; R	PR	2/8
UZ-KH-12	Comb	Maloxat Qurbonova	Alexandra	2	Consistent	R; R	PR	2
UZ-KH-13	Comb	Nazokat Aminova	Jean	2	Consistent	R; R	PS	8
UZ-SK-1	Comb	Nigora	Mairead	1	None	R	PR	6
UZ-SK-2	Comb	Muftuna Narzulloeva	Carol	1	None	R	None	15
UZ-SK-3	Comb	Bashorat	Kathleen	1	None	R	PR	2.5

Carpet ID	Beater Type	Weaver	Pseudonym	Number of Weavers	Weaving Position	Handedness	Oversight	Experience
MU-AS-1	-	-	-	-	-	-	-	-
MU-AS-2a	-	-	-	-	-	-	-	-
MU-AS-2b	-	-	-	-	-	-	-	-
MU-AS-3	-	-	-	-	-	-	-	-
MU-AS-4a	-	-	-	-	-	-	-	-
MU-AS-4b	-	-	-	-	-	-	-	-
MU-AS-4c	-	-	-	-	-	-	-	-
MU-AS-5	-	-	-	-	-	-	-	-
MU-AS-6	-	-	-	-	-	-	-	-
MU-AS-7	-	-	-	-	-	-	-	-
MU-AS-8	-	-	-	-	-	-	-	-
MU-AS-8	-	-	-	-	-	-	-	-
MU-AS-8	-	-	-	-	-	-	-	-
MU-AS-8	-	-	-	-	-	-	-	-
MU-AS-9ab	-	-	-	-	-	-	-	-
MU-AS-9ab	-	-	-	-	-	-	-	-

Carpet ID	Beater Type	Weaver	Pseudonym	Number of Weavers	Weaving Position	Handedness	Oversight	Experience
MU-AS-9c	-	-	-	-	-	-	-	-
MU-AS-9d	-	-	-	-	-	-	-	-
MU-AS-10	-	-	-	-	-	-	-	-
MU-AS-10	-	-	-	-	-	-	-	-
MU-AS-11	-	-	-	-	-	-	-	-
MU-AS-11	-	-	-	-	-	-	-	-
MU-AS-11	-	-	-	-	-	-	-	-
MU-AS-11	-	-	-	-	-	-	-	-
MU-AS-11	-	-	-	-	-	-	-	-
MU-AS-12	-	-	-	-	-	-	-	-
MU-AS-13	-	-	-	-	-	-	-	-
MU-AS-14	-	-	-	-	-	-	-	-
MU-AS-16	-	-	-	-	-	-	-	-
MU-AS-17ef	-	-	-	-	-	-	-	-
MU-AS-17ef	-	-	-	-	-	-	-	-

Carpet ID	Beater Type	Weaver	Pseudonym	Number of Weavers	Weaving Position	Handedness	Oversight	Experience
MU-AS-17g	-	-	-	-	-	-	-	-
MU-AS-18	-	-	-	-	-	-	-	-
MU-CH-1	-	-	-	-	-	-	-	-
MU-CH-2	-	-	-	-	-	-	-	-
MU-CH-3	-	-	-	-	-	-	-	-
MU-CH-4	-	-	-	-	-	-	-	-
MU-CH-5	-	-	-	-	-	-	-	-
MU-CH-6	-	-	-	-	-	-	-	-
MU-CH-7	-	-	-	-	-	-	-	-
MU-DY-1a	-	-	-	-	-	-	-	-
MU-DY-1b	-	-	-	-	-	-	-	-
MU-DY-1c	-	-	-	-	-	-	-	-
MU-DY-1d	-	-	-	-	-	-	-	-
MU-DY-2a	-	-	-	-	-	-	-	-
MU-DY-2b	-	-	-	-	-	-	-	-

Carpet ID	Workload	Production Setting	Country	City	Village	Community
KZ-OT-1	<2	Domestic	Kazakhstan	Shauldir	None	None
KZ-OT-2	<2	Domestic	Kazakhstan	Shauldir	None	None
KZ-OT-3	<2	Domestic	Kazakhstan	Shauldir	None	None
KZ-SH-1	3	Workshop	Kazakhstan	Shymkent	None	Altyn Orda
KZ-SH-2	8	Workshop	Kazakhstan	Shymkent	None	Altyn Orda
TK-MA-1	2.5	Collective	Turkmenistan	Mary	None	Collective-Mary
TK-MA-2	8.5	Collective	Turkmenistan	Mary	None	Collective-Mary
TK-MA-3	2	Collective	Turkmenistan	Mary	None	Collective-Mary
TK-MA-4	2	Collective	Turkmenistan	Mary	None	Collective-Mary
TK-MA-5	8.5	Collective	Turkmenistan	Mary	None	Collective-Mary
TK-MA-6	8.5	Collective	Turkmenistan	Mary	None	Collective-Mary
TK-MA-7	2.5	Collective	Turkmenistan	Mary	None	Collective-Mary
TK-MA-8	6	Collective	Turkmenistan	Mary	None	Collective-Mary
TK-MA-9	6.5	Collective	Turkmenistan	Mary	None	Collective-Mary
UZ-KH-1	6.5	Collective	Uzbekistan	Khiva	Angarik	Collective-Khiva

Carpet ID	Workload	Production Setting	Country	City	Village	Community
UZ-KH-2	6.5	Collective	Uzbekistan	Khiva	Angarik	Collective-Khiva
UZ-KH-3	8.5	Collective	Uzbekistan	Khiva	Ingilis	Collective-Khiva
UZ-KH-4	8.5	Collective	Uzbekistan	Khiva	Ingilis	Collective-Khiva
UZ-KH-5	8	Collective	Uzbekistan	Khiva	Gondimiyon	Collective-Khiva
UZ-KH-6	8	Collective	Uzbekistan	Khiva	Gondimiyon	Collective-Khiva
UZ-KH-7	7.5	Collective	Uzbekistan	Khiva	Gondimiyon	Collective-Khiva
UZ-KH-8	7.5	Collective	Uzbekistan	Khiva	Gondimiyon	Collective-Khiva
UZ-KH-9	8	Workshop	Uzbekistan	Khiva	None	Khiva Silk Workshop
UZ-KH-10	8	Workshop	Uzbekistan	Khiva	None	Khiva Silk Workshop
UZ-KH-11	8/8	Workshop	Uzbekistan	Khiva	None	Khiva Silk Workshop
UZ-KH-12	8	Workshop	Uzbekistan	Khiva	None	Khiva Silk Workshop
UZ-KH-13	8	Workshop	Uzbekistan	Khiva	None	Khiva Silk Workshop
UZ-SK-1	8	Workshop	Uzbekistan	Samarkand	None	Samarkand Silk Workshop
UZ-SK-2	8	Workshop	Uzbekistan	Samarkand	None	Samarkand Silk Workshop
UZ-SK-3	8	Workshop	Uzbekistan	Samarkand	None	Samarkand Silk Workshop

Carpet ID	Workload	Production Setting	Country	City	Village	Community
MU-AS-1	-	-	Afghanistan	Faryab	Maymana	-
MU-AS-2a	-	-	Afghanistan	Samangan	-	-
MU-AS-2b	-	-	Afghanistan	Samangan	-	-
MU-AS-3	-	-	Persia	East	-	-
MU-AS-4a	-	-	Persia	East	-	-
MU-AS-4b	-	-	Persia	East	-	-
MU-AS-4c	-	-	Persia	East	-	-
MU-AS-5	-	-	Persia	East	-	-
MU-AS-6	-	-	Afghanistan	Samangan	-	-
MU-AS-7	-	-	Afghanistan	Faryab	Maymana	-
MU-AS-8	-	-	Afghanistan	Samangan	-	-
MU-AS-8	-	-	Afghanistan	Samangan	-	-
MU-AS-8	-	-	Afghanistan	Samangan	-	-
MU-AS-8	-	-	Afghanistan	Samangan	-	-
MU-AS-9ab	-	-	Afghanistan	Samangan	-	-
MU-AS-9ab	-	-	Afghanistan	Samangan	-	-

Carpet ID	Workload	Production Setting	Country	City	Village	Community
MU-AS-9c	-	-	Afghanistan	Samangan	-	-
MU-AS-9d	-	-	Afghanistan	Samangan	-	-
MU-AS-10	-	-	Afghanistan	Faryab	Maymana	-
MU-AS-10	-	-	Afghanistan	Faryab	Maymana	-
MU-AS-11	-	-	Afghanistan	Samangan	-	-
MU-AS-11	-	-	Afghanistan	Samangan	-	-
MU-AS-11	-	-	Afghanistan	Samangan	-	-
MU-AS-11	-	-	Afghanistan	Samangan	-	-
MU-AS-11	-	-	Afghanistan	Samangan	-	-
MU-AS-12	-	-	Afghanistan	Samangan	-	-
MU-AS-13	-	-	Afghanistan	Herat	-	-
MU-AS-14	-	-	Afghanistan	Samangan	-	-
MU-AS-16	-	-	Afghanistan	Samangan	-	-
MU-AS-17ef	-	-	Afghanistan	Samangan	-	-
MU-AS-17ef	-	-	Afghanistan	Samangan	-	-

Carpet ID	Workload	Production Setting	Country	City	Village	Community
MU-AS-17g	-	-	Afghanistan	Samangan	-	-
MU-AS-18	-	-	Afghanistan	Samana	-	-
MU-CH-1	-	-	China	Xinjiang	Khotan	-
MU-CH-2	-	-	China	Xinjiang	Tarim Basin	-
MU-CH-3	-	-	Turkestan	East	-	-
MU-CH-4	-	-	Turkey	West	-	-
MU-CH-5	-	-	China	Beijing	-	-
MU-CH-6	-	-	China	North	-	-
MU-CH-7	-	-	China	North	-	-
MU-DY-1a	-	-	Turkey	Ushak	-	-
MU-DY-1b	-	-	Turkey	Ushak	-	-
MU-DY-1c	-	-	Turkey	Ushak	-	-
MU-DY-1d	-	-	Turkey	Ushak	-	-
MU-DY-2a	-	-	Turkestan	-	-	-
MU-DY-2b	-	-	Turkestan	-	-	-

Carpet ID	Workload	Production Setting	Country	City	Village	Community
MU-DY-2c	-	-	Turkestan	-	-	-
MU-IN-1	-	-	Iran	Khorasan	Torbat-e Heydarieh	-
MU-IN-2	-	-	Iran	Khorasan	Qaen	-
MU-IN-3	-	-	Iran	Khorasan	Torbat-e Heydarieh	-
MU-IN-4	-	-	Iran	Khorasan	Qaen	-
MU-IN-5	-	-	Iran	Khorasan	Torbat-e Heydarieh	-
MU-IN-6	-	-	Iran	Khorasan	Torbat-e Heydarieh	-
MU-IN-7	-	-	Iran	Khorasan	Torbat-e Heydarieh	-
MU-SO-1	-	-	Turkey	Ushak	-	-
MU-SO-2	-	-	Turkestan	East	-	-
MU-SO-3	-	-	Turkey	Ushak	-	-
MU-SO-4	-	-	Iran	-	Isfahan	-
MU-VA-1	-	-	Turkey	-	-	-
MU-VA-2	-	-	Iran	-	Tabriz	-
MU-VA-3	-	-	China	Xinjiang	Loulan	-
MU-VA-4	-	-	China	Xinjiang	Loulan	-

Appendix D. Analysis Plots

This section contains all of the plots produced to evaluate the distributions of the production characteristics, including both the knot-size and knot-shape analyses. The p-values for the Levene's tests and Student's t-tests are given where appropriate. It also includes statistical metadata on sample size and correlation, and histograms of the base distributions.

All figures by V. Sluka.

Plot & Analysis Result Key

Variable Class: Structural, Technological, Social, or Idiosyncratic
Variable Type: Categorical or Numeric
Observations (n_k / n_c): n_k = total knots in group, n_c = total carpets represented in group;
Reduced samples of 5,000 used in Levene's Tests
Duplicating Variables: variables with exactly the same division of data
Reference Page: in-text reference

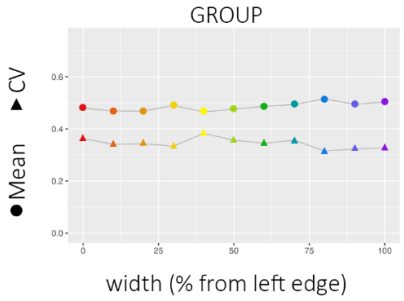
Results of Levene's Test (F-statistic):
project α = 0.05
* = significant
median value used for repeated tests

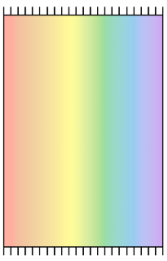
all-knot histogram
by standardized size

Results of Student's Test (T-statistic):
project α = 0.05
* = significant
median value used for repeated tests
2-sample tests performed for all combinations of traits;
results represent all combinations unless otherwise specified

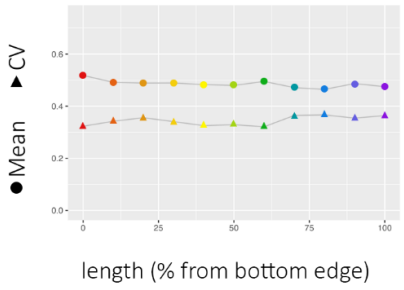
Knot Size

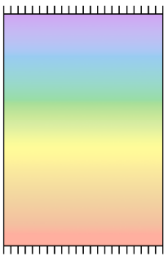
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





plot represents change across width of carpet, measuring from **left**

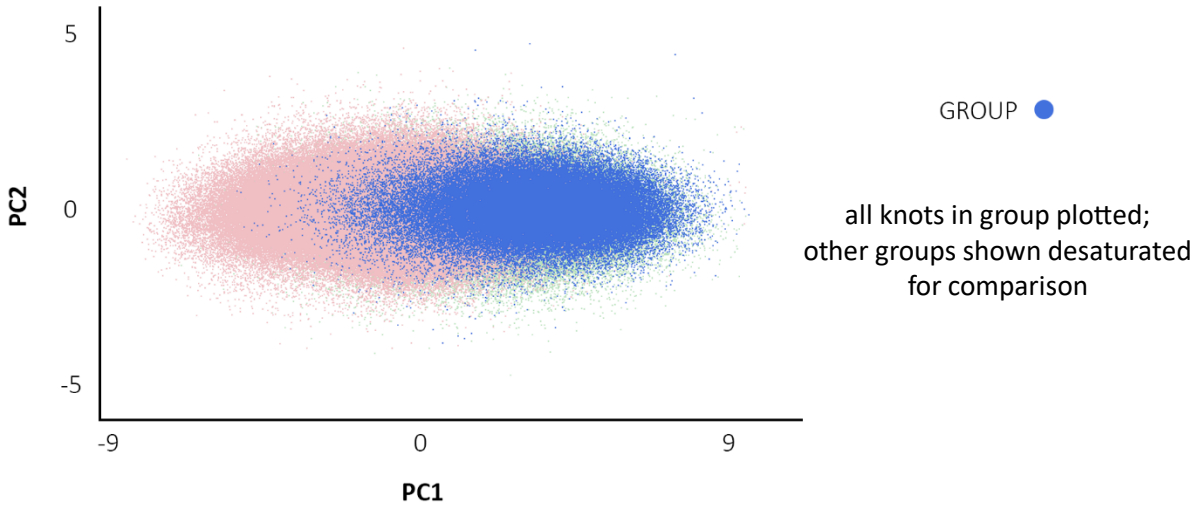




plot represents change across length of carpet, measuring from **bottom**

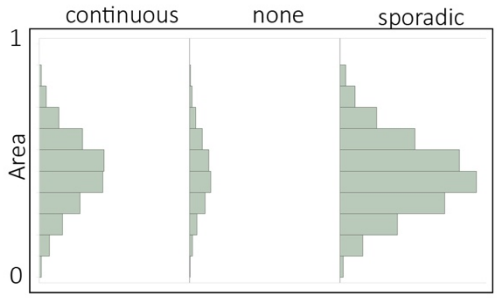
Knot Shape

Ethnographic knot shapes, condensed to two Principal Components



CARTOON USE

Variable Class: Social
Variable Type: Categorical-Ordinal
Observations (n_k / n_c): Continuous (155,325/7); Sporadic (323,596/16); None (49,209/7)
Duplicating Variables: none
Reference Page: 338



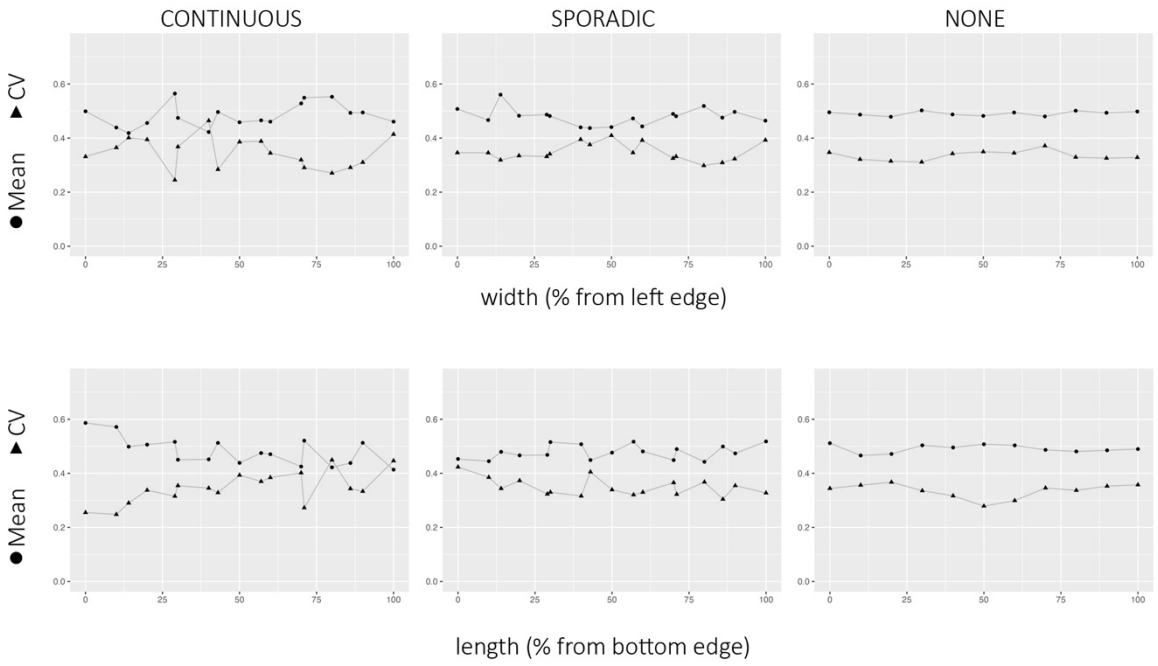
Levene's Test (F-statistic):
Knot Size:
average p-value: 0.237
median p-value: 0.190

Knot Shape:
average p-value: <0.001*
median p-value: <0.001*

Student's Test (T-statistic) for Shape:
not applicable, unequal variances

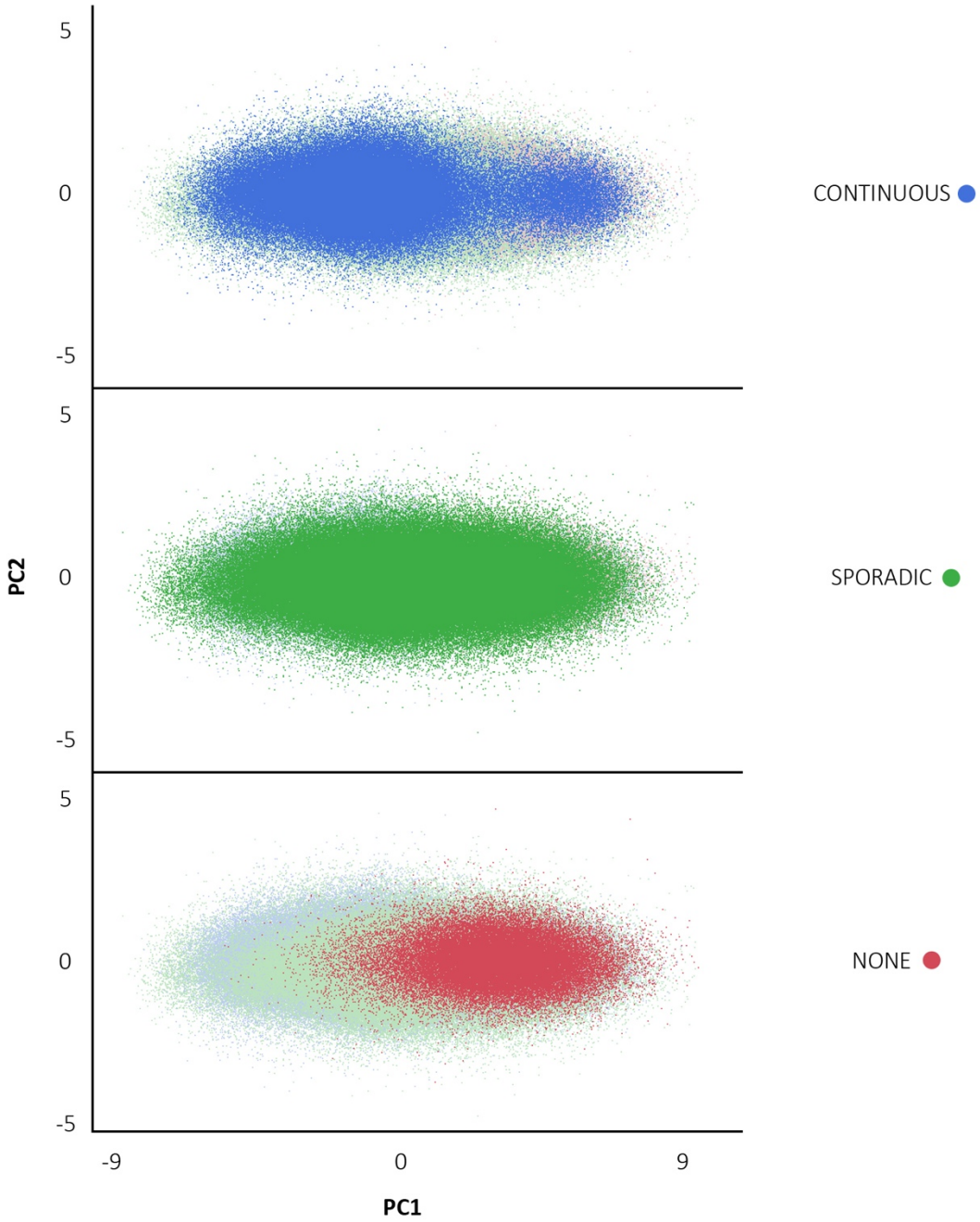
Knot Size

Ethnographic Knot Size Means & CVs, by Carpet Width & Length



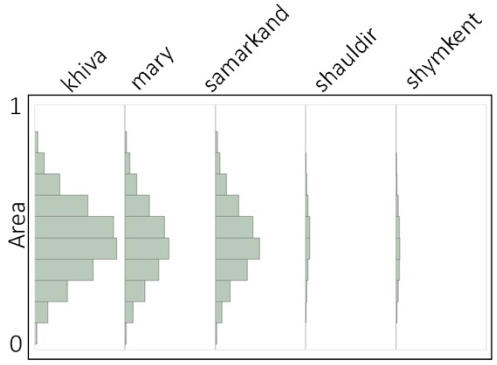
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



CITY

Variable Class: Idiosyncratic
Variable Type: Categorical
Observations (n_k / n_c): Khiva (249,640/13); Mary (131,895/9); Samarkand (123,458/3); Shauldir (11,300/3); Shymkent (11,837/2)
Duplicating Variables: none
Reference Page: 360



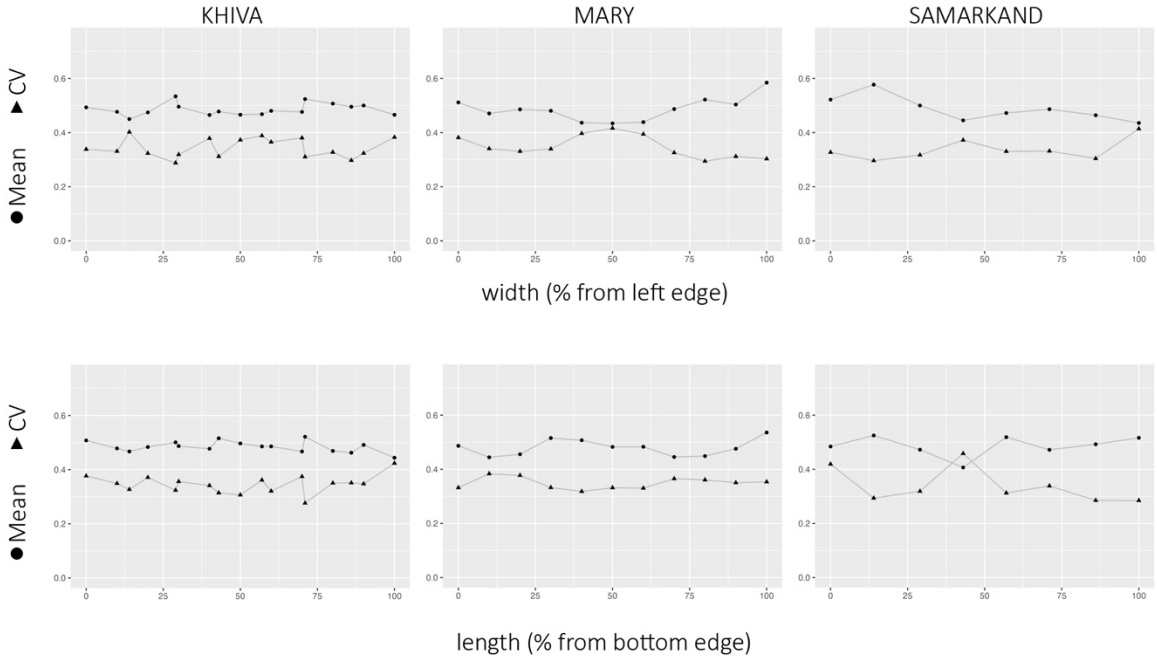
Levene's Test (F-statistic):
Knot Size:
average p-value: <0.001*
median p-value: <0.001*

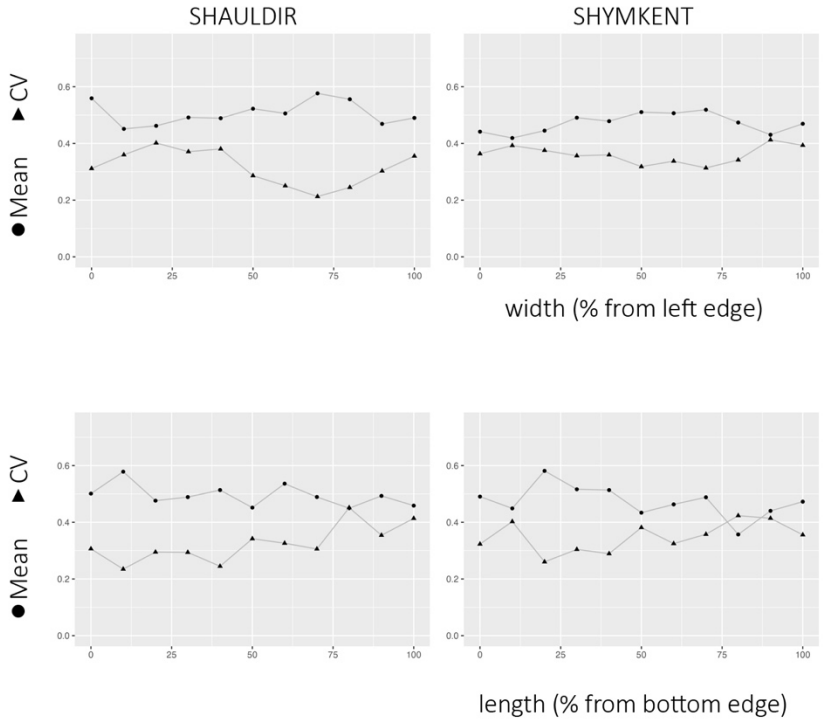
Knot Shape:
average p-value: <0.001*
median p-value: <0.001*

Student's Test (T-statistic) for Shape:
not applicable, unequal variances

Knot Size

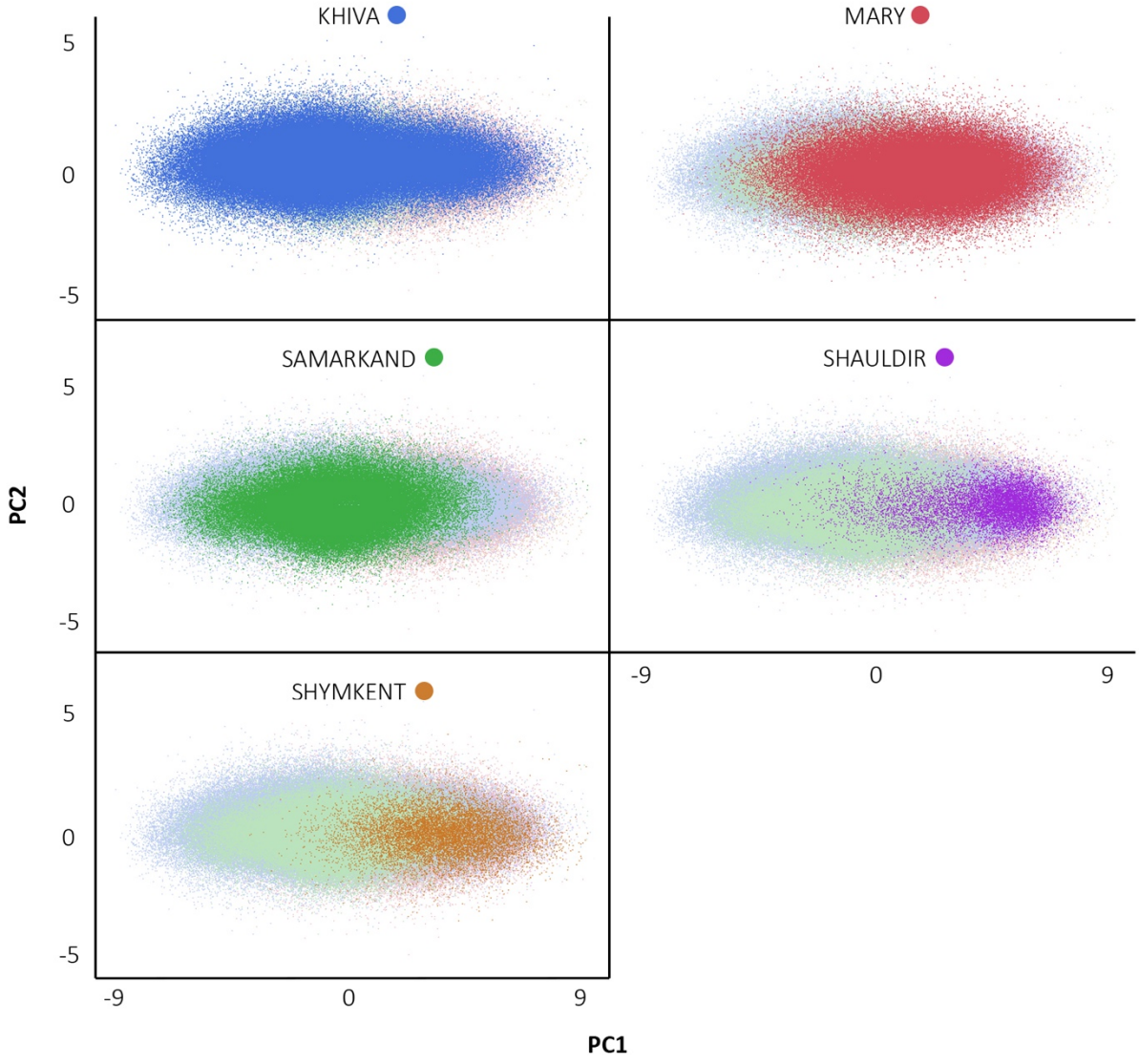
Ethnographic Knot Size Means & CVs, by Carpet Width & Length




SHAULDIR
SHYMKENT
● Mean ▲ CV
0.0
0.2
0.4
0.6
0
25
50
75
100
width (% from left edge)
length (% from bottom edge)

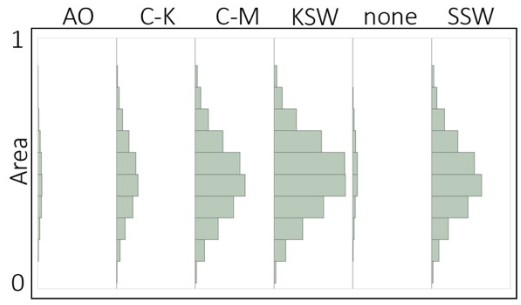
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



COMMUNITY

Variable Class: Social
Variable Type: Categorical
Observations (n_k / n_c): Altyn Orda (11,837/2); Collective-Khiva (56,495/8);
Collective-Mary (131,895/9); Khiva Silk Workshop (193,145/5);
Samarkand Silk Workshop (123,458/3); None (11,300/3)
Duplicating Variables: none
Reference Page: 360



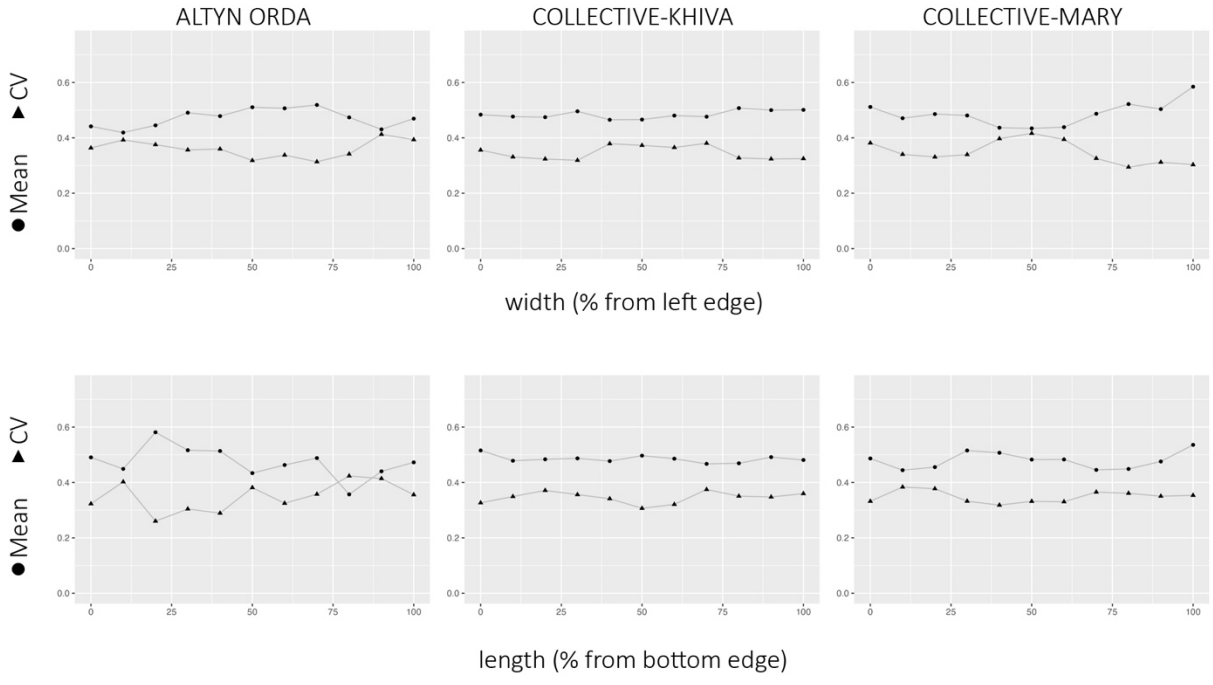
Levene's Test (F-statistic):
Knot Size:
average p-value: <0.001*
median p-value: <0.001*

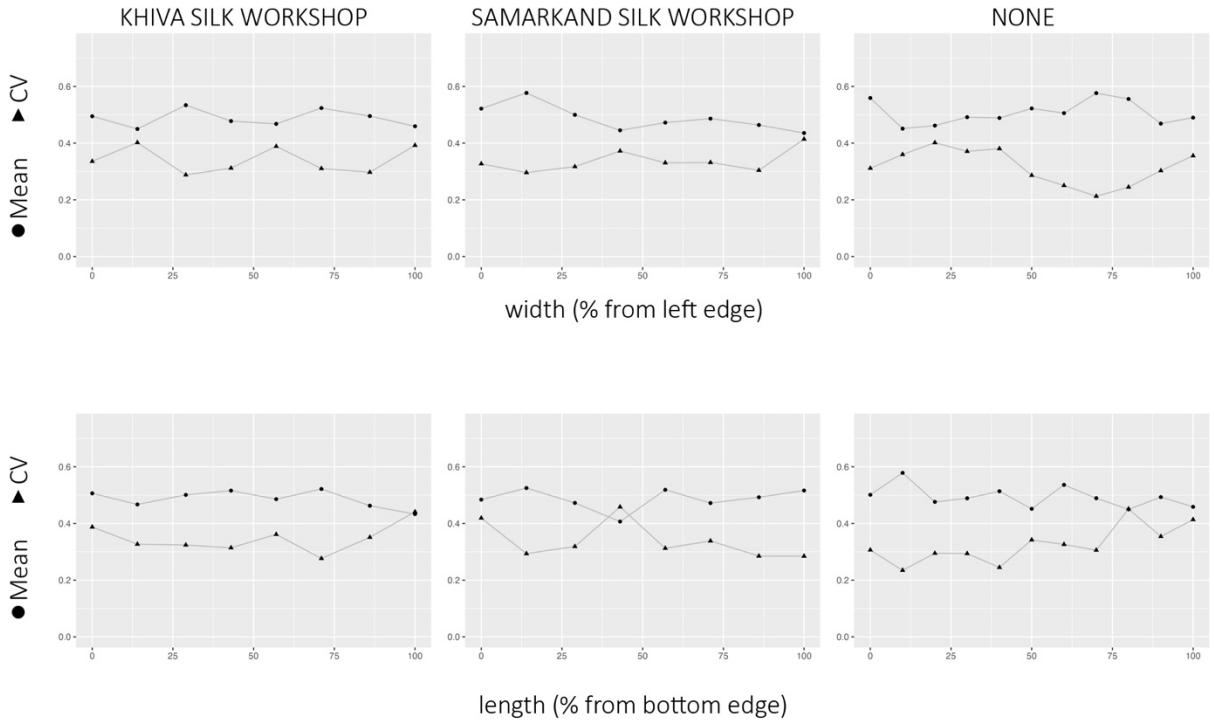
Knot Shape:
average p-value: <0.001*
median p-value: <0.001*

Student's Test (T-statistic) for Shape:
not applicable, unequal variances

Knot Size

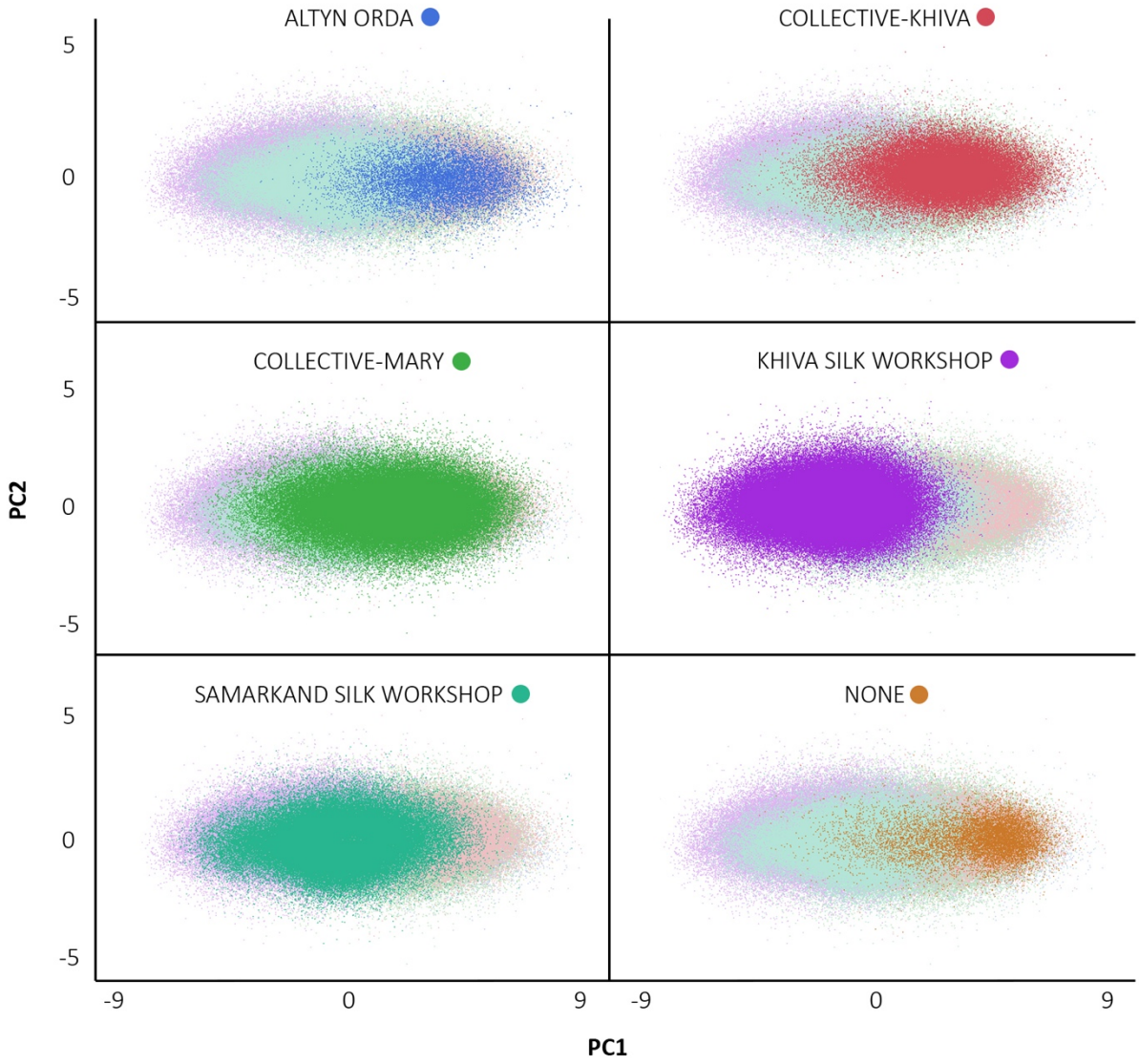
Ethnographic Knot Size Means & CVs, by Carpet Width & Length




KHIVA SILK WORKSHOP
SAMARKAND SILK WORKSHOP
NONE
● Mean ▲ CV
0.0
0.2
0.4
0.6
0
25
50
75
100
width (% from left edge)
length (% from bottom edge)

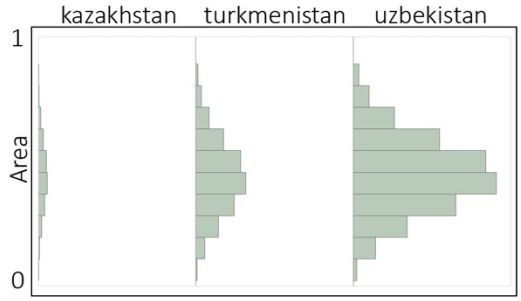
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



COUNTRY

Variable Class: Idiosyncratic
Variable Type: Categorical
Observations (n_k / n_c): Kazakhstan (23,137/5); Turkmenistan (131,895/9);
Uzbekistan (373,098/16)
Duplicating Variables: none
Reference Page: 360



Levene's Test (F-statistic):

Knot Size:

average p-value: 0.325
median p-value: 0.284

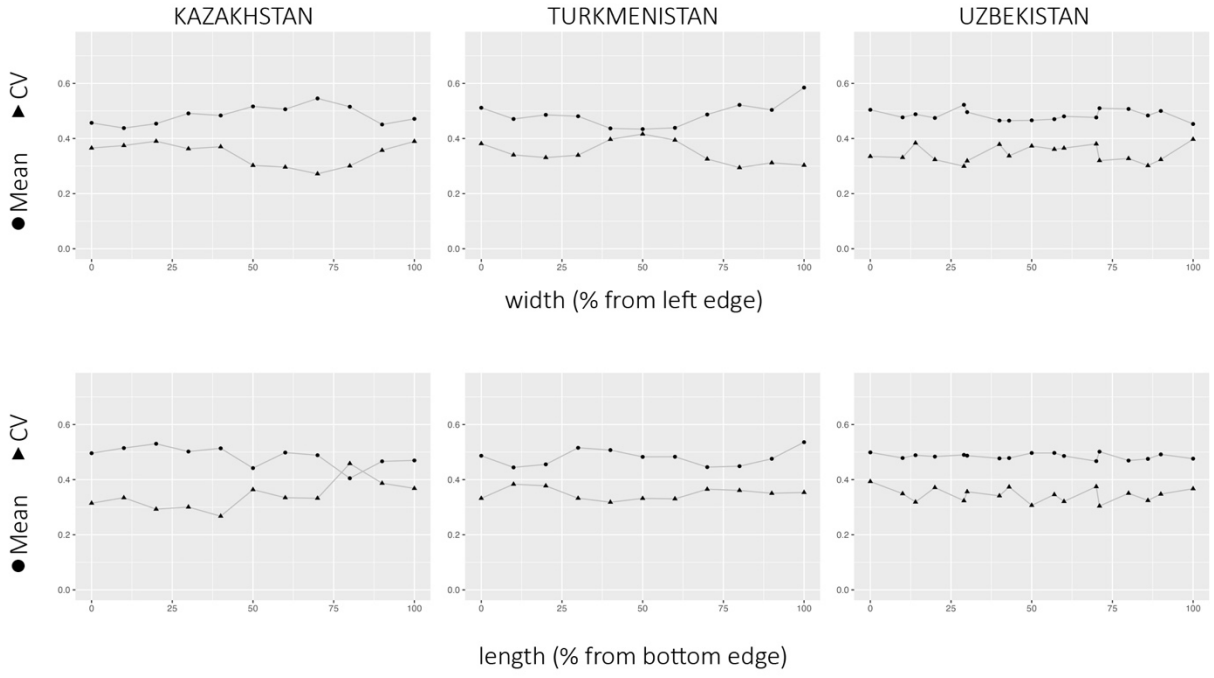
Knot Shape:

average p-value: <0.001*
median p-value: <0.001*

Student's Test (T-statistic) for Shape:
not applicable, unequal variances

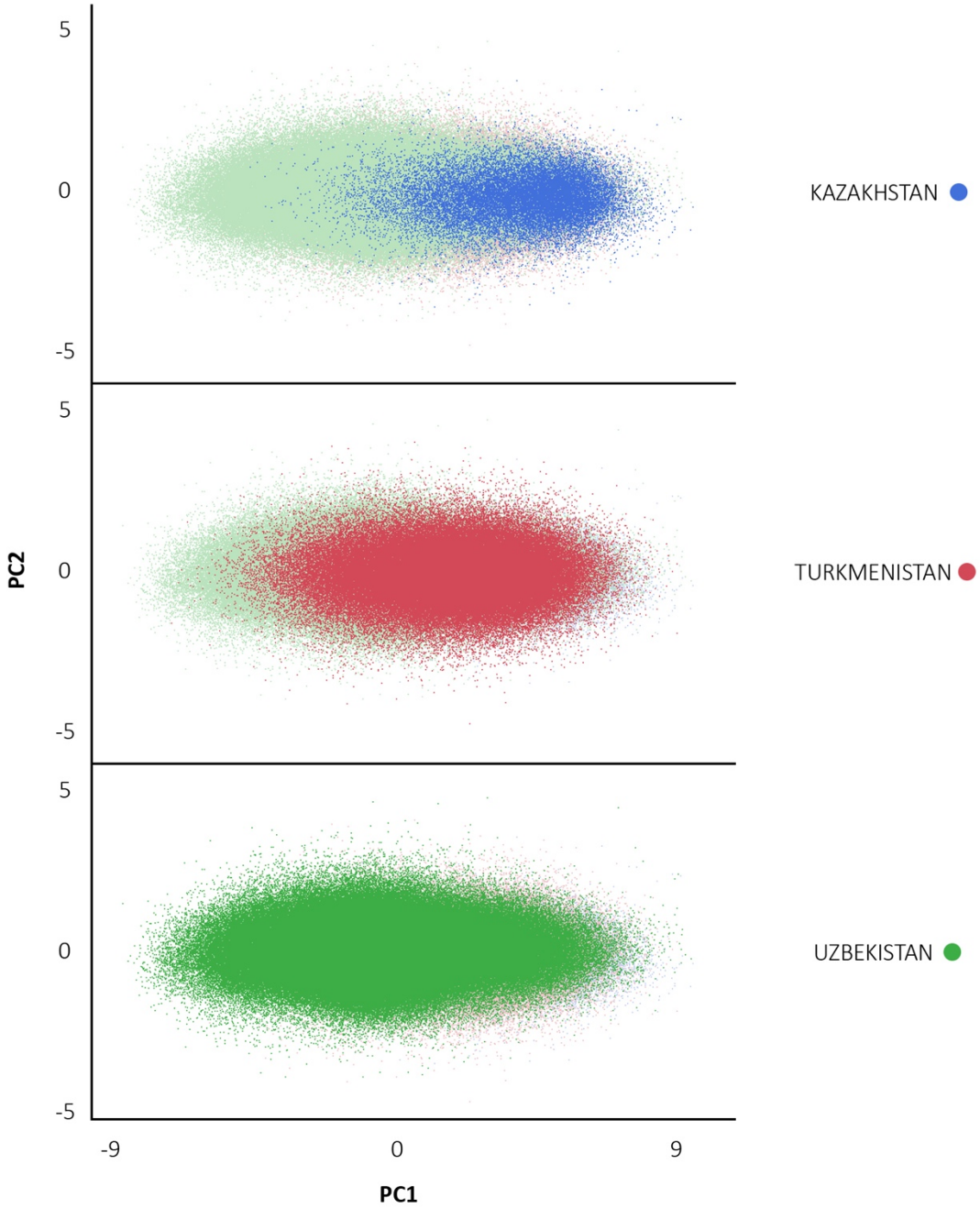
Knot Size

Ethnographic Knot Size Means & CVs, by Carpet Width & Length



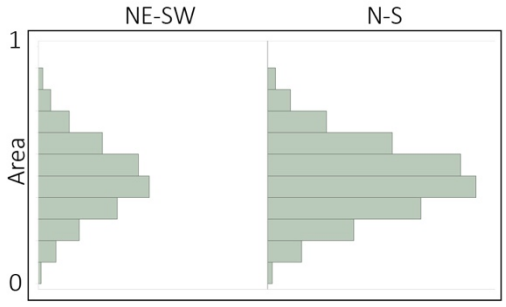
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



CUTTING DIRECTION

Variable Class: Idiosyncratic
Variable Type: Categorical-Ordinal
Observations (n_k / n_c): N-S (347,780/18); NE-SW (180,250/12)
Duplicating Variables: none
Reference Page: 349



Levene's Test (F-statistic):

Knot Size:

average p-value:	0.434
median p-value:	0.418

Knot Shape:

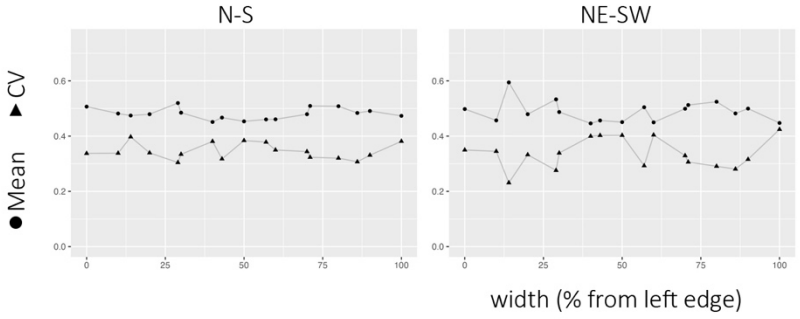
average p-value:	<0.001*
median p-value:	<0.001*

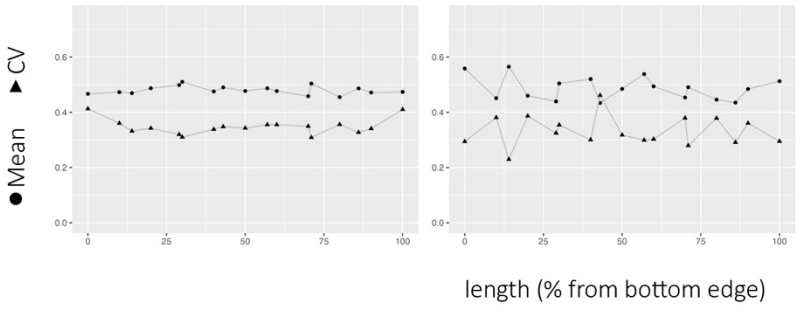
Student's Test (T-statistic) for Shape:

not applicable, unequal variances

Knot Size

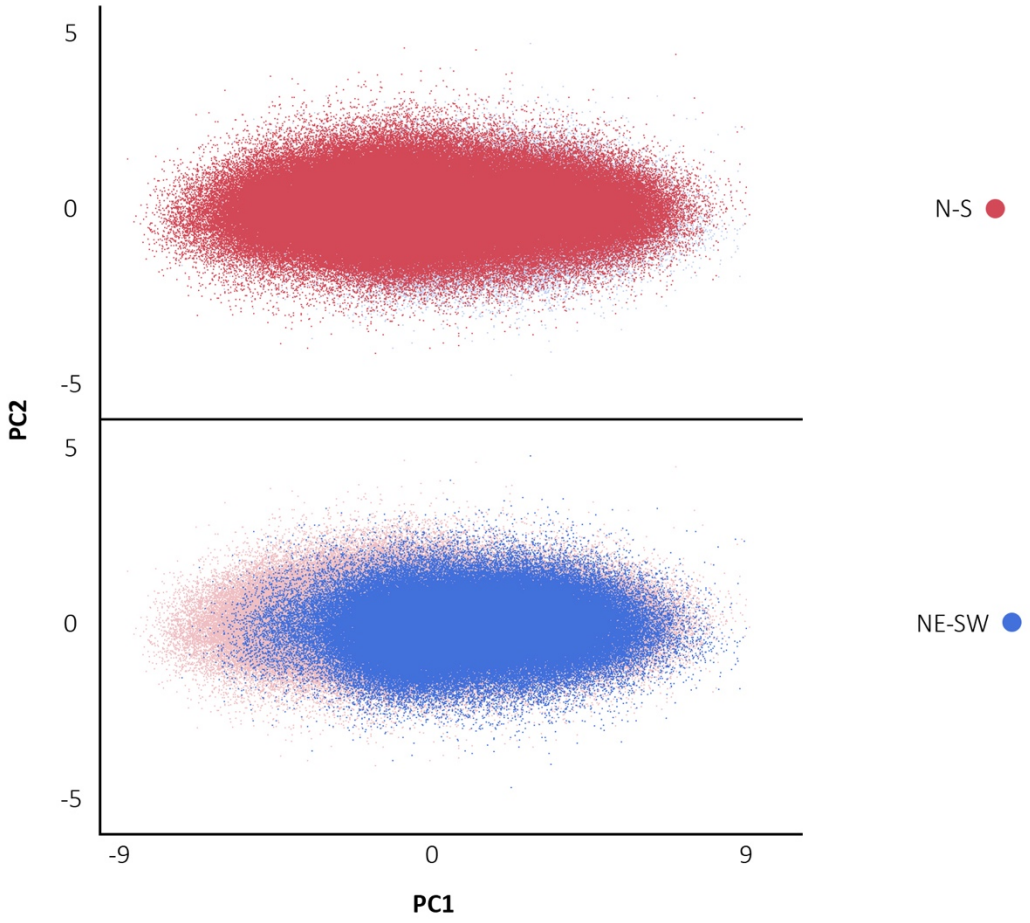
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





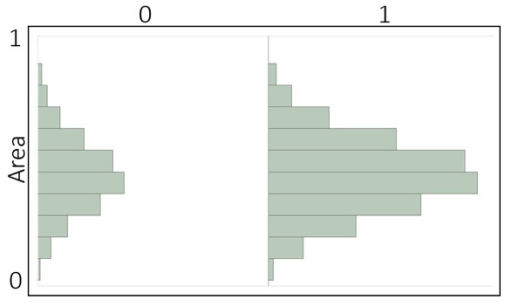
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



DOUBLE-SHED HEDDLES

Variable Class: Technological
Variable Type: Numeric-Discrete (functions like categorical-ordinal)
Observations (n_k / n_c): 0 Heddles (146,595/8); 1 Heddle (381,535/22)
Duplicating Variables: Shed Rods, Single-Shed Heddles
Reference Page: 311



Levene's Test (F-statistic):

Knot Size:

average p-value:	0.232
median p-value:	0.152

Knot Shape:

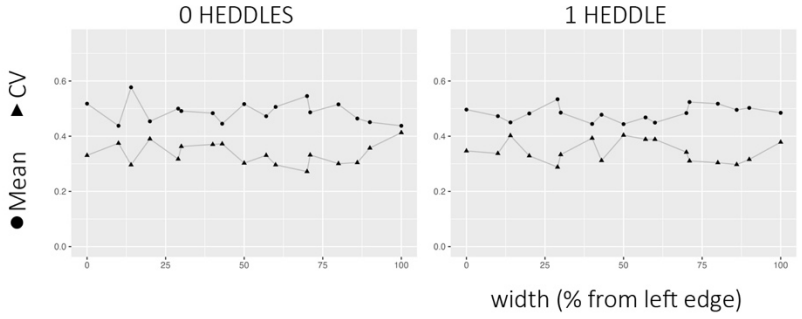
average p-value:	<0.001*
median p-value:	<0.001*

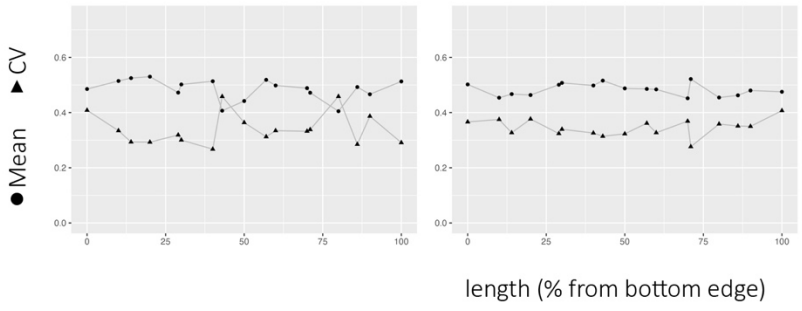
Student's Test (T-statistic) for Shape:

not applicable, unequal variances

Knot Size

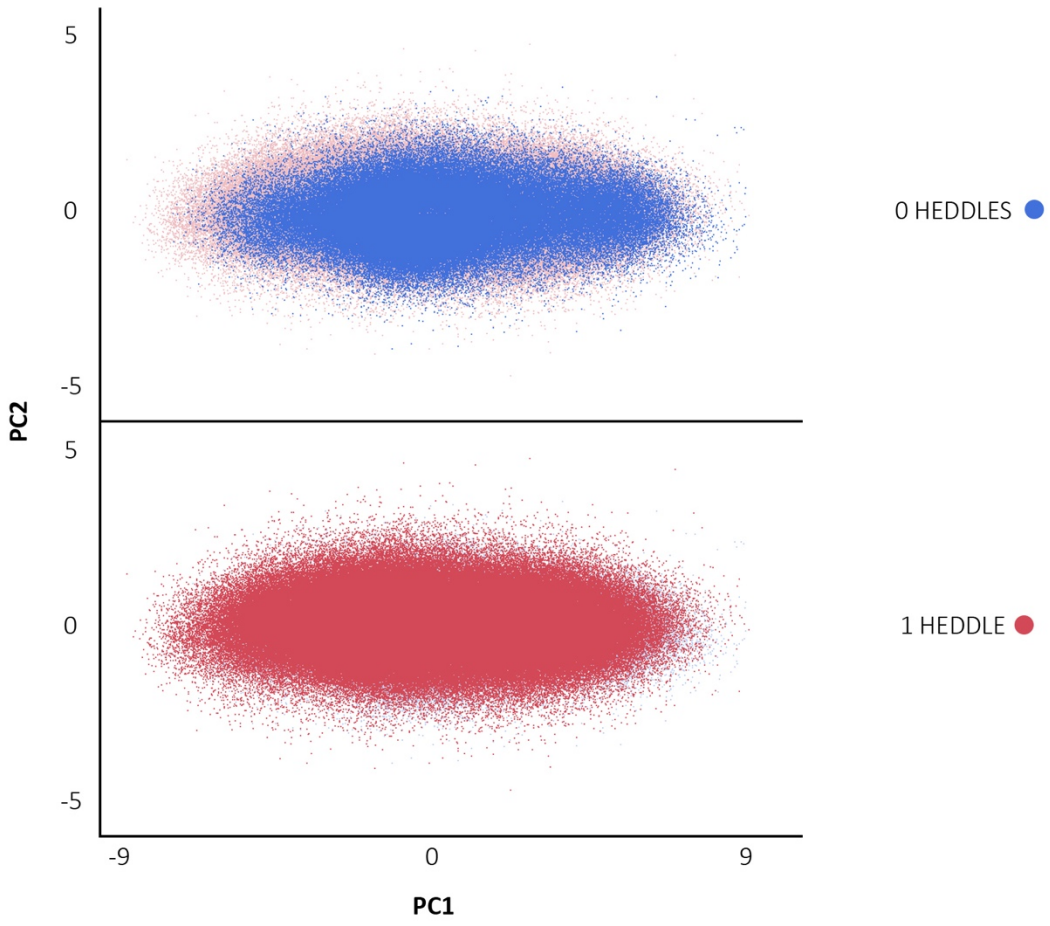
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





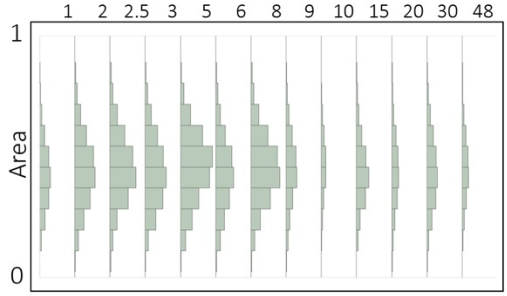
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



EXPERIENCE

Variable Class: Idiosyncratic
Variable Type: Numeric-Continuous
Observations (n_k / n_c): 1 Year (27,247/2); 2 (53,603/4); 2.5 (63,140/1); 3 (56,406/2); 5 (80,651/1); 6 (47,597/2); 8 (71,735/3); 9 (27,024/2); 10 (11,300/3); 15 (28,236/1); 20 (17,692/3); 30 (28,172/4); 48 (15,327/2)
Duplicating Variables: none
Reference Page: 358



Levene's Test not applicable

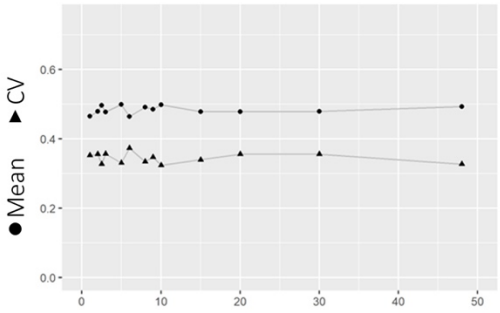
Linear Regression R^2:

Knot Size:

Mean:	0.003
CV:	0.040

Knot Shape:

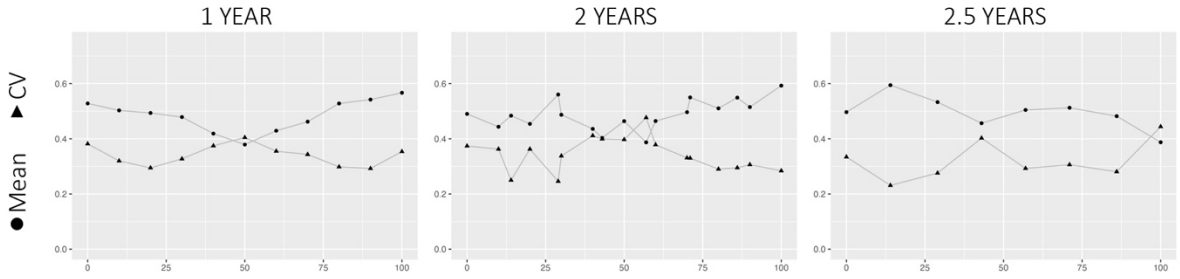
PC1:	0.297



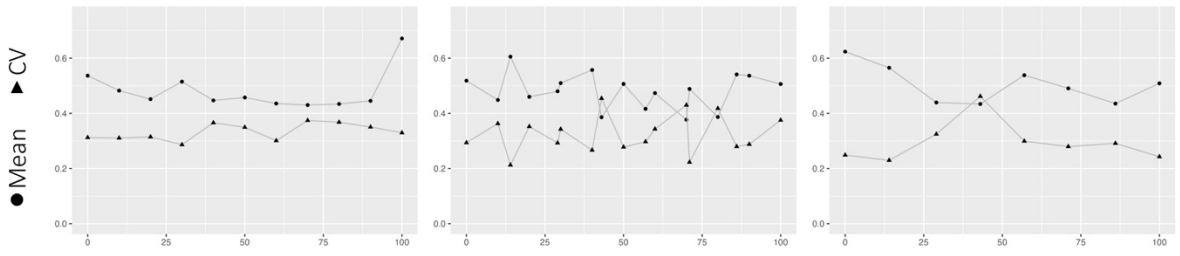
Years of Weaving Experience

Knot Size

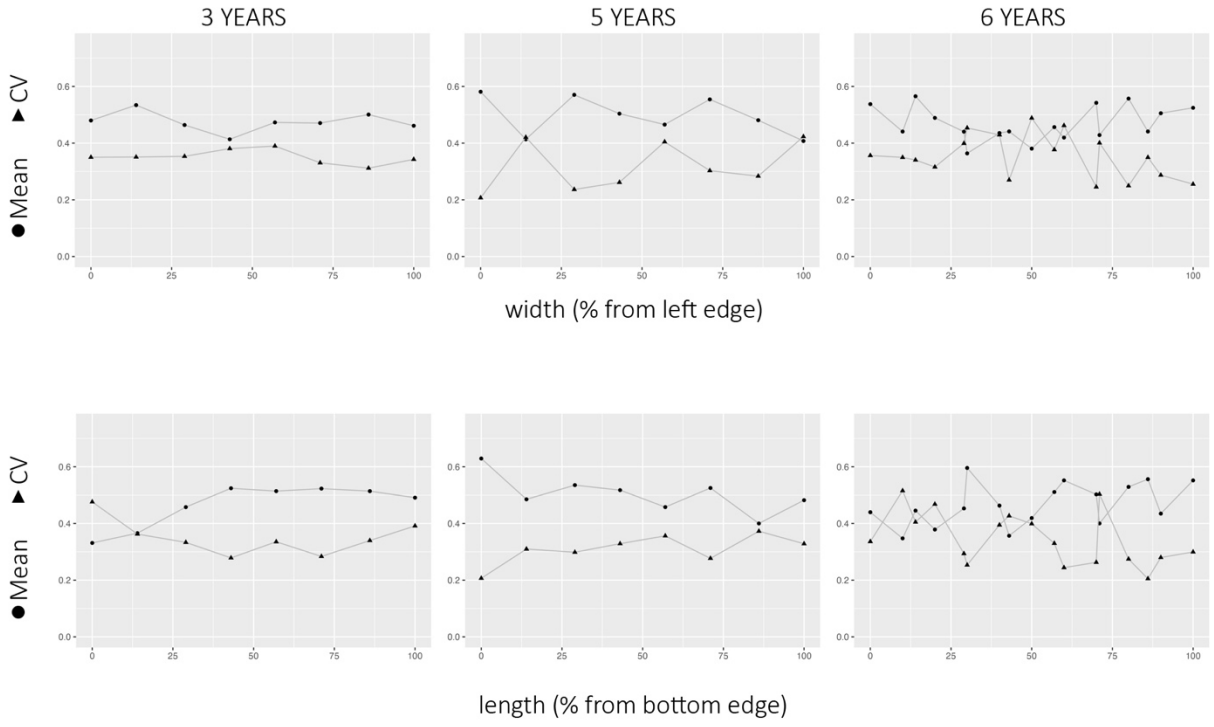
Ethnographic Knot Size Means & CVs, by Carpet Width & Length

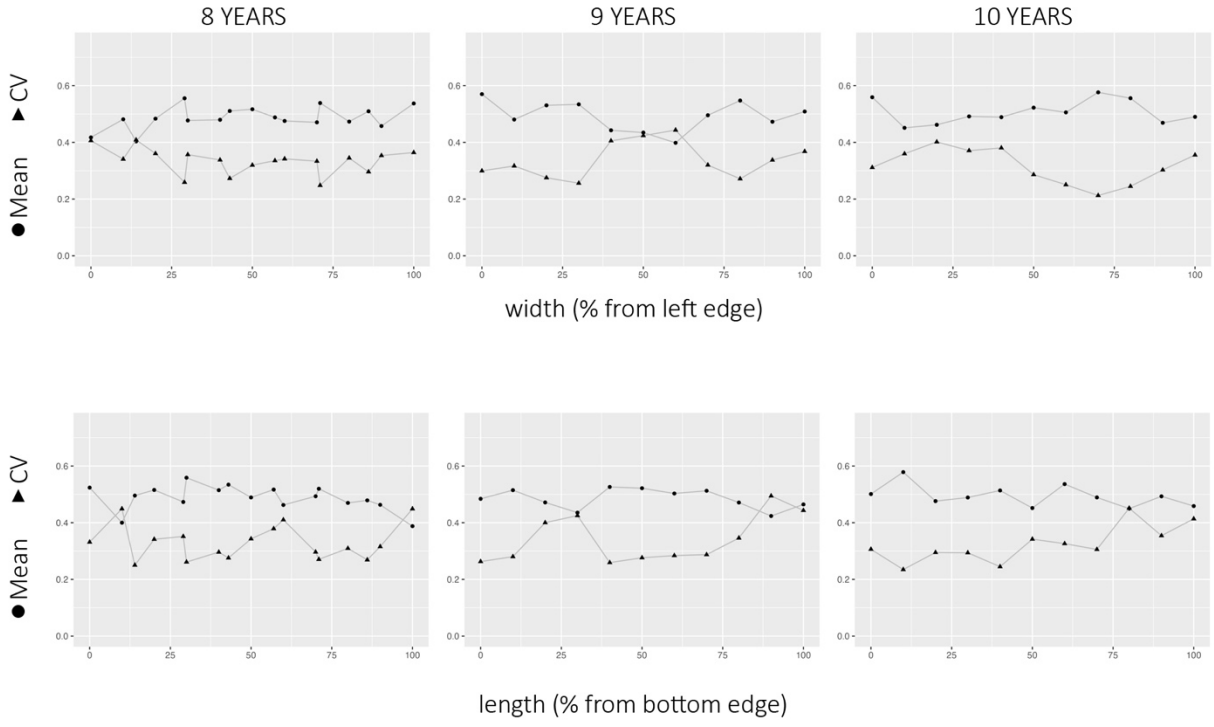


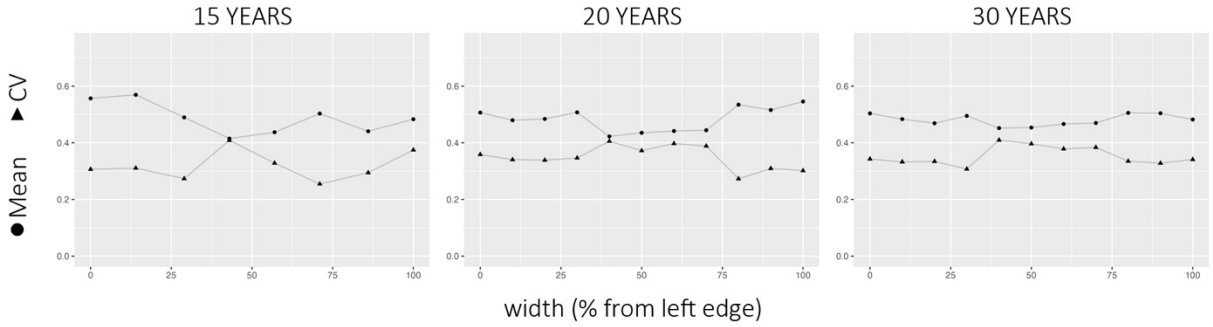
width (% from left edge)

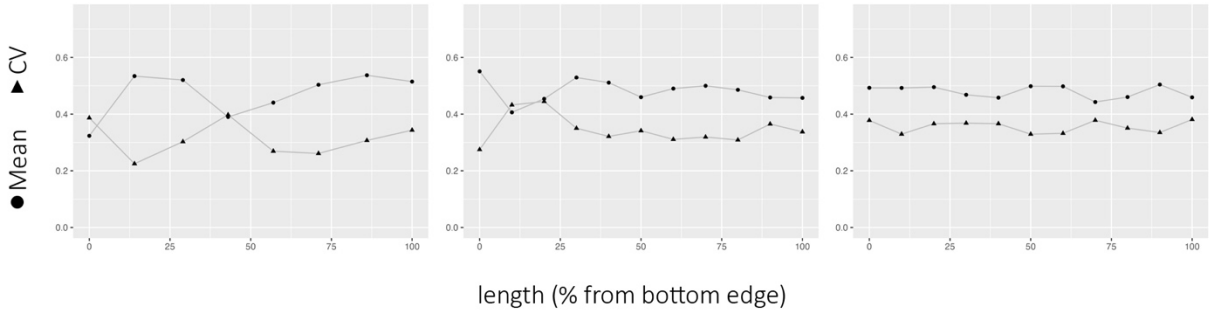


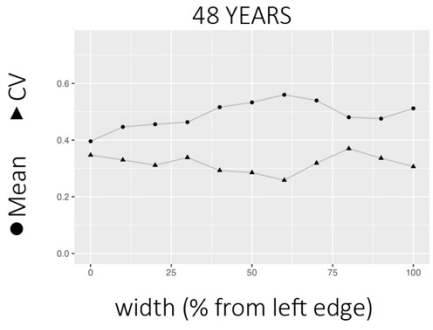
length (% from bottom edge)

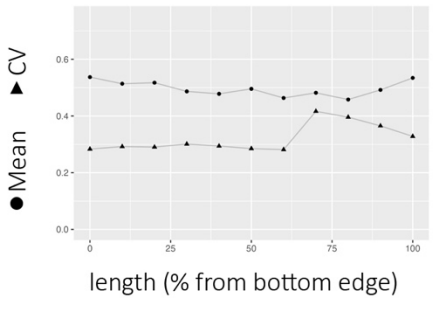

3 YEARS
5 YEARS
6 YEARS
● Mean ▲ CV
width (% from left edge)
length (% from bottom edge)


8 YEARS
9 YEARS
10 YEARS
● Mean ▲ CV
width (% from left edge)
length (% from bottom edge)


15 YEARS
20 YEARS
30 YEARS
● Mean ▲ CV
0.0
0.2
0.4
0.6
0
25
50
75
100
width (% from left edge)

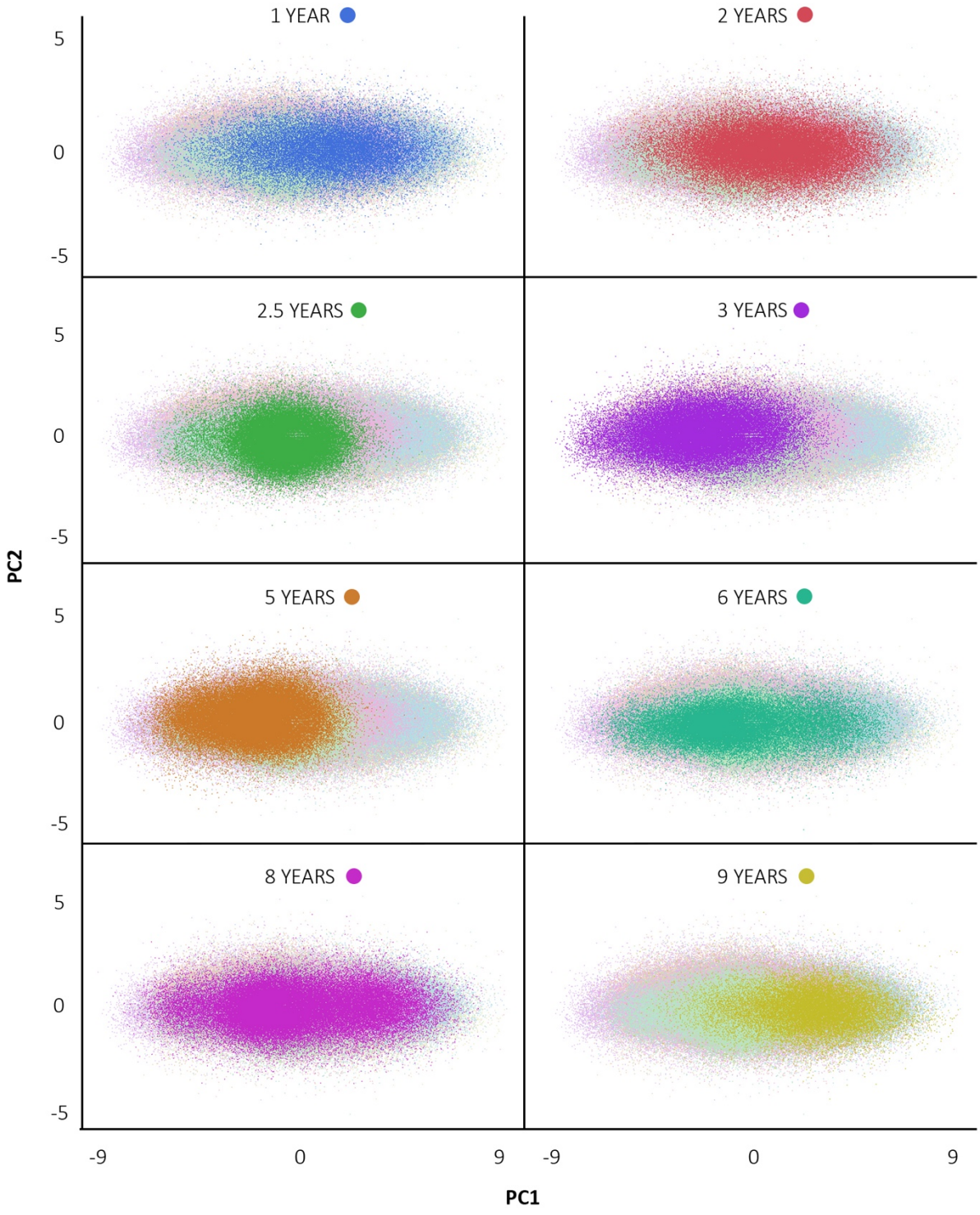

● Mean ▲ CV
0.0
0.2
0.4
0.6
0
25
50
75
100
length (% from bottom edge)

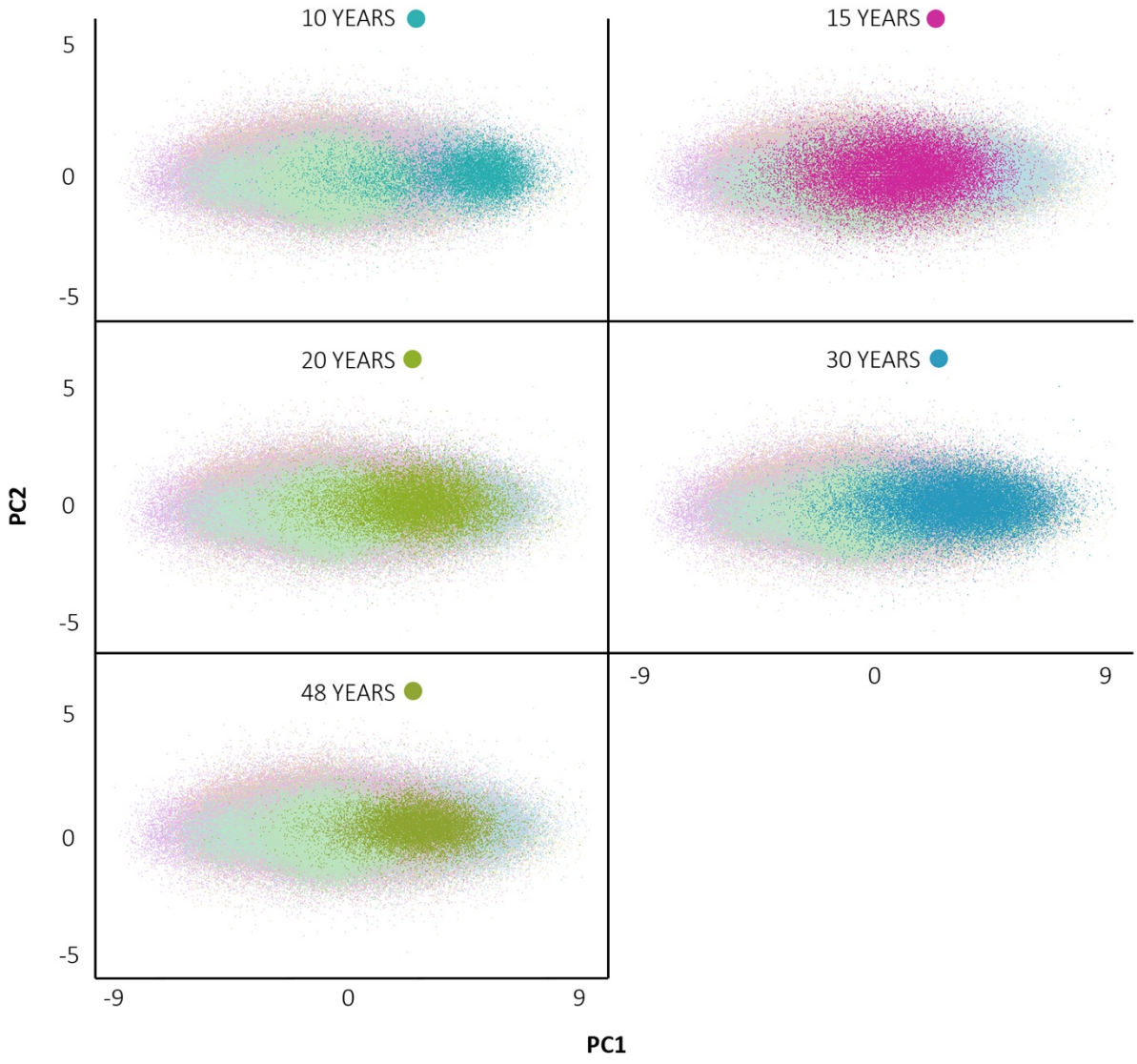

48 YEARS
● Mean ▲ CV
0.0
0.2
0.4
0.6
0
25
50
75
100
width (% from left edge)


● Mean ▲ CV
0.0
0.2
0.4
0.6
0
25
50
75
100
length (% from bottom edge)

Knot Shape

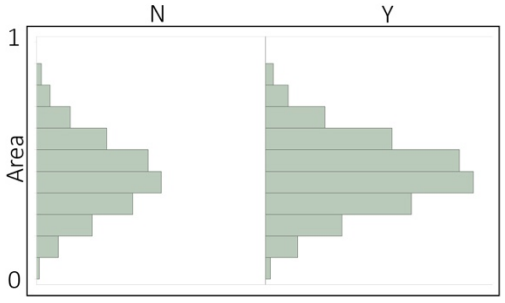
Ethnographic Knot Shapes, condensed to Two Principal Components




10 YEARS
15 YEARS
20 YEARS
30 YEARS
48 YEARS
5
0
-5
-9
0
9
PC2
PC1

HOOK

Variable Class: Technological
Variable Type: Categorical
Observations (n_k / n_c): N (200,227/19); Y (327,903/11)
Duplicating Variables: Knife Type
Reference Page: 350



Levene's Test (F-statistic):

Knot Size:

average p-value: 0.159
median p-value: 0.063

Knot Shape:

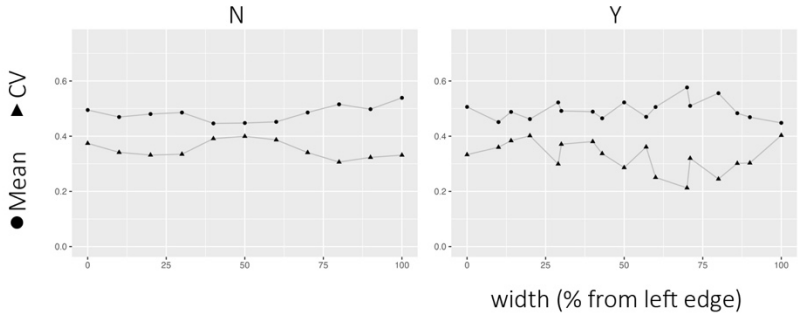
average p-value: 0.074
median p-value: 0.021*

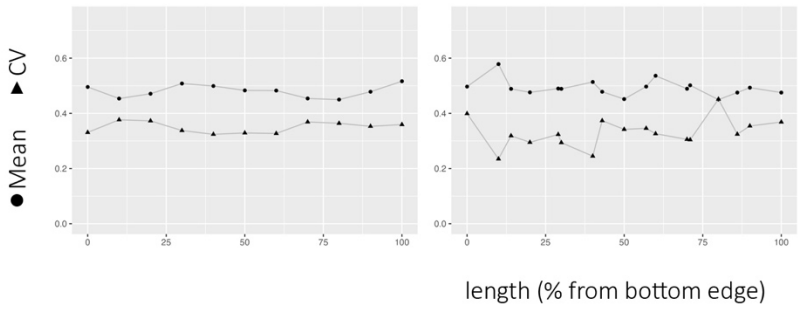
Student's Test (T-statistic) for Shape:

not applicable, unequal variances

Knot Size

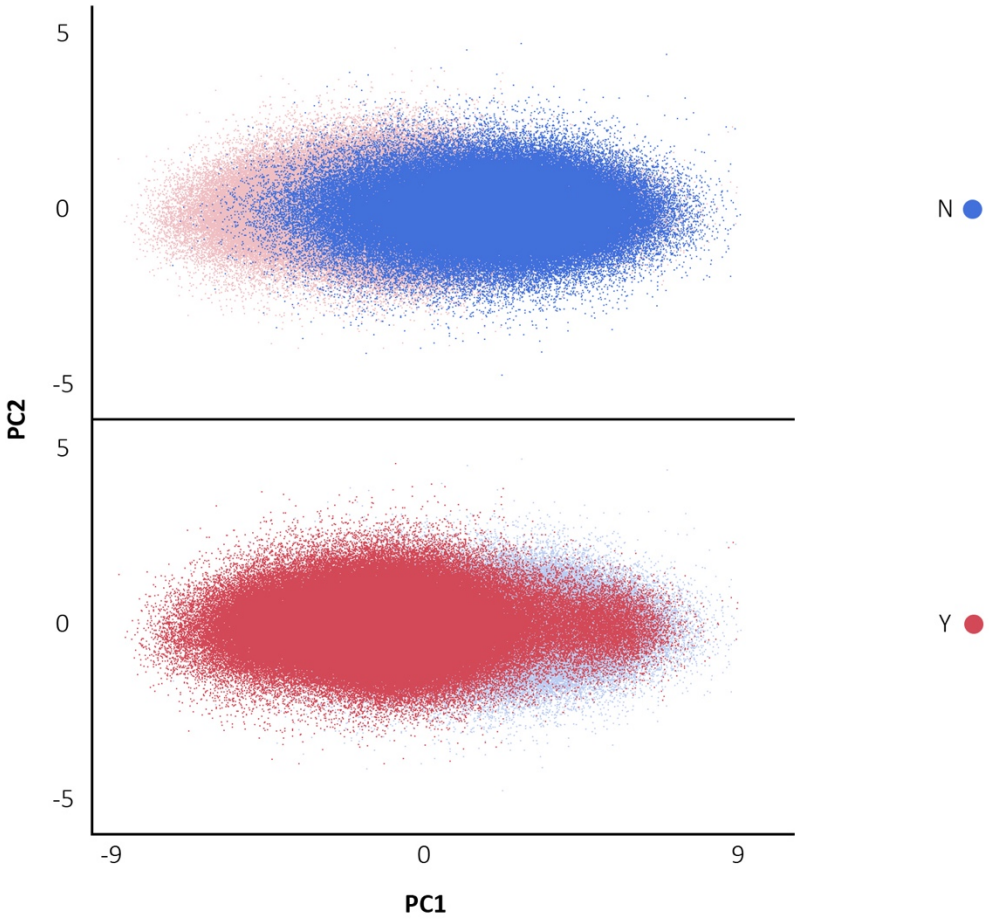
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





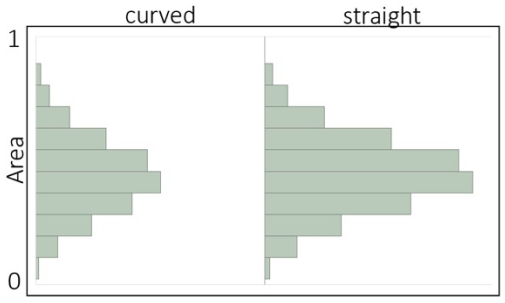
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



KNIFE TYPE

Variable Class: Technological
Variable Type: Categorical
Observations (n_k / n_c): Curved (200,227/19); Straight (327,903/11)
Duplicating Variables: Hook
Reference Page: 348



Levene's Test (F-statistic):

Knot Size:

average p-value: 0.299
median p-value: 0.291

Knot Shape:

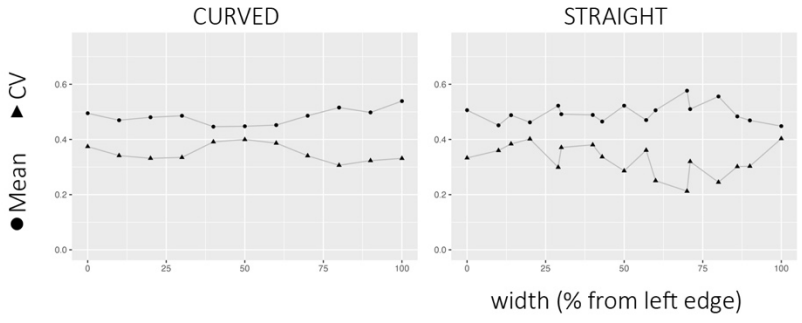
average p-value: 0.046*
median p-value: 0.009*

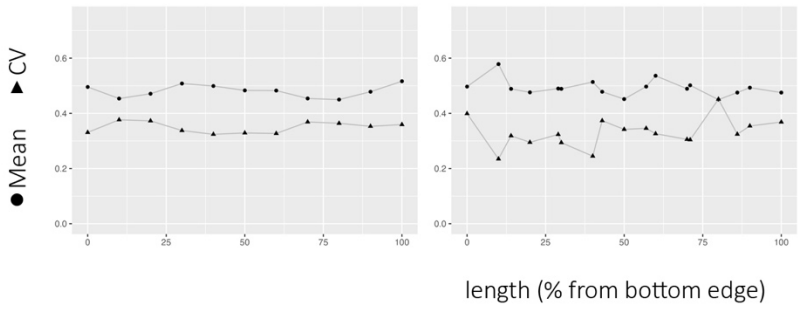
Student's Test (T-statistic) for Shape:

not applicable, unequal variances

Knot Size

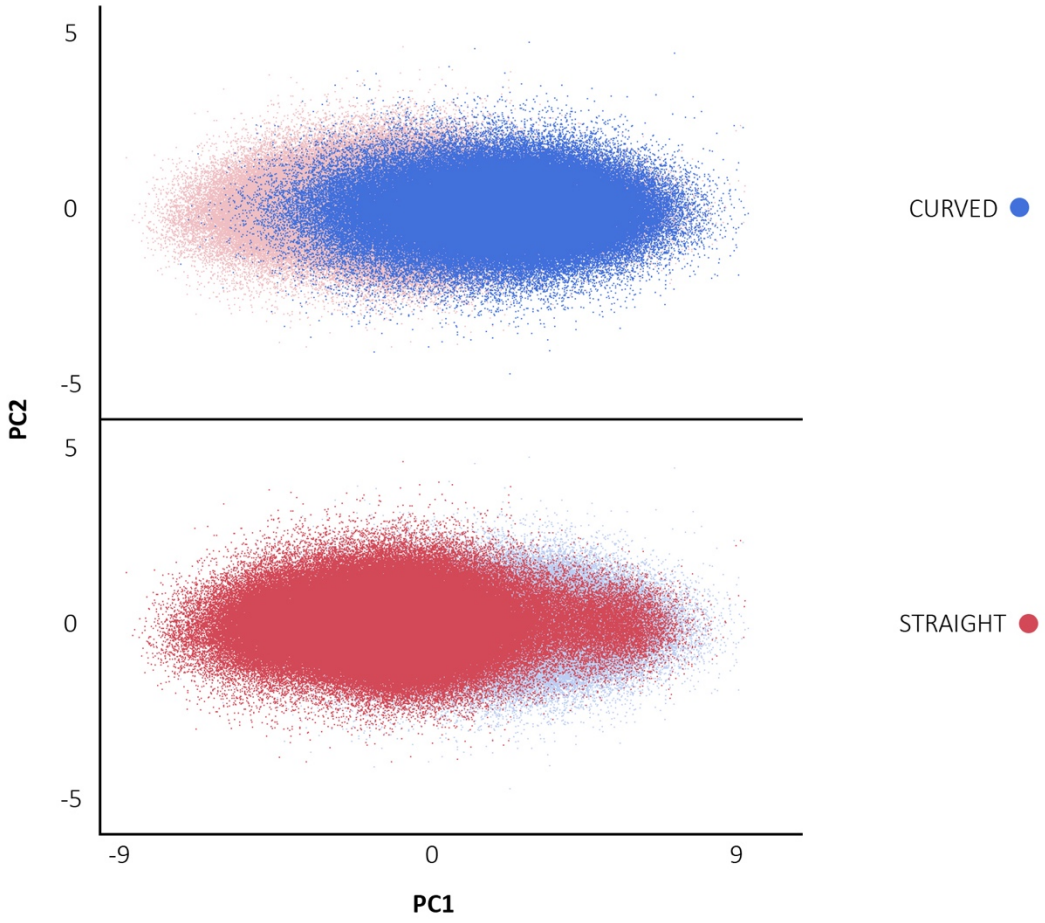
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





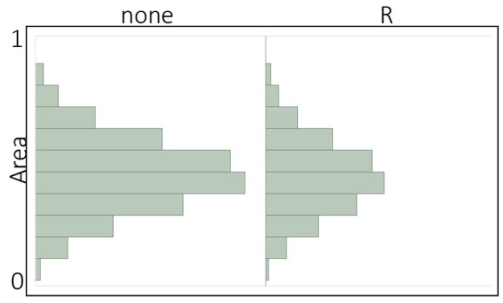
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



KNOT DIRECTION

Variable Class: Structural
Variable Type: Categorical
Observations (n_k / n_c): R (193,086/18); None (335,044/12)
Duplicating Variables: Knot Type
Reference Page: 322



Levene's Test (F-statistic):

Knot Size:

average p-value: 0.254
median p-value: 0.220

Knot Shape:

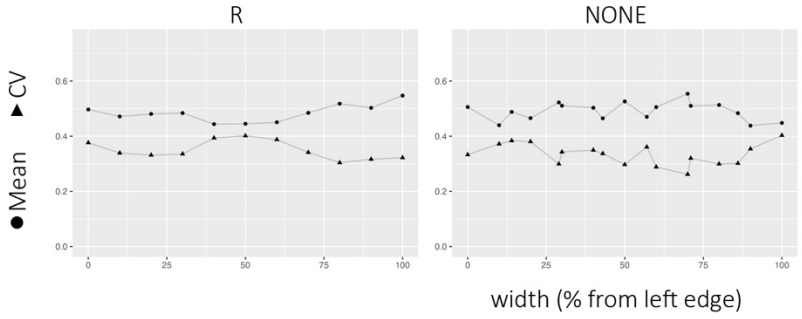
average p-value: 0.434
median p-value: 0.436

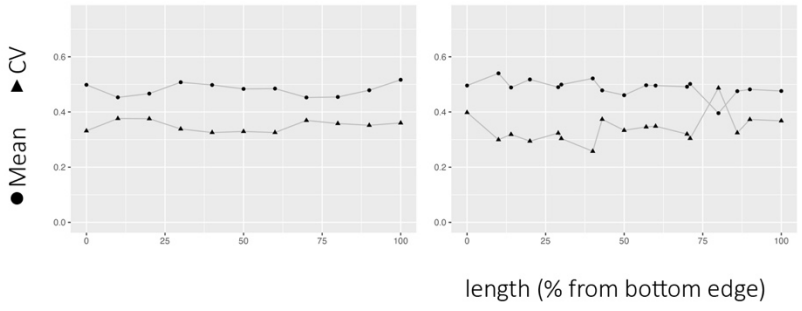
Student's Test (T-statistic) for Shape:

average p-value: <0.001*
median p-value: <0.001*

Knot Size

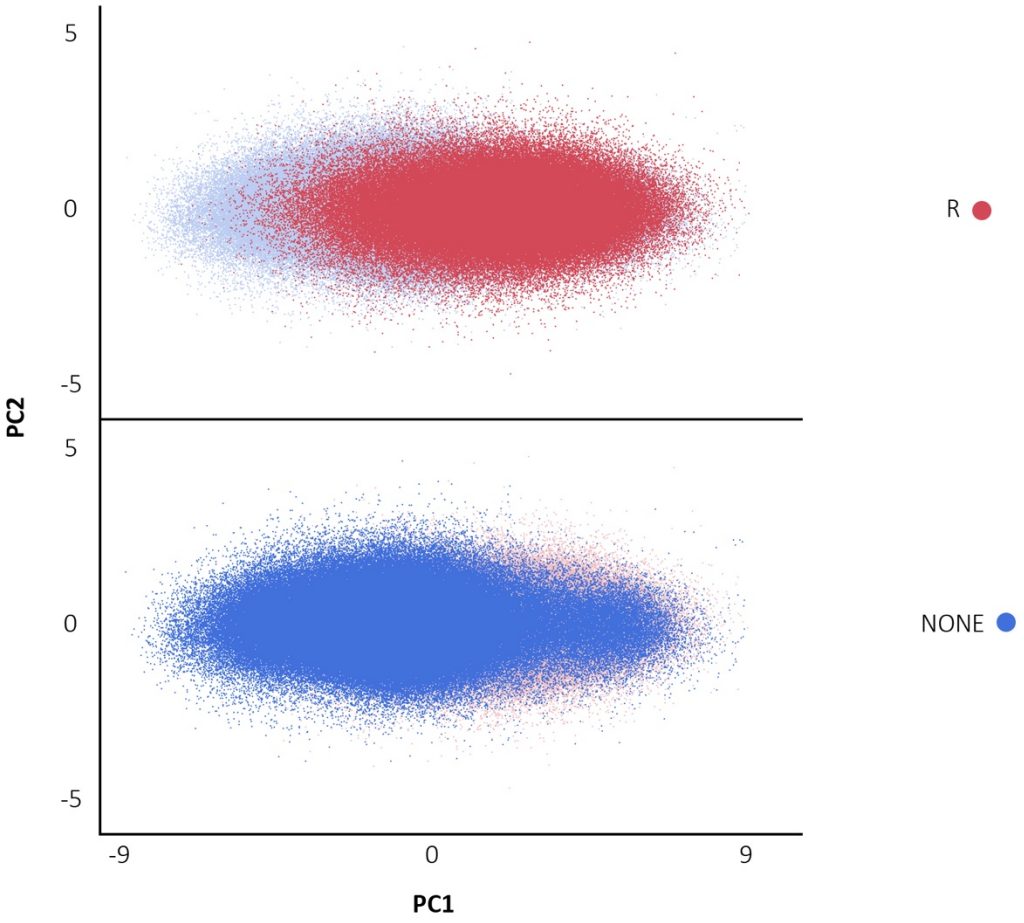
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





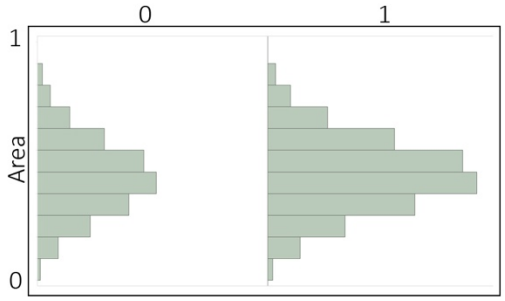
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



KNOT TYPE

Variable Class: Structural
Variable Type: Categorical
Observations (n_k / n_c): AS (193,086/18); SY (335,044/12)
Duplicating Variables: Knot Direction
Reference Page: 322

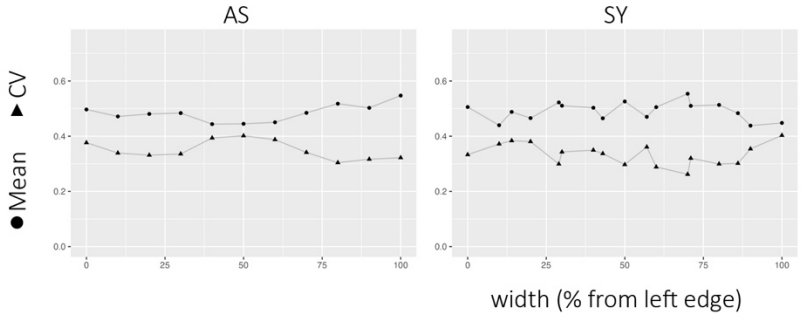


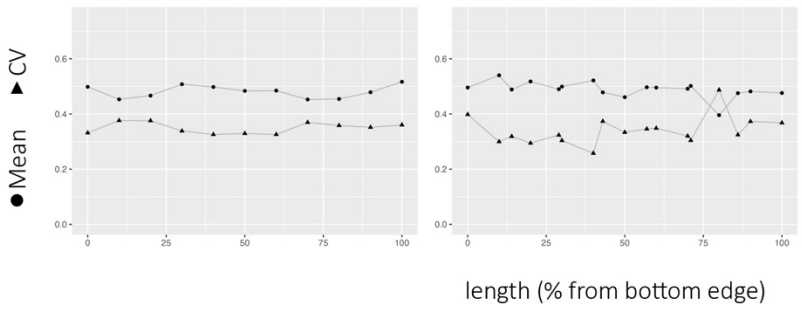
Levene's Test (F-statistic):
- Knot Size:
  - average p-value: 0.328
  - median p-value: 0.240
- Knot Shape:
  - average p-value: 0.400
  - median p-value: 0.386

Student's Test (T-statistic) for Shape:
- average p-value: <0.001*
- median p-value: <0.001*

Knot Size

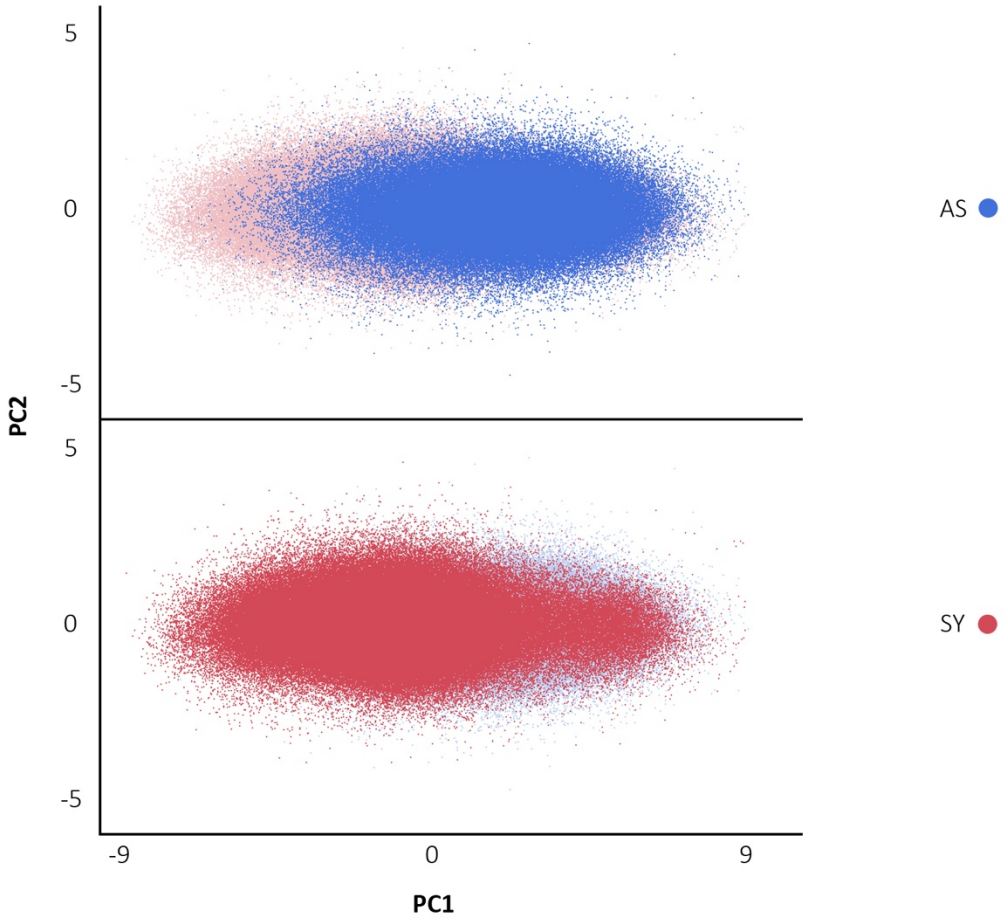
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





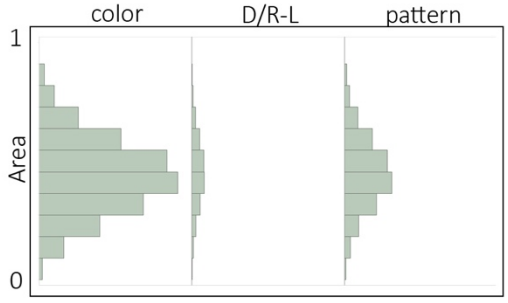
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



KNOTTING ORDER

Variable Class: Technological
Variable Type: Categorical
Observations (n_k / n_c): Color (376,607/20); D/L-R (32,409/6); Pattern (119,114/4)
Duplicating Variables: none
Reference Page: 334



Levene's Test (F-statistic):

Knot Size:

average p-value:	0.043*
median p-value:	0.004*

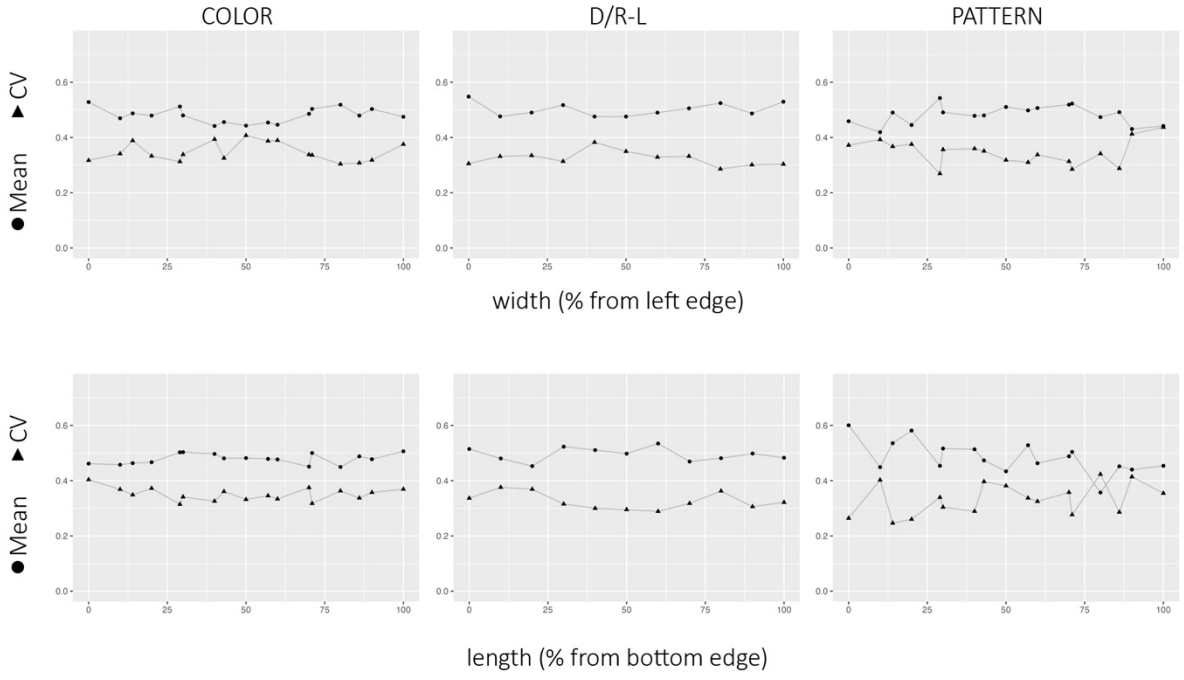
Knot Shape:

average p-value:	<0.001*
median p-value:	<0.001*

Student's Test (T-statistic) for Shape:
not applicable, unequal variances

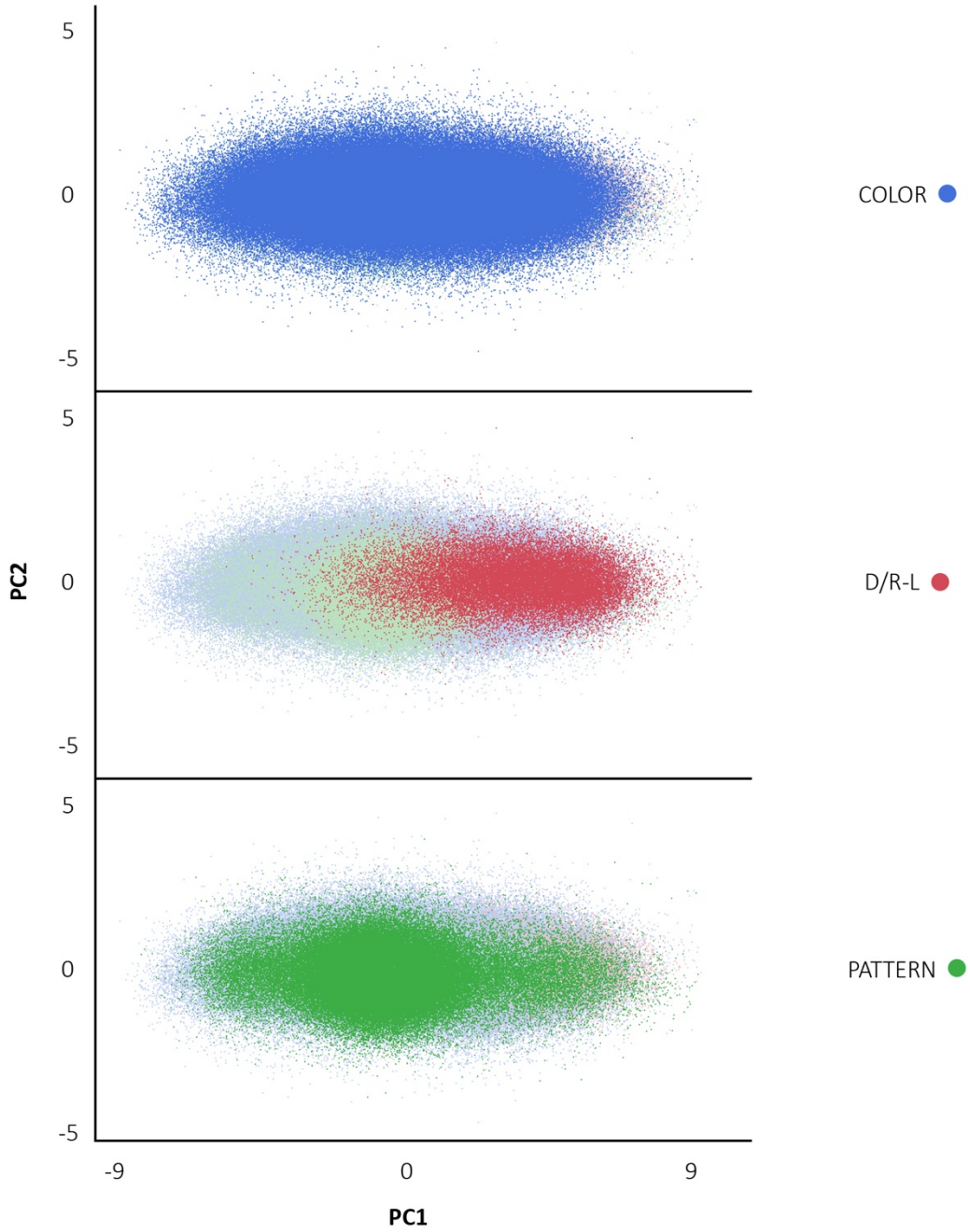
Knot Size

Ethnographic Knot Size Means & CVs, by Carpet Width & Length



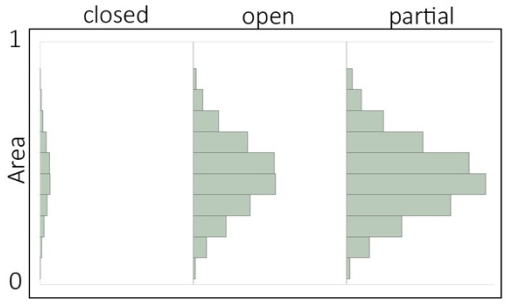
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



KNOTTING SHED POSITION

Variable Class: Technological
Variable Type: Categorical-Ordinal
Observations (n_k / n_c): Open (193,145/5); Partial (311,848/20); Closed (23,137/5)
Duplicating Variables: none
Reference Page: 326



Levene's Test (F-statistic):

Knot Size:

average p-value:	0.533
median p-value:	0.472

Knot Shape:

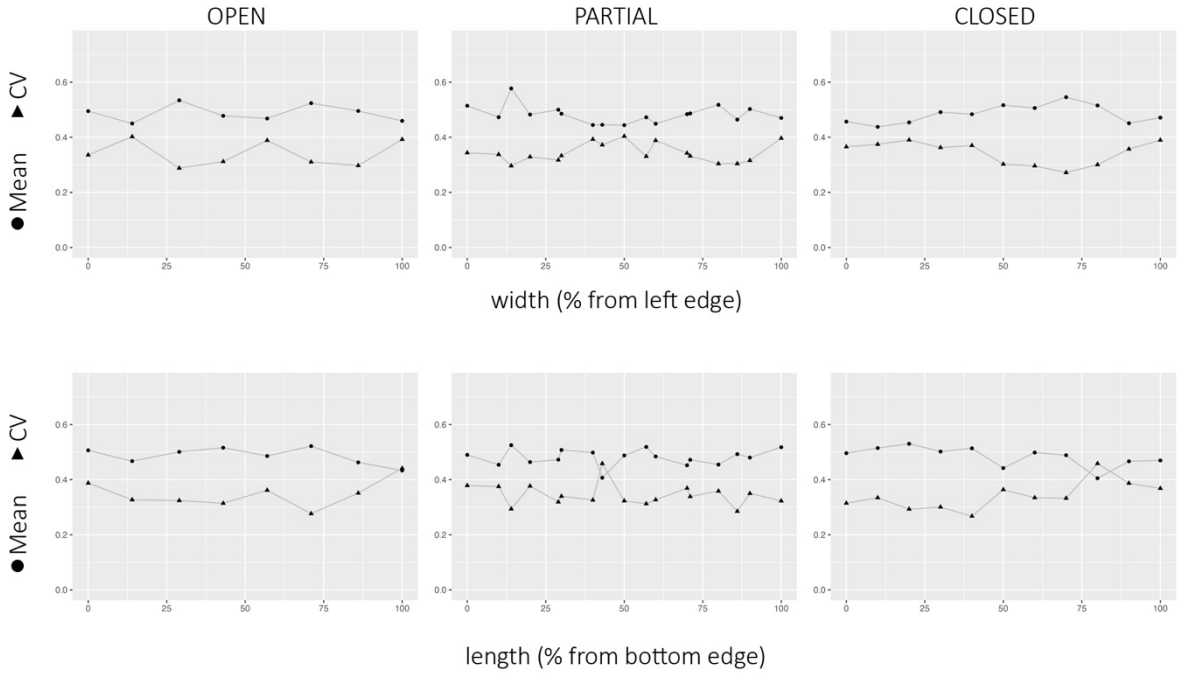
average p-value:	<0.001*
median p-value:	<0.001*

Student's Test (T-statistic) for Shape:

not applicable, unequal variances

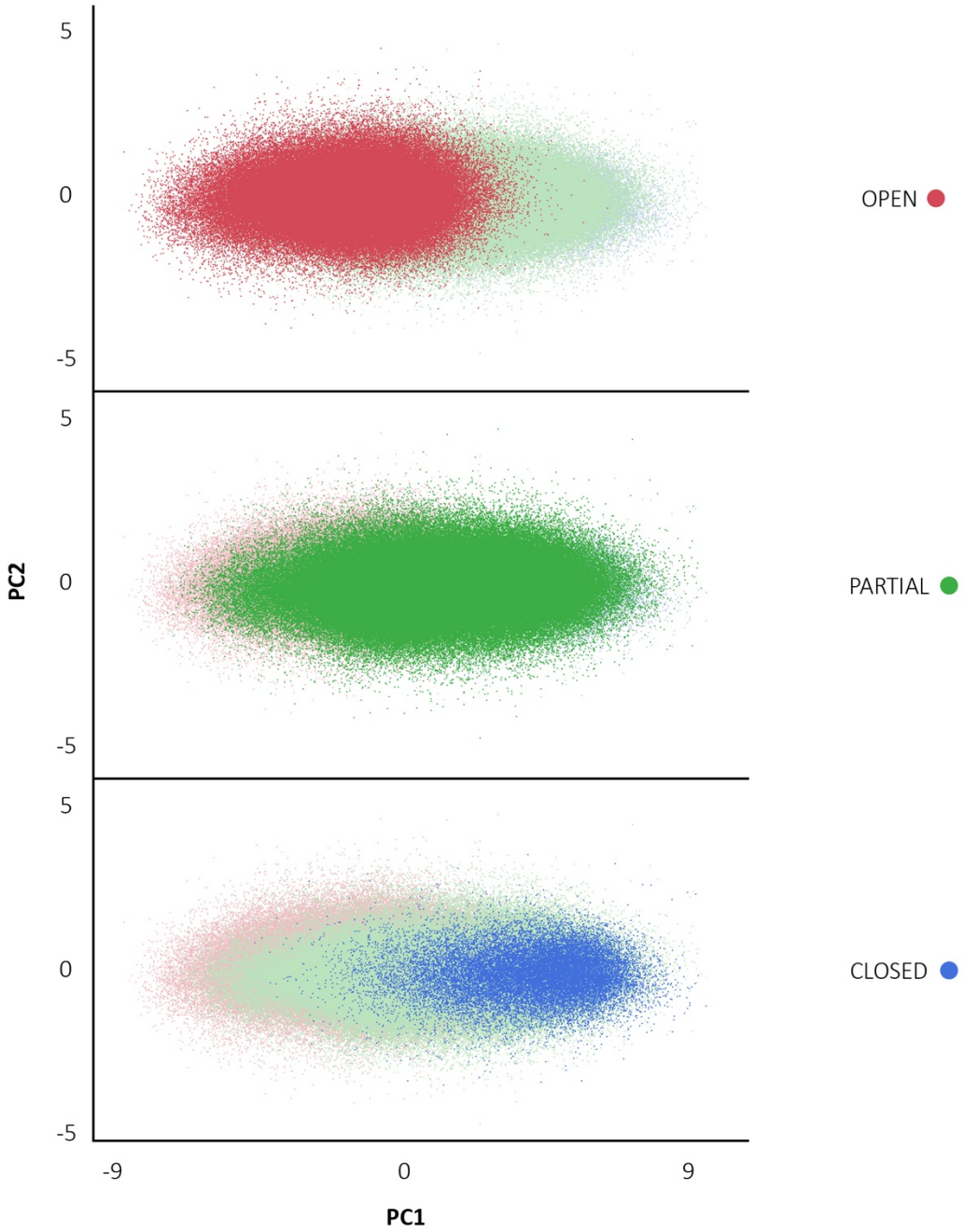
Knot Size

Ethnographic Knot Size Means & CVs, by Carpet Width & Length



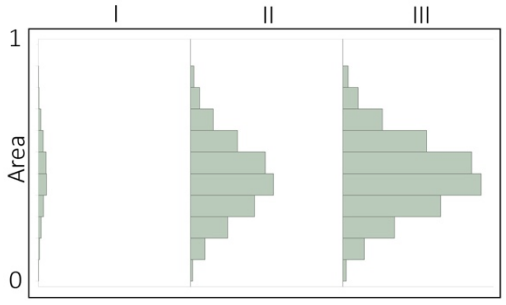
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



KNOT-WARP PATTERN

Variable Class: Structural
Variable Type: Categorical
Observations (n_k / n_c): I (18,441/4); II (193,086/18); III (316,603/8)
Duplicating Variables: none
Reference Page: 325



Levene's Test (F-statistic):

Knot Size:

average p-value:	0.169
median p-value:	0.097

Knot Shape:

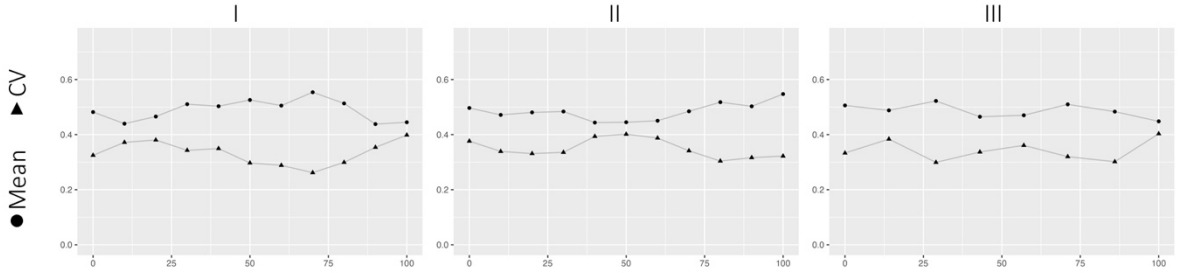
average p-value:	<0.001*
median p-value:	<0.001*

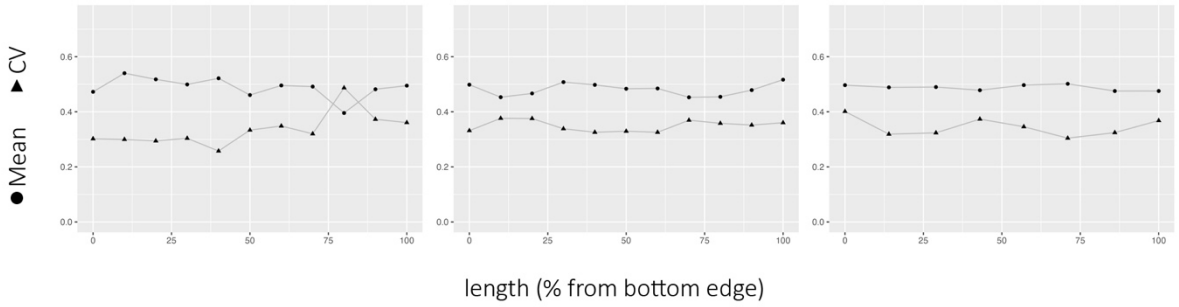
Student's Test (T-statistic) for Shape:

not applicable, unequal variances

Knot Size

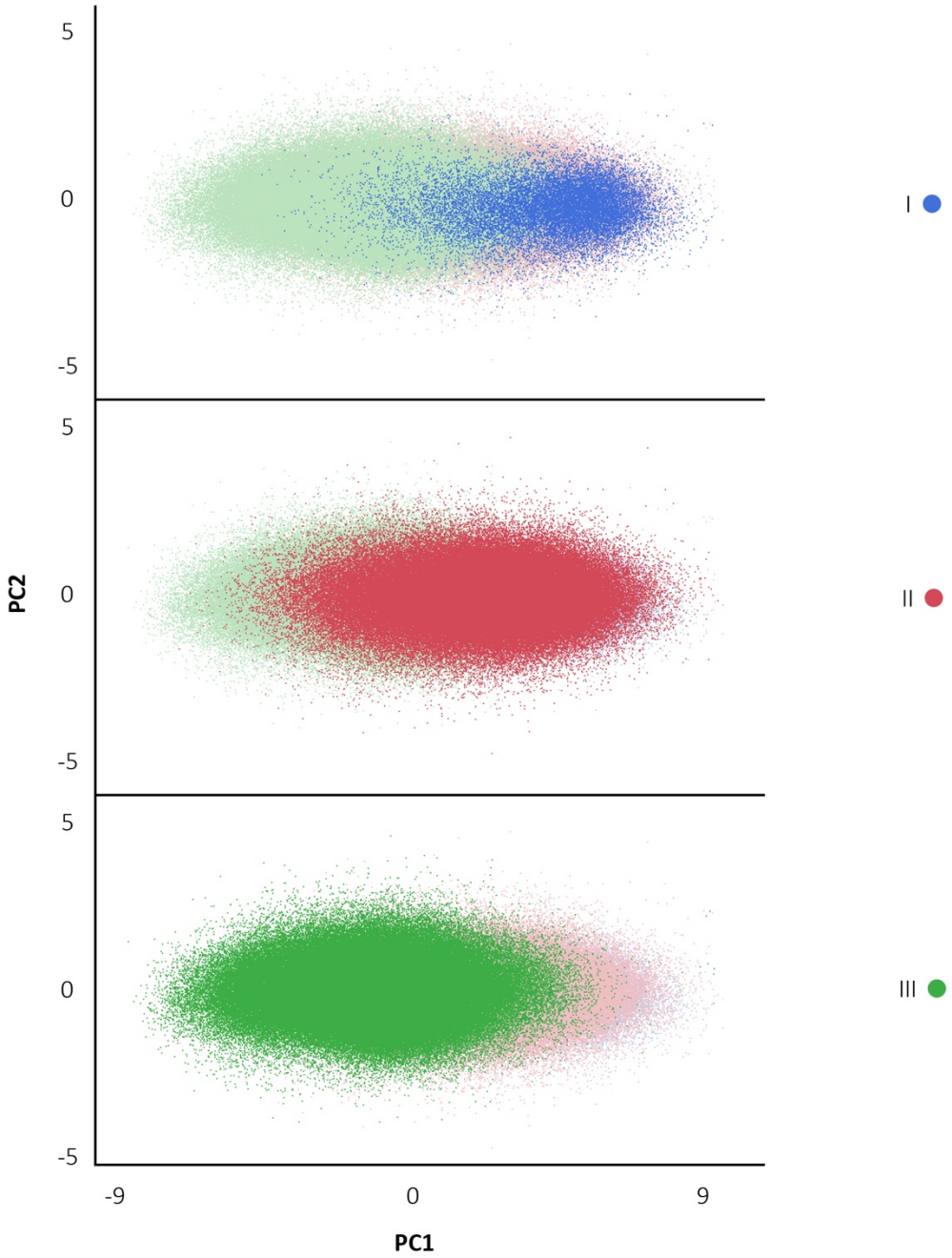
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





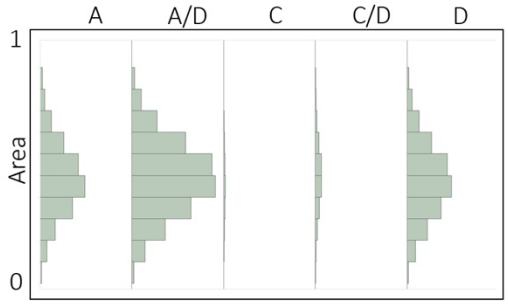
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



KNOT-WEFT PATTERN

Variable Class: Structural
Variable Type: Categorical
Observations (n_k / n_c): A (123, 458/3); A/D (249,640/13); C (4,696/1); C/D (18,441/4); D (131,895/8)
Duplicating Variables: none
Reference Page: 326

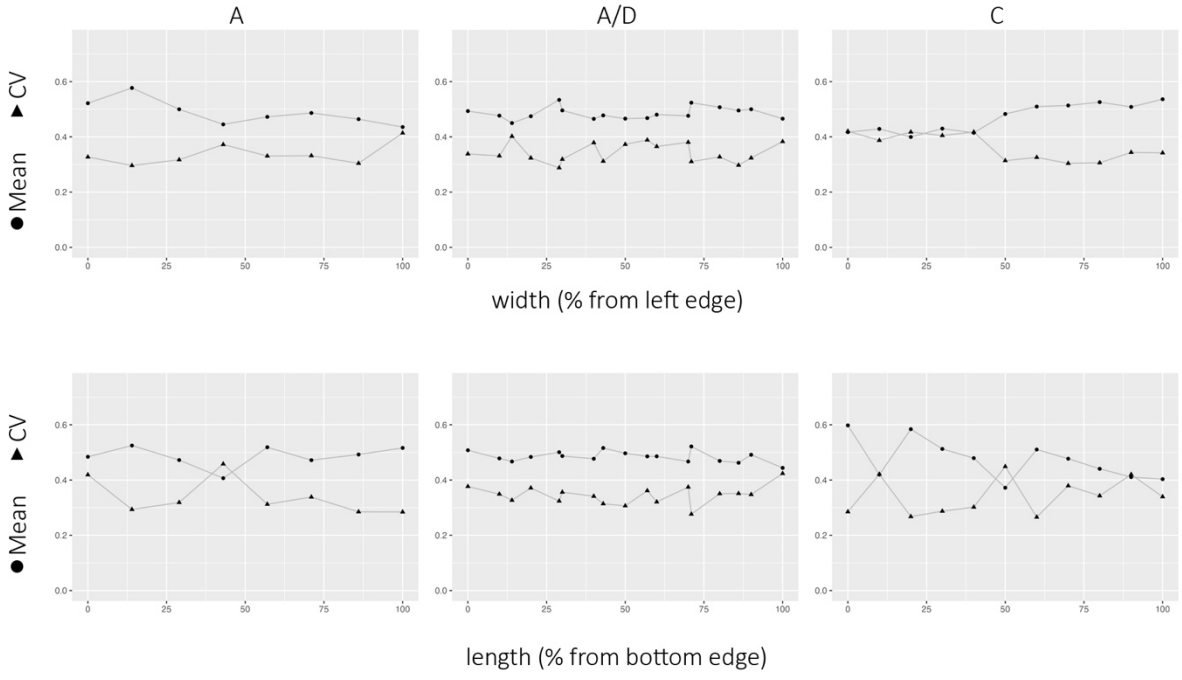


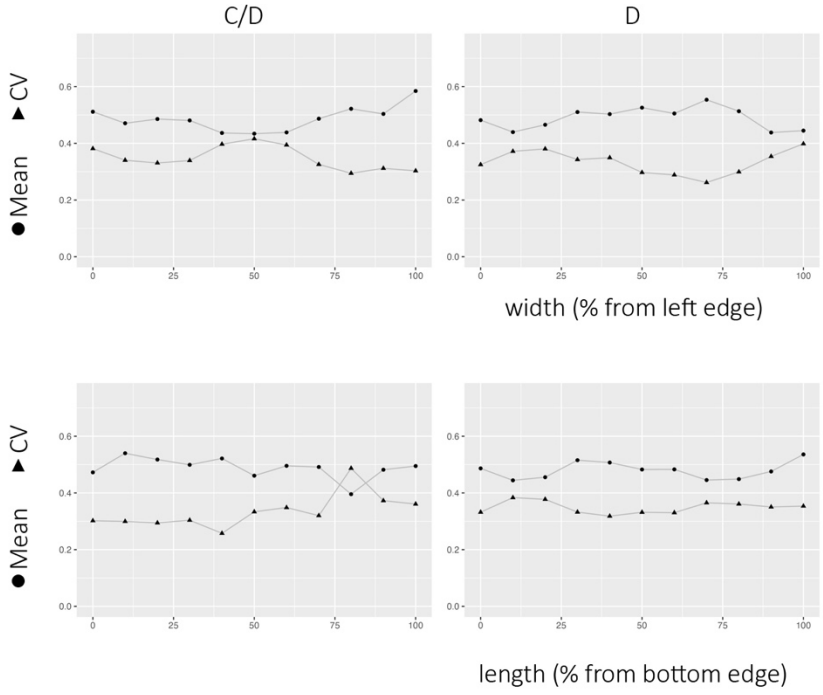
Levene's Test (F-statistic):
- Knot Size:
  - average p-value: <0.001*
  - median p-value: <0.001*
- Knot Shape:
  - average p-value: 0.146
  - median p-value: 0.127

Student's Test (T-statistic) for Shape:
- average p-value: <0.001*
- median p-value: <0.001*

Knot Size

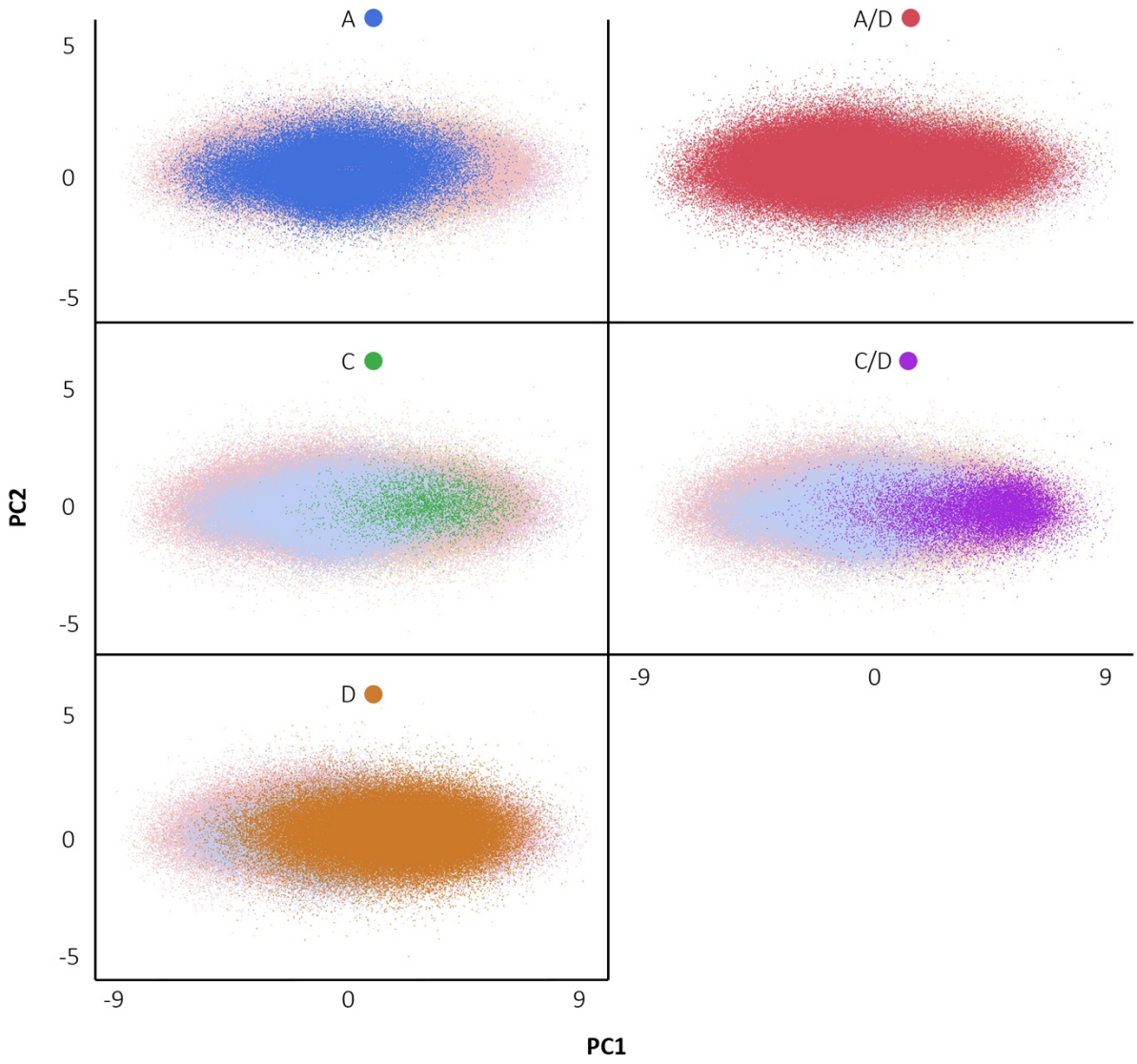
Ethnographic Knot Size Means & CVs, by Carpet Width & Length




C/D
D
● Mean ▲ CV
0.0
0.2
0.4
0.6
0
25
50
75
100
width (% from left edge)
● Mean ▲ CV
length (% from bottom edge)

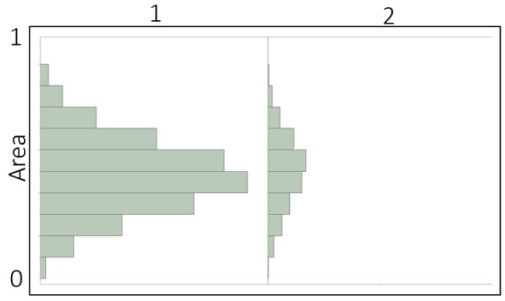
KNOT SHAPE

Ethnographic Knot Shapes, condensed to Two Principal Components



NUMBER OF WEAVERS

Variable Class: Idiosyncratic
Variable Type: Numeric-Discrete (operates as categorical-ordinal)
Observations (n_k / n_c): 1 Weaver (447,479/29); 2 (80,651/1)
Duplicating Variables: none
Reference Page: 356



Levene's Test (F-statistic):

Knot Size:

average p-value: 0.356
median p-value: 0.304

Knot Shape:

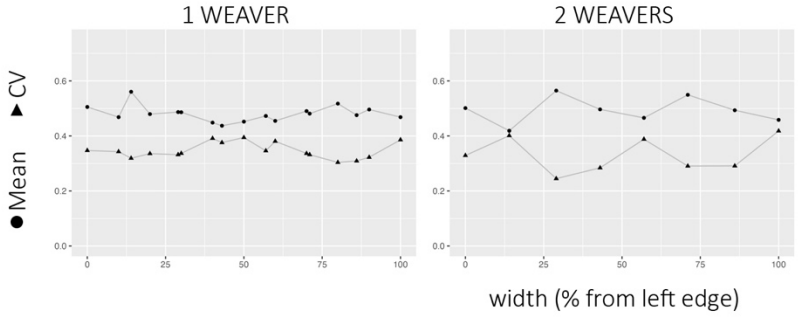
average p-value: <0.001*
median p-value: <0.001*

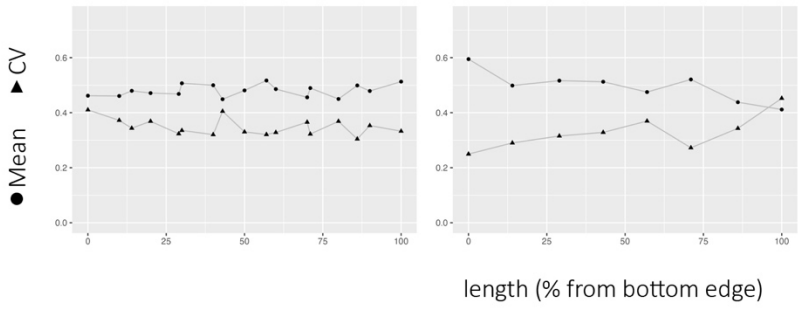
Student's Test (T-statistic) for Shape:

not applicable, unequal variances

Knot Size

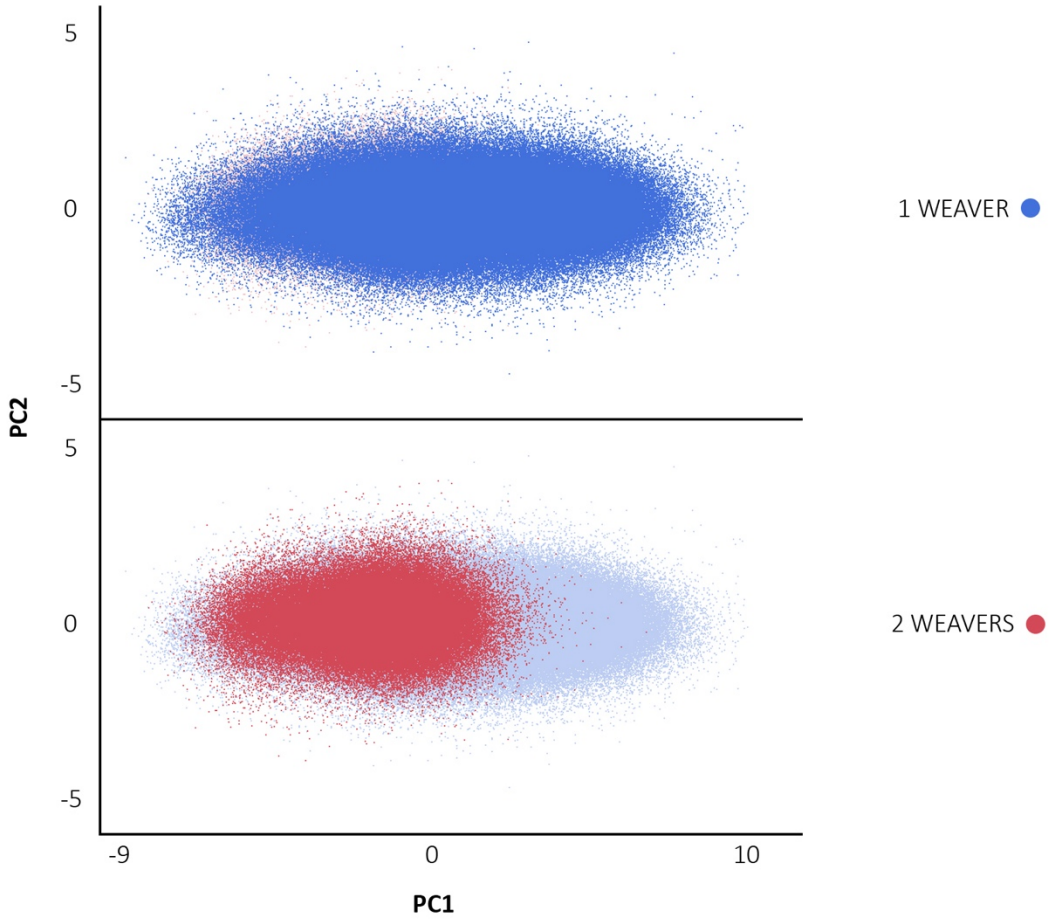
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





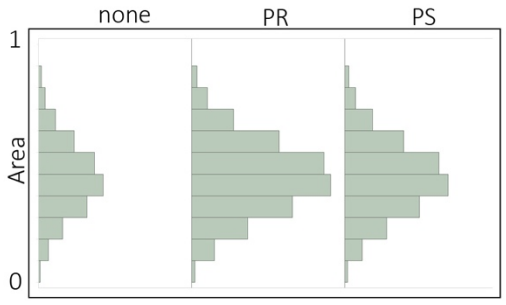
KNOT SHAPE

Ethnographic Knot Shapes, condensed to Two Principal Components



OVERSIGHT

Variable Class: Social
Variable Type: Categorical-Ordinal
Observations (n_k / n_c): PR (244,230/6); PS (176,032/10); None (107,868/14)
Duplicating Variables: none
Reference Page: 357



Levene's Test (F-statistic):

Knot Size:

average p-value: 0.325
median p-value: 0.288

Knot Shape:

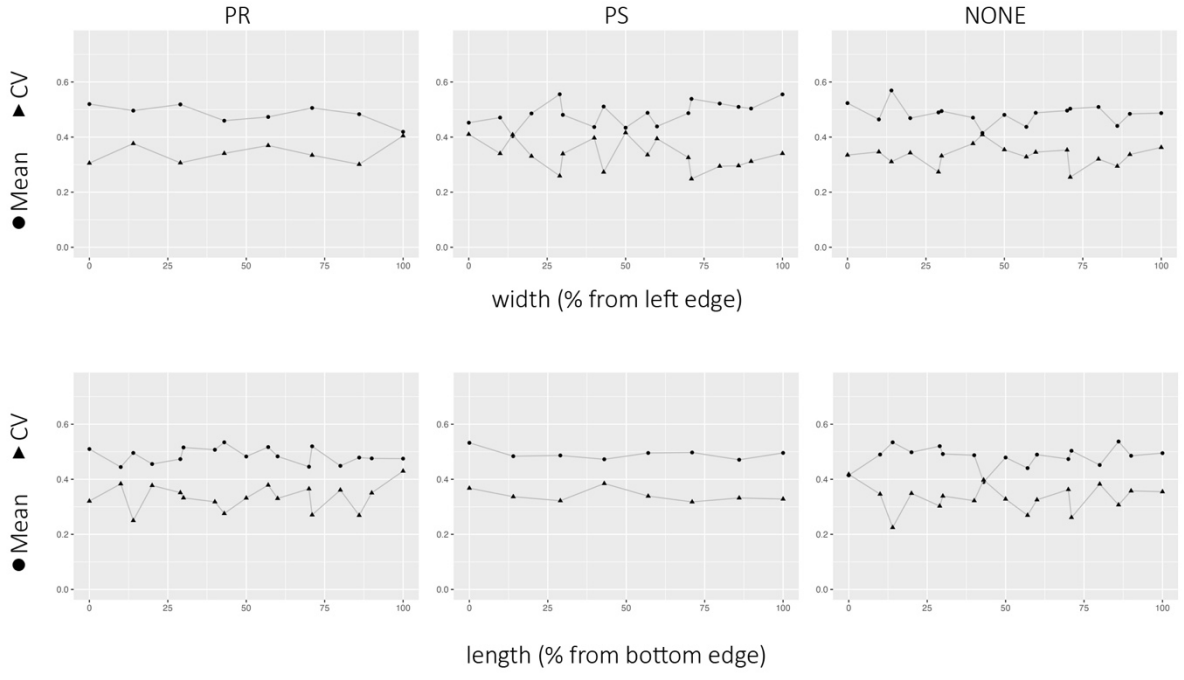
average p-value: <0.001*
median p-value: <0.001*

Student's Test (T-statistic) for Shape:

not applicable, unequal variances

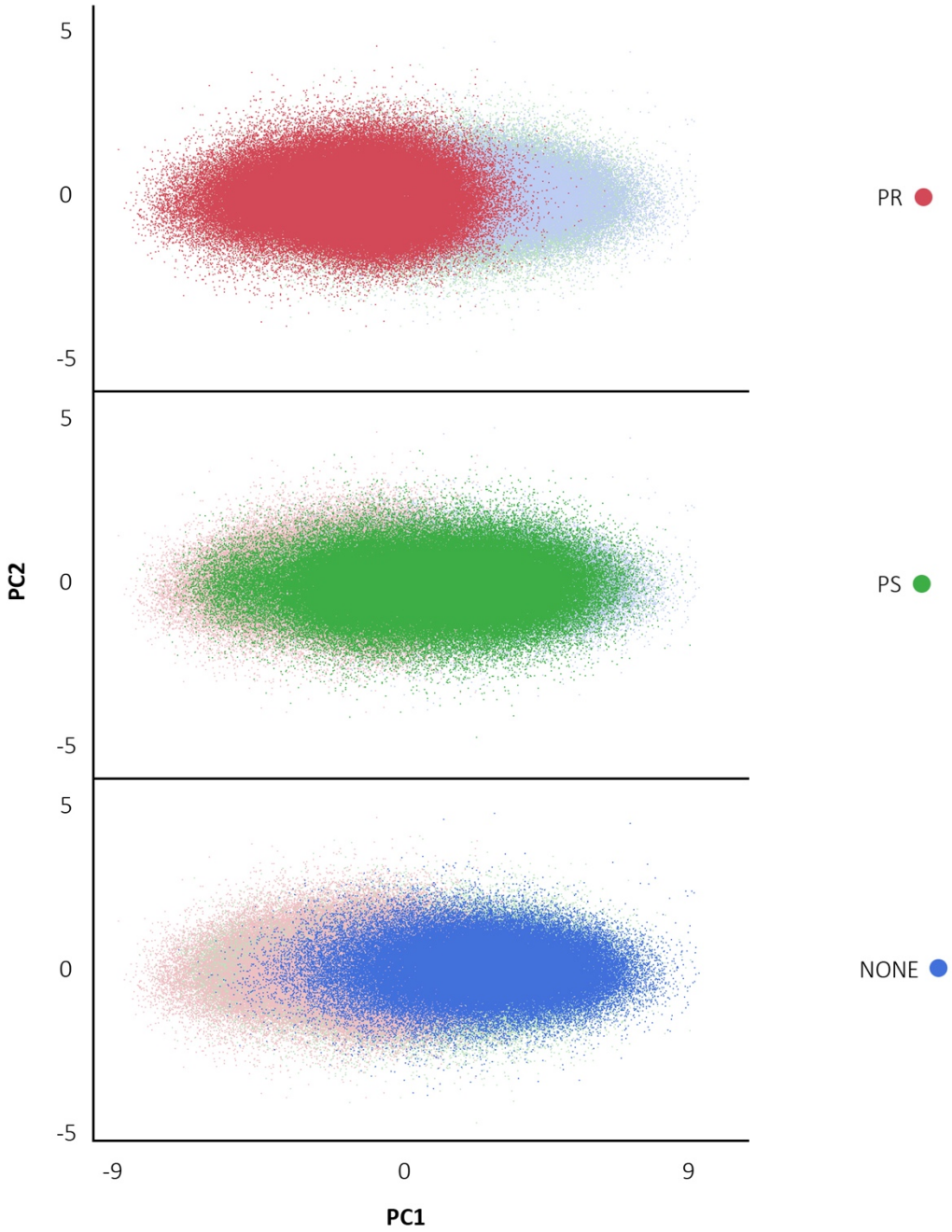
Knot Size

Ethnographic Knot Size Means & CVs, by Carpet Width & Length



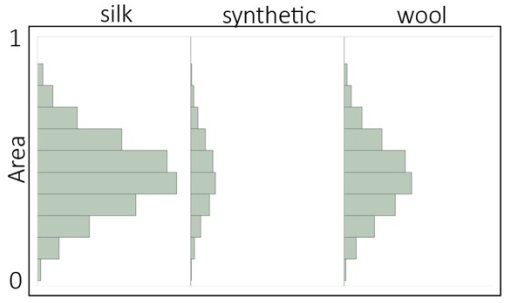
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



PILE MATERIAL

Variable Class: Structural
Variable Type: Categorical
Observations (n_k / n_c): Silk (316,603/8); Synthetic (56,495/7); Wool (155,032/14)
Duplicating Variables: none
Reference Page: 313



Levene's Test (F-statistic):

Knot Size:

average p-value:	0.397
median p-value:	0.422

Knot Shape:

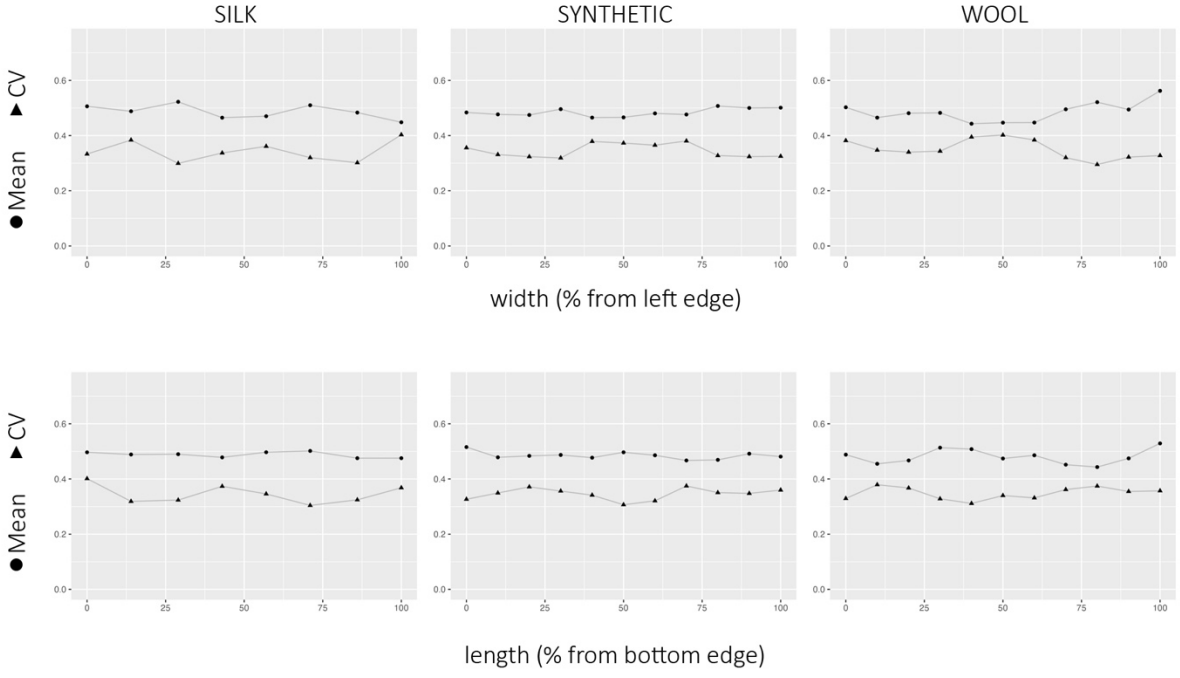
average p-value:	<0.001*
median p-value:	<0.001*

Student's Test (T-statistic) for Shape:

not applicable, unequal variances

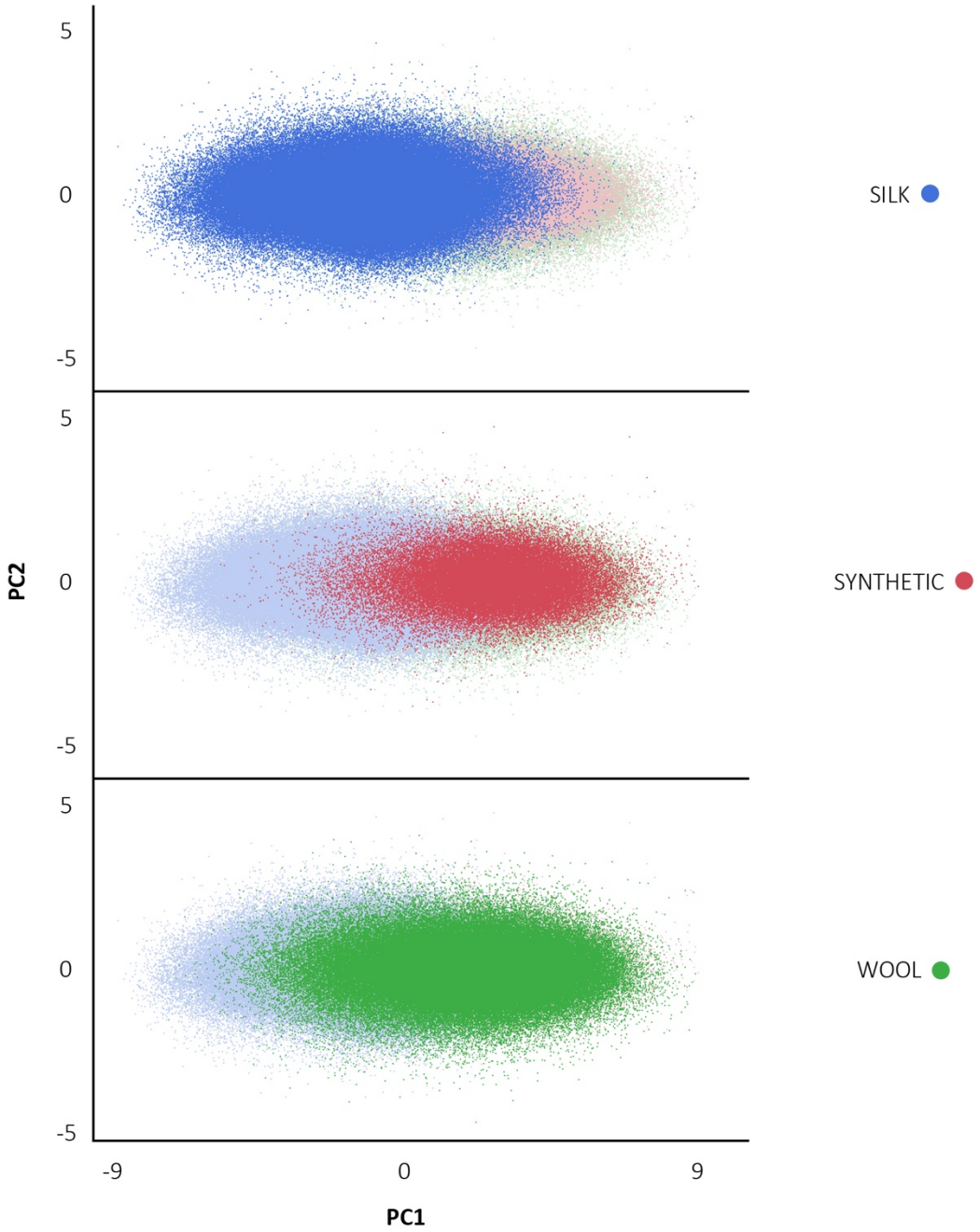
Knot Shape

Ethnographic Knot Size Means & CVs, by Carpet Width & Length



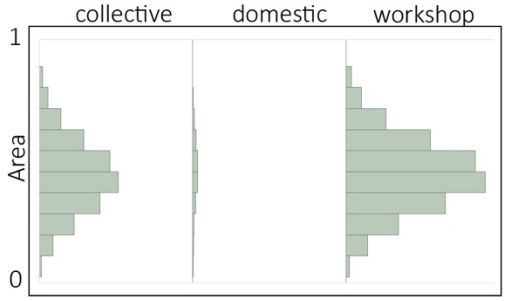
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



PRODUCTION SETTING

Variable Class: Social
Variable Type: Categorical-Ordinal
Observations (n_k / n_c): Domestic (11,300/3); Collective (188,390/17); Workshop (328,440/10)
Duplicating Variables: none
Reference Page: 358



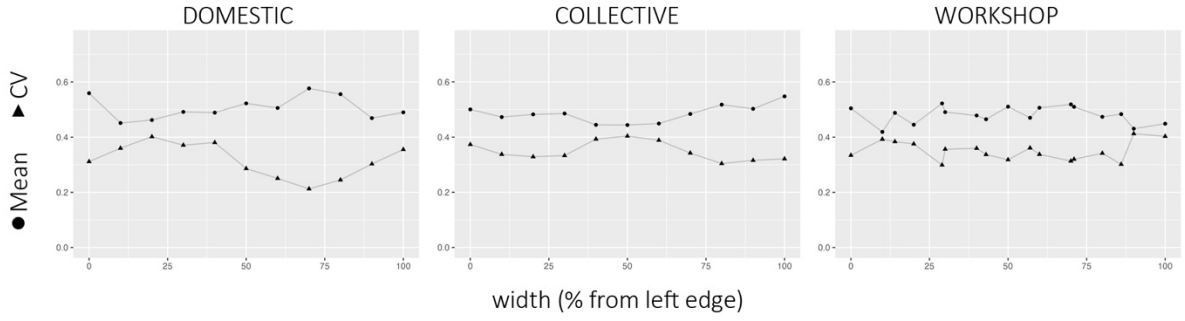
Levene's Test (F-statistic):
Knot Size:
average p-value: <0.001*
median p-value: <0.001*

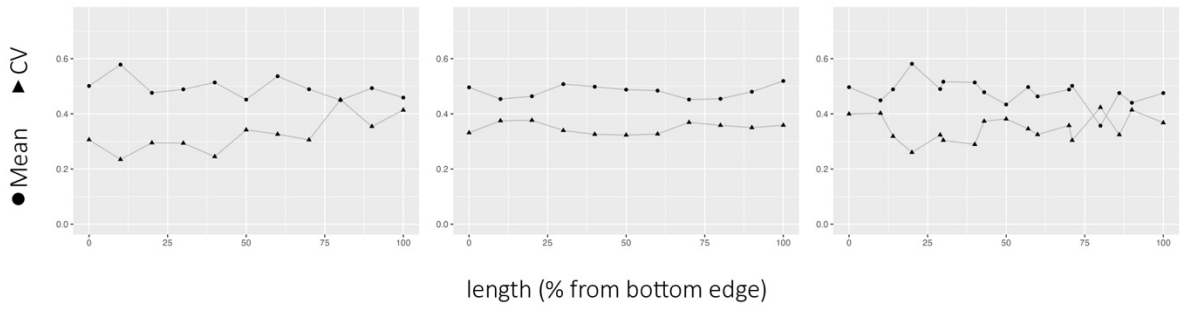
Knot Shape:
average p-value: <0.001*
median p-value: <0.001*

Student's Test (T-statistic) for Shape:
not applicable, unequal variances

Knot Size

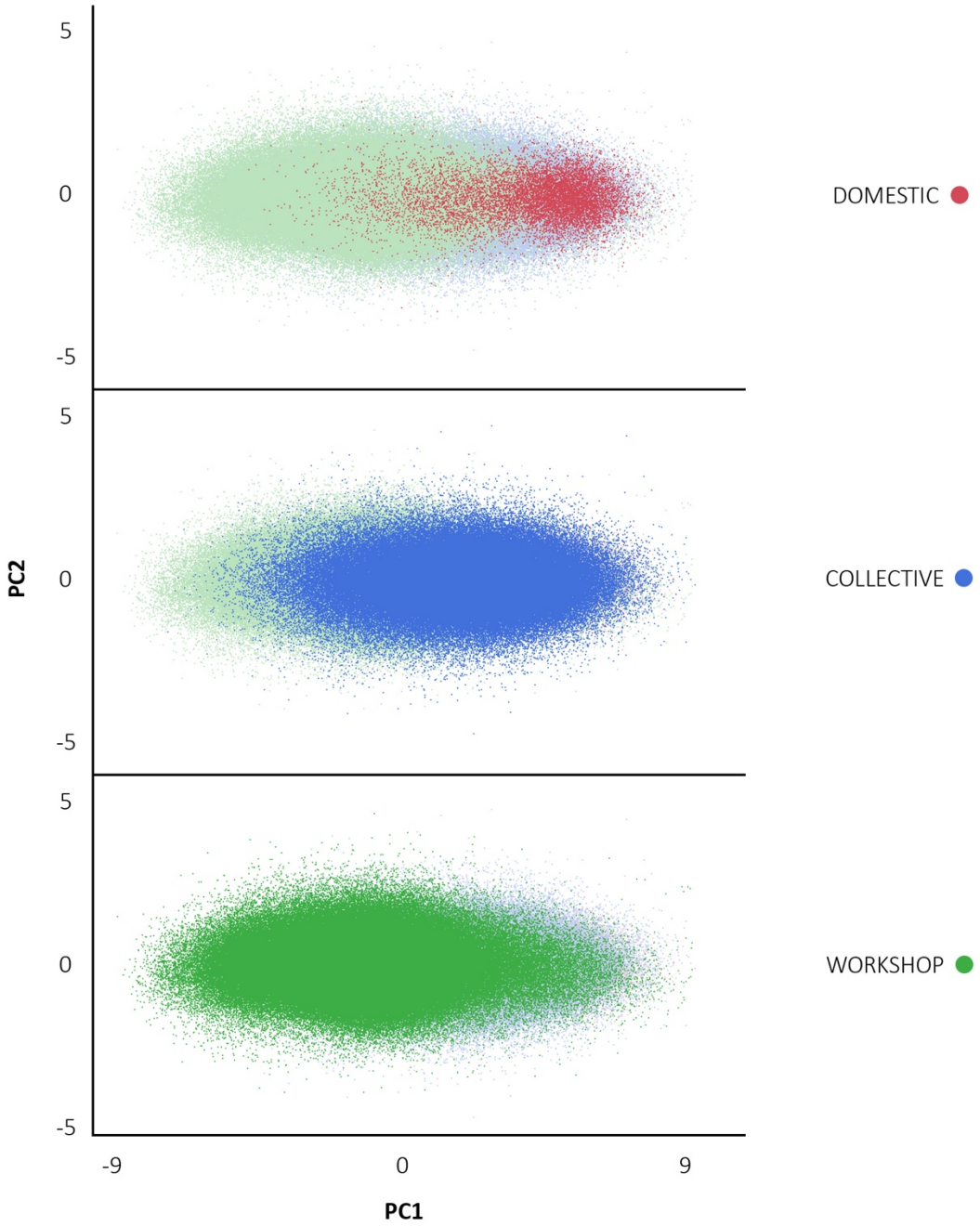
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





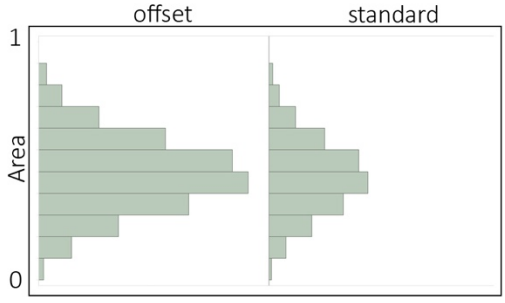
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



SCISSOR TYPE

Variable Class: Technological
Variable Type: Categorical
Observations (n_k / n_c): Offset (357,771/14); Standard (170,359/16)
Duplicating Variables: none
Reference Page: 349



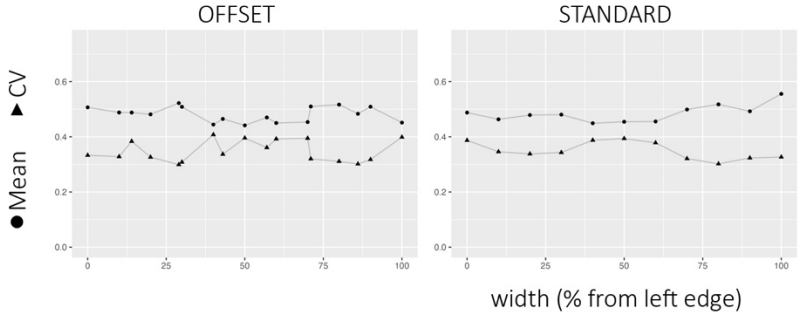
Levene's Test (F-statistic):
Knot Size:
average p-value: 0.464
median p-value: 0.452

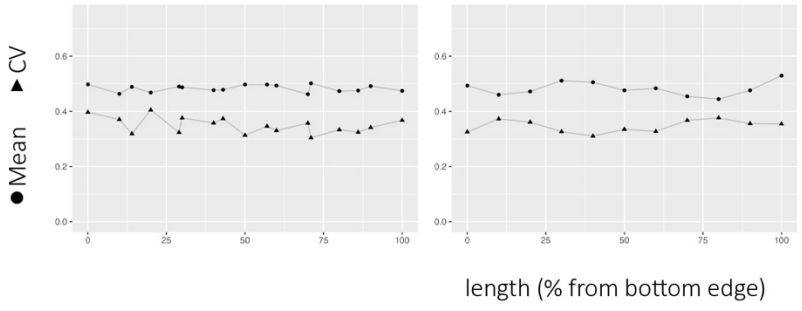
Knot Shape:
average p-value: 0.338
median p-value: 0.367

Student's Test (T-statistic) for Shape:
average p-value: <0.001*
median p-value: <0.001*

Knot Size

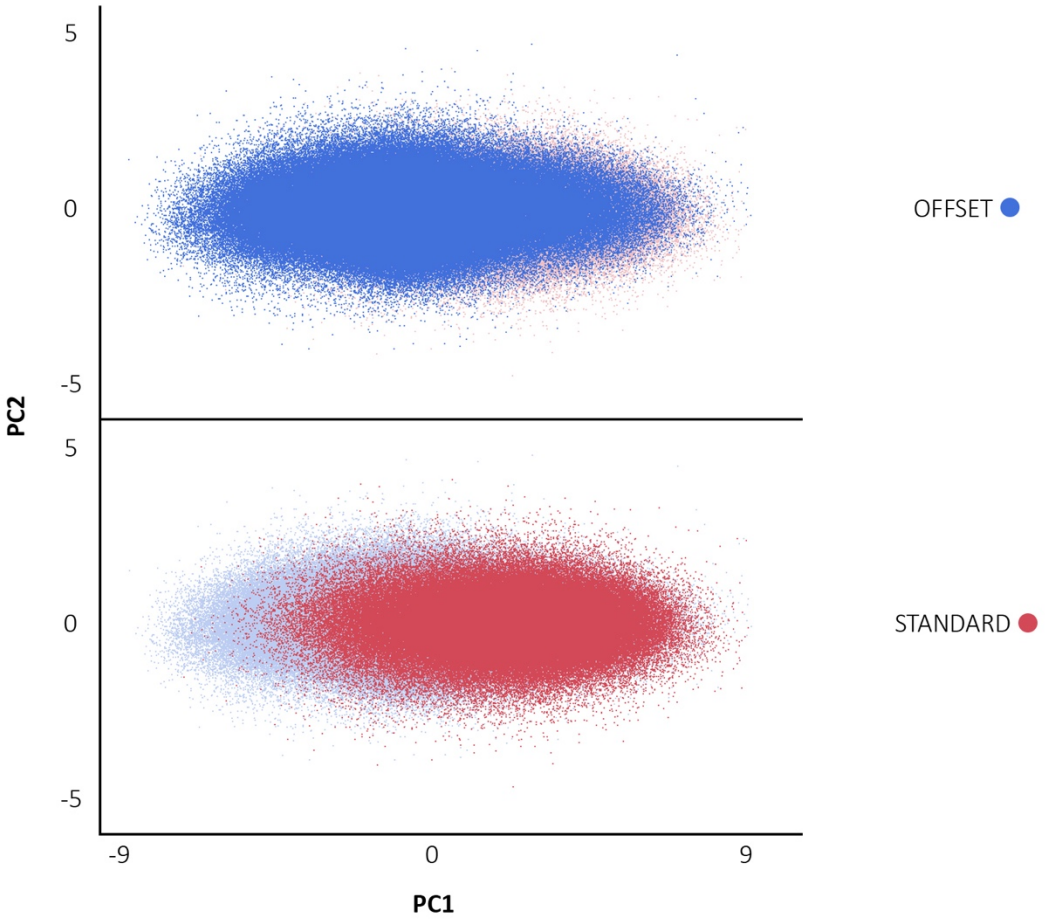
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





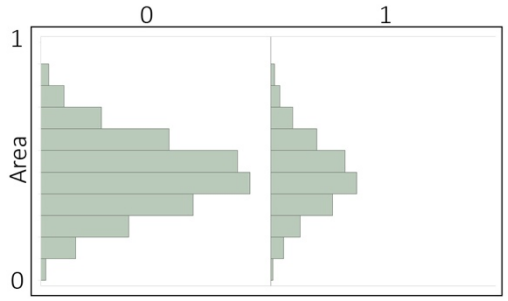
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



SHED RODS

Variable Class: Technological
Variable Type: Numeric-Discrete (functions like categorical-ordinal)
Observations (n_k / n_c): 0 Rods (381,535/22); 1 Rod (146,595/8)
Duplicating Variables: Single-Shed Heddles, Double-Shed Heddles
Reference Page: 311



Levene's Test (F-statistic):

Knot Size:

average p-value: 0.327
median p-value: 0.184

Knot Shape:

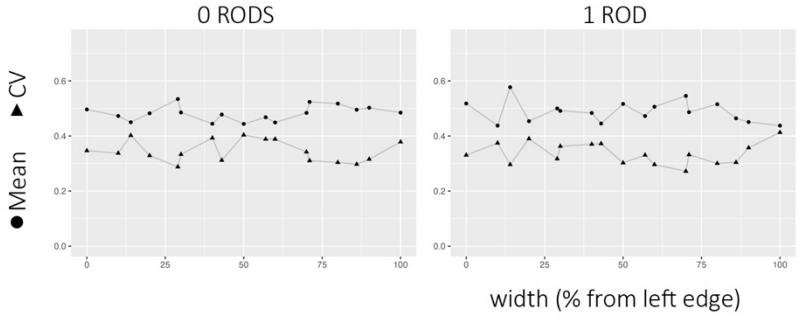
average p-value: <0.001*
median p-value: <0.001*

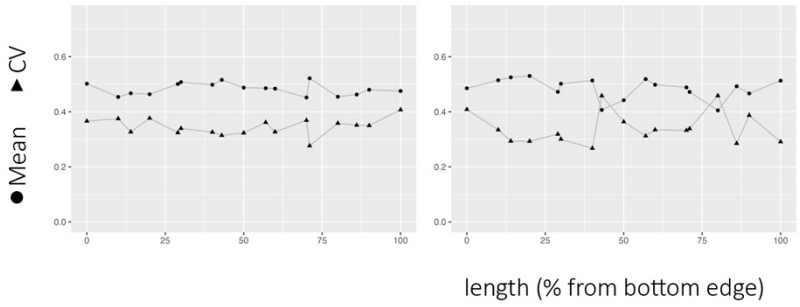
Student's Test (T-statistic) for Shape:

not applicable, unequal variances

Knot Size

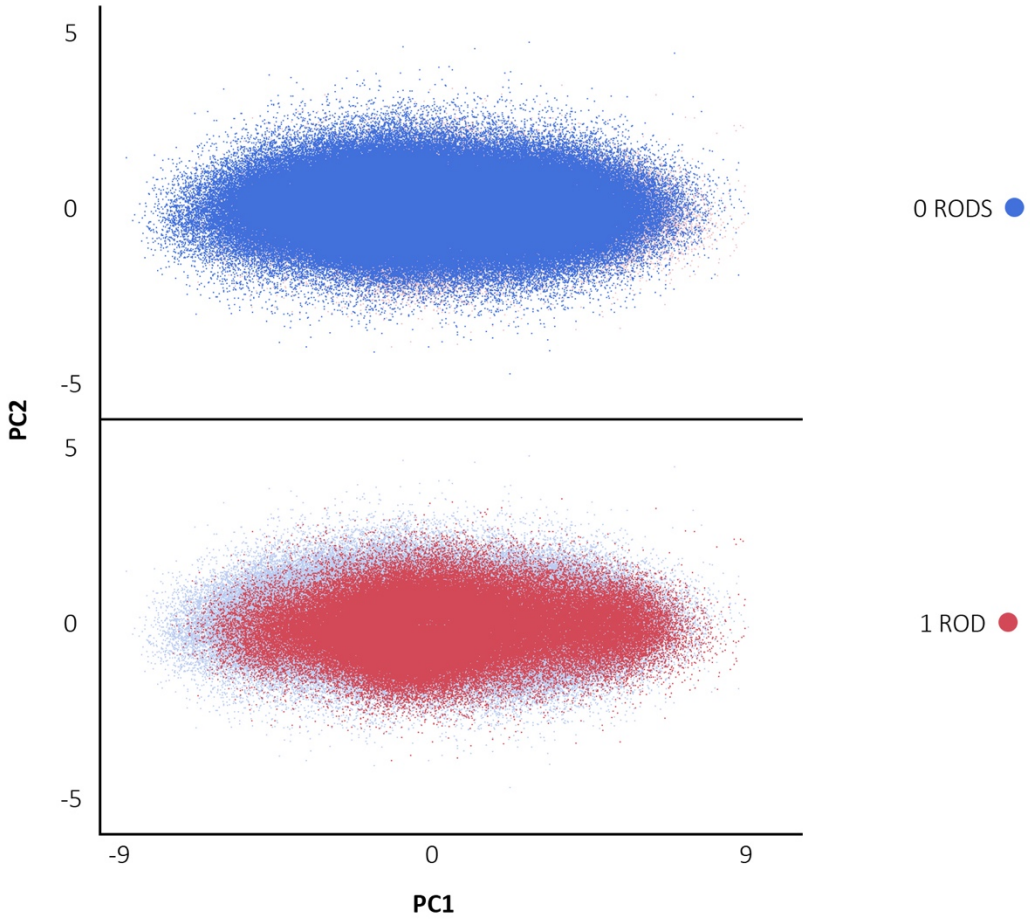
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





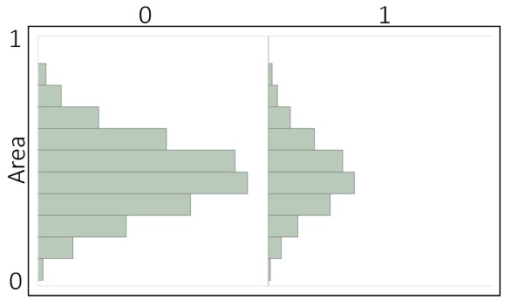
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



SINGLE-SHED HEDDLES

Variable Class: Technological
Variable Type: Numeric-Discrete (functions like categorical-ordinal)
Observations (n_k / n_c): 0 Heddles (381,535/22); 1 Heddle (146,595/8)
Duplicating Variables: Shed Rods, Double-Shed Heddles
Reference Page: 311



Levene's Test (F-statistic):

Knot Size:

average p-value:	0.244
median p-value:	0.131

Knot Shape:

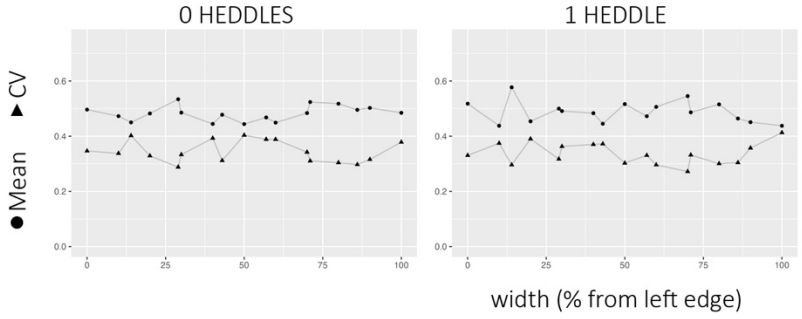
average p-value:	<0.001*
median p-value:	<0.001*

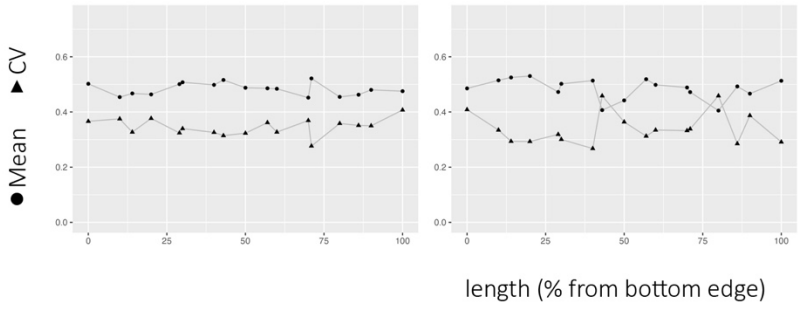
Student's Test (T-statistic) for Shape:

not applicable, unequal variances

Knot Size

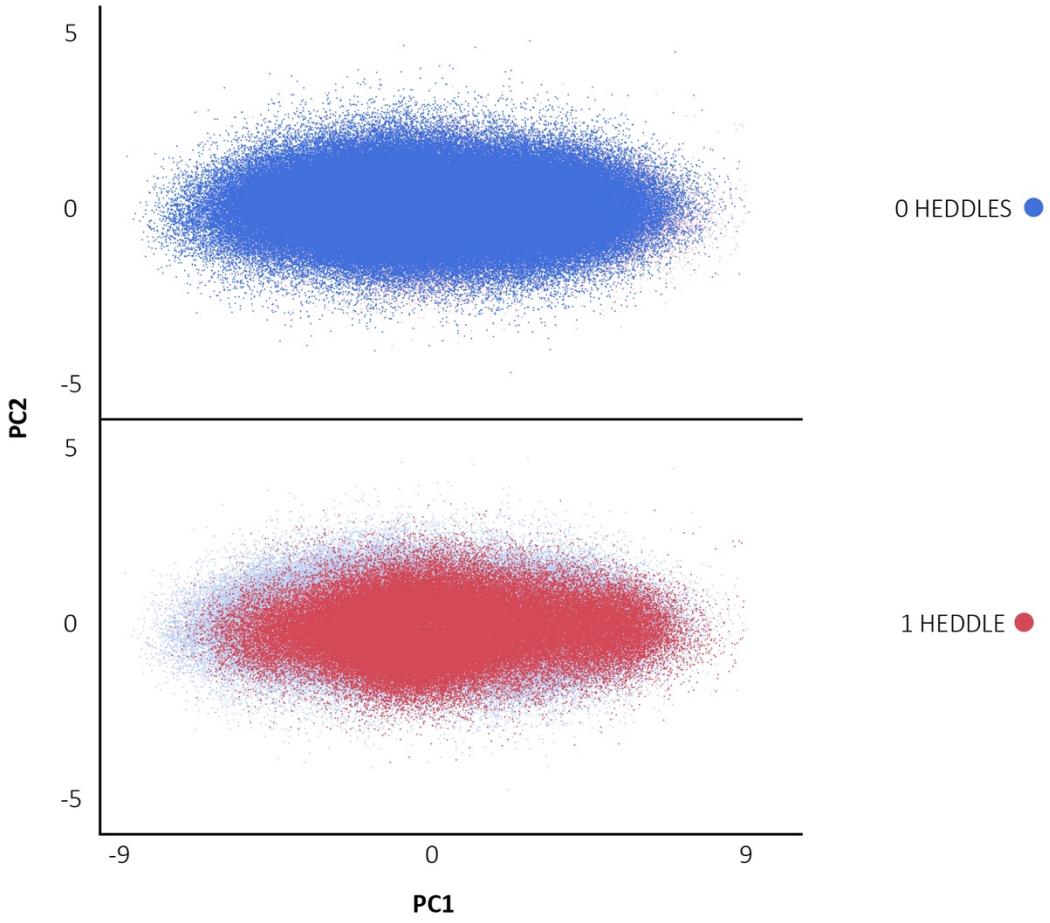
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





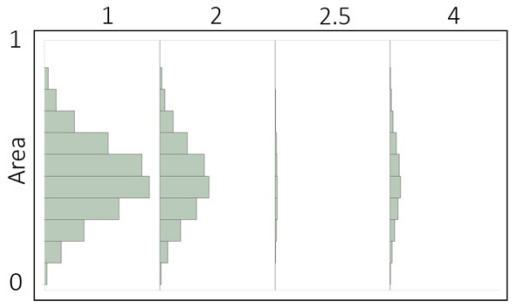
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



STRANDS PER KNOT

Variable Class: Structural
Variable Type: Numeric-Continuous (functions like categorical-ordinal)
Observations (n_k / n_c): 1 Strand (332,118/9); 2 (155,186/15); 2.5 (7,141/1); 4 (33,685/5)
Duplicating Variables: none
Reference Page: 325



Levene's Test (F-statistic):

Knot Size:

average p-value:	0.017*
median p-value:	0.045*

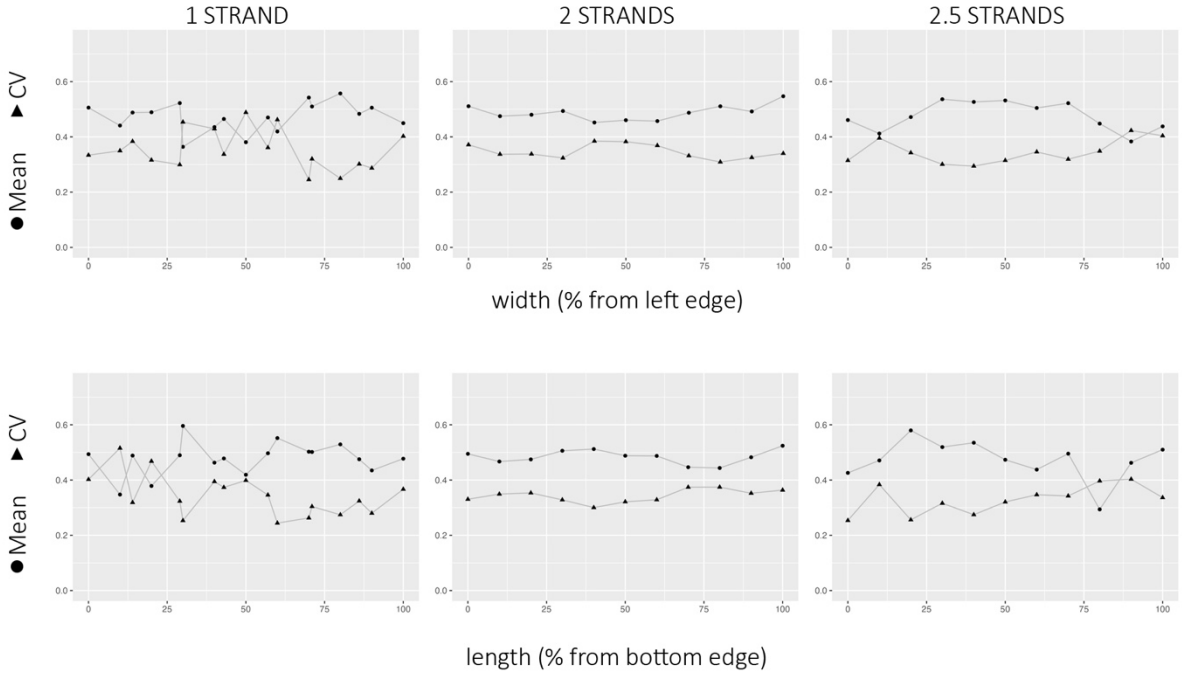
Knot Shape:

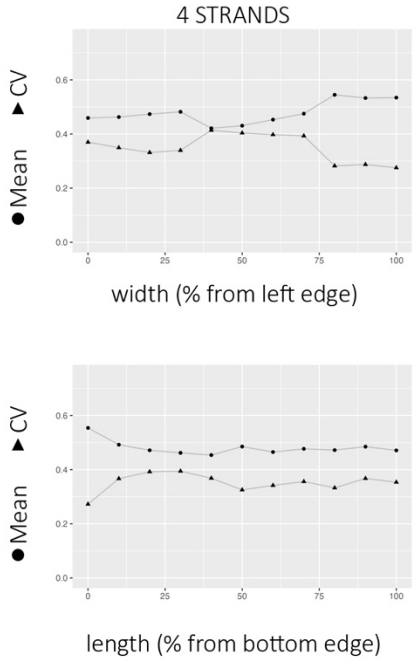
average p-value:	<0.001*
median p-value:	<0.001*

Student's Test (T-statistic) for Shape:
not applicable, unequal variances

Knot Size

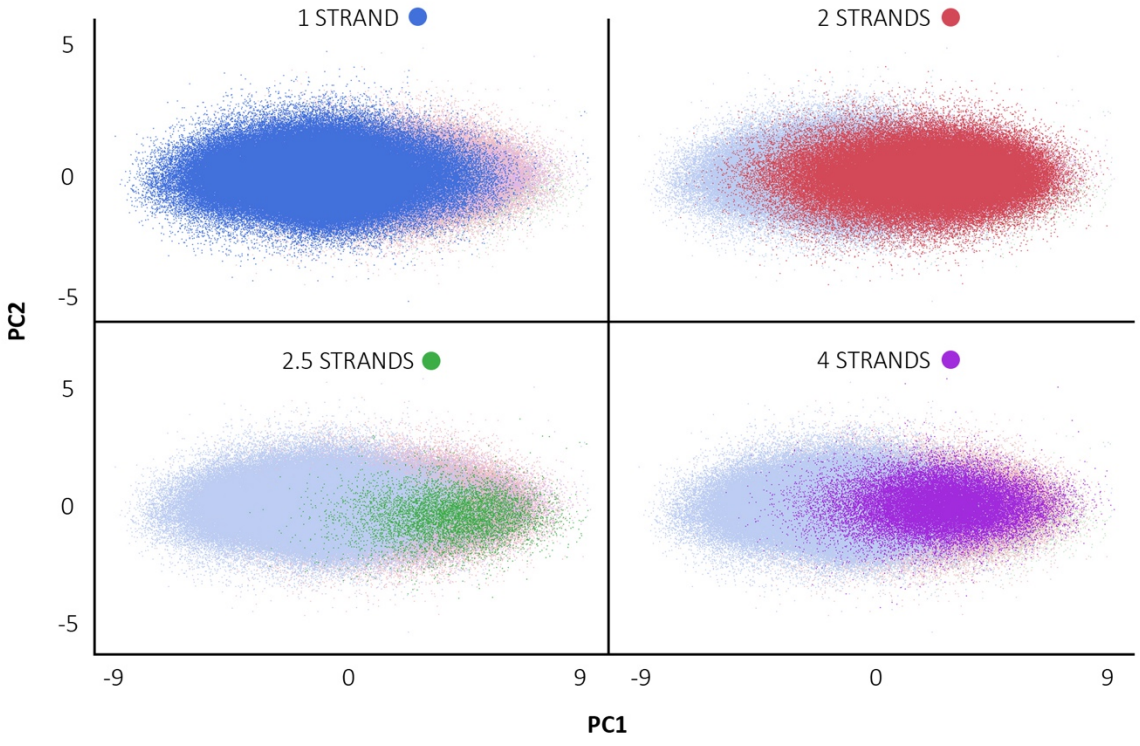
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





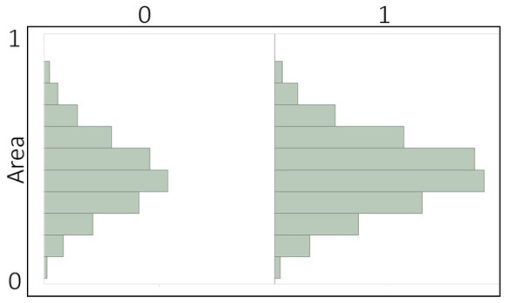
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



TENSION RODS - BOTTOM

Variable Class: Technological
Variable Type: Numeric-Discrete (functions like categorical-ordinal)
Observations (n_k / n_c): 0 Rods (191,701/7); 1 Rod (336,429/23)
Duplicating Variables: none
Reference Page: 309



Levene's Test (F-statistic):

Knot Size:

average p-value:	0.511
median p-value:	0.479

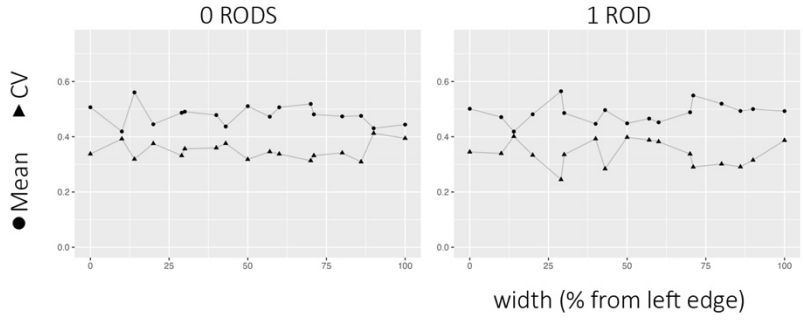
Knot Shape:

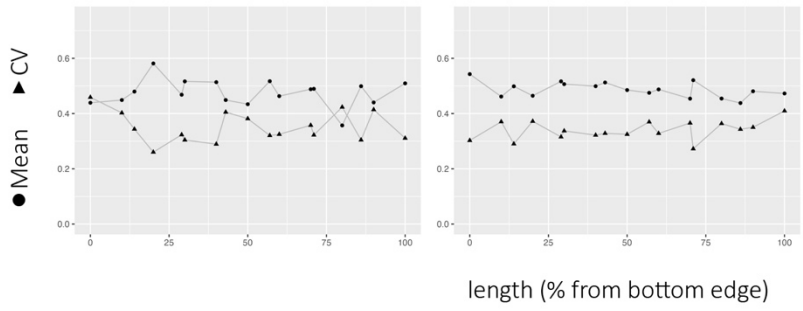
average p-value:	<0.001*
median p-value:	<0.001*

Student's Test (T-statistic) for Shape:
not applicable, unequal variances

Knot Shape

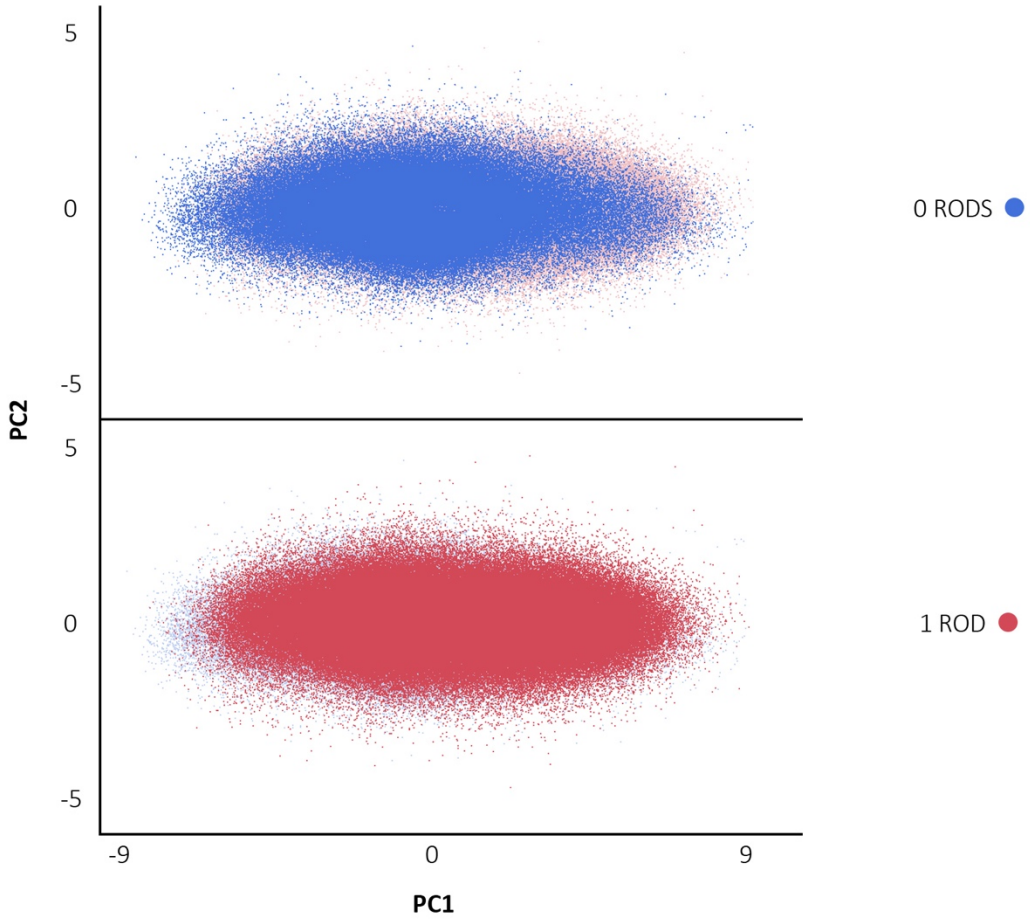
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





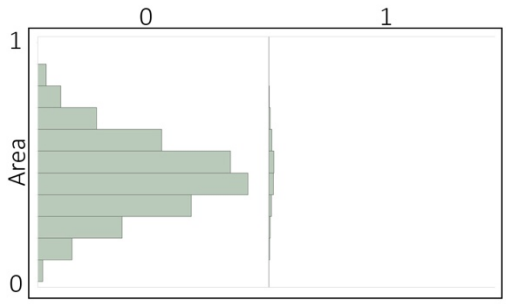
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



TENSION RODS - TOP

Variable Class: Technological
Variable Type: Numeric-Discrete (functions like categorical-ordinal)
Observations (n_k / n_c): 0 Rods (516,830/27); 1 Rod (11,300/3)
Duplicating Variables: none
Reference Page: 309



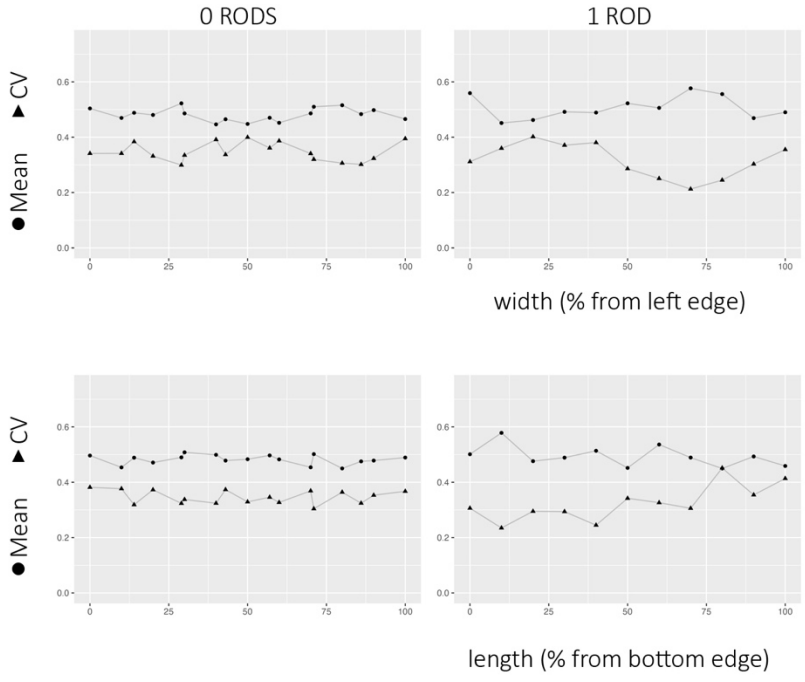
Levene's Test (F-statistic):
Knot Size:
average p-value: 0.001*
median p-value: <0.001*

Knot Shape:
average p-value: <0.001*
median p-value: <0.001*

Student's Test (T-statistic) for Shape:
not applicable, unequal variances

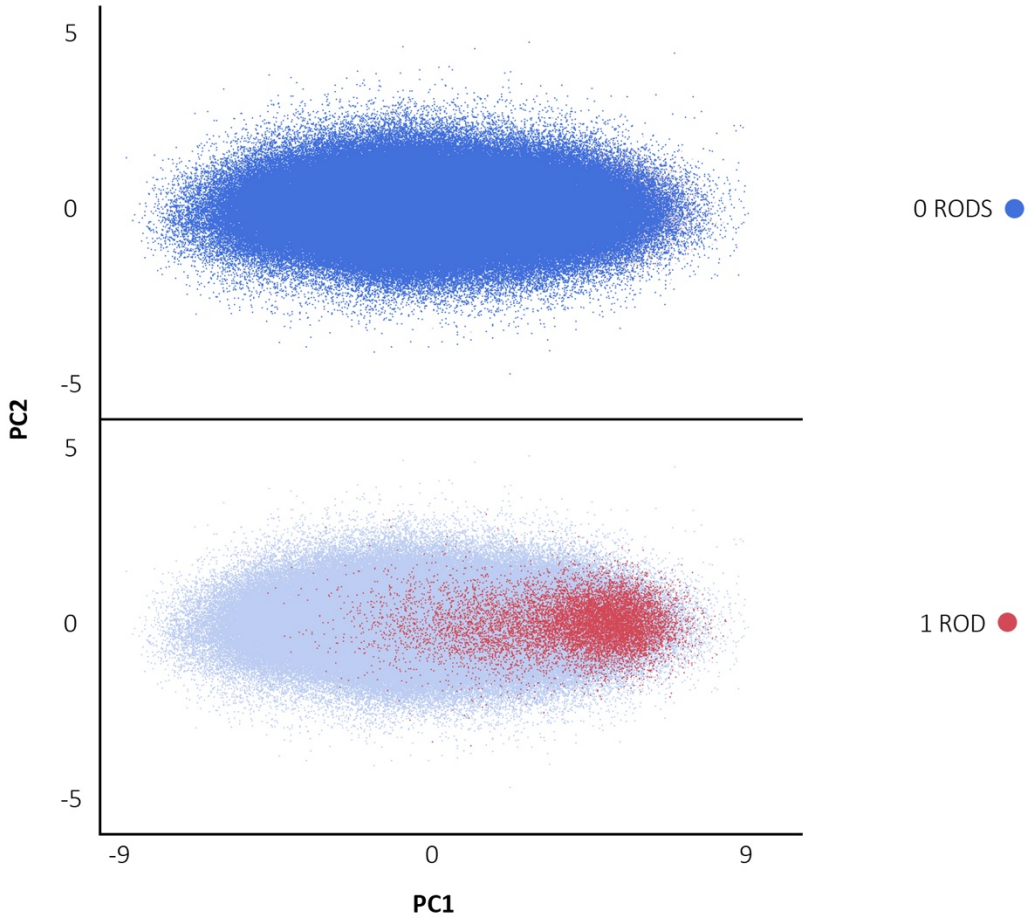
Knot Size

Ethnographic Knot Size Means & CVs, by Carpet Width & Length



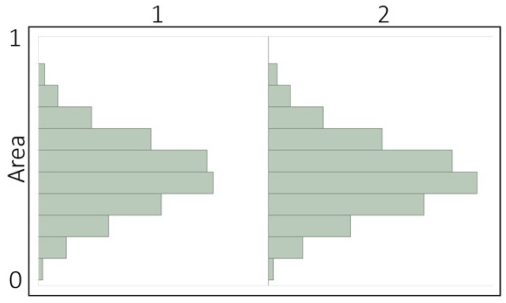
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



TRIM FREQUENCY

Variable Class: Structural
Variable Type: Numeric-Discrete (operates as categorical-ordinal)
Observations (n_k / n_c): 1 Row (246,103/14); 2 (282,027/16)
Duplicating Variables: none
Reference Page: 349



Levene's Test (F-statistic):

Knot Size:

average p-value: 0.494
median p-value: 0.509

Knot Shape:

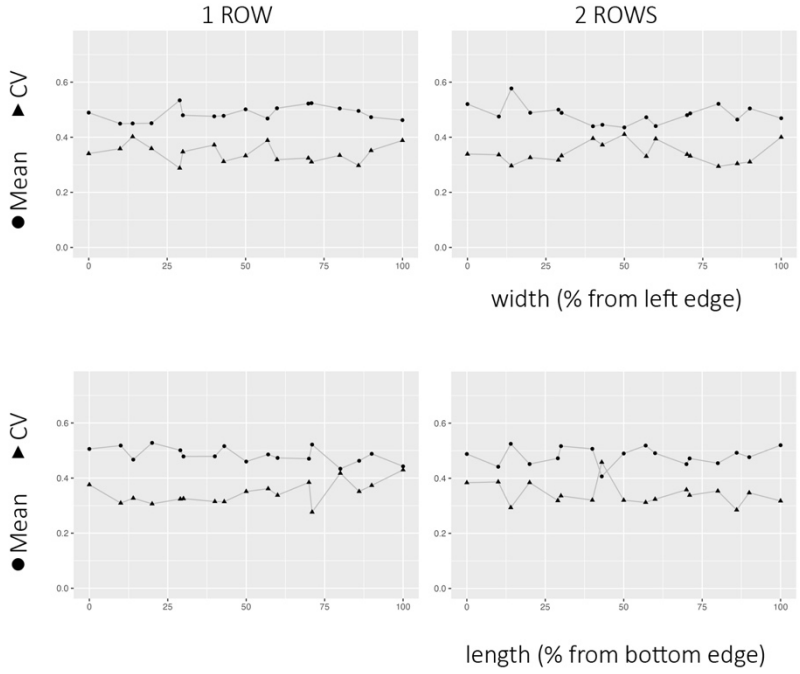
average p-value: <0.001*
median p-value: <0.001*

Student's Test (T-statistic) for Shape:

not applicable, unequal variances

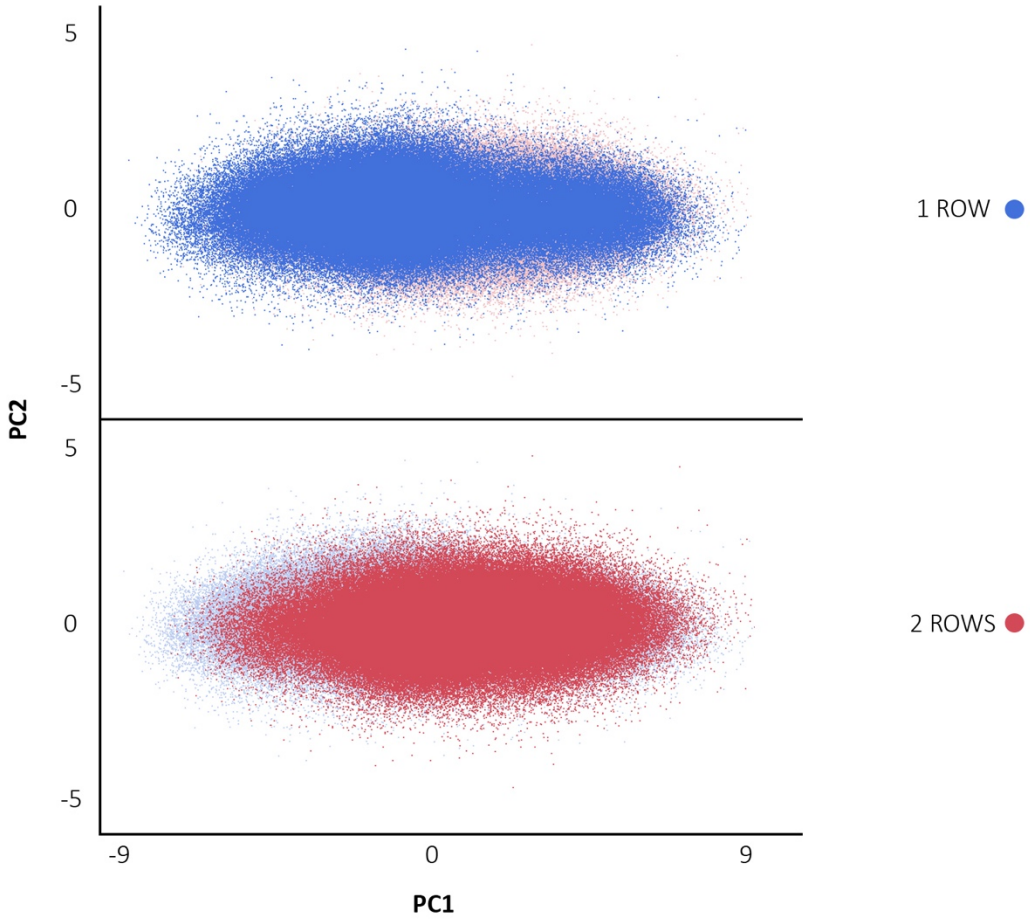
Knot Size

Ethnographic Knot Size Means & CVs, by Carpet Width & Length



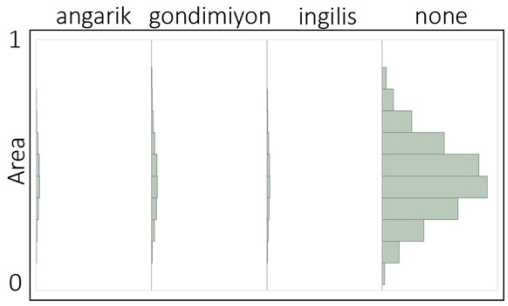
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



VILLAGE

Variable Class: Idiosyncratic
Variable Type: Categorical
Observations (n_k / n_c): Angarik (15,327/2); Gondimiyon (28,172/4); Ingilis (12,996/2); None (471,635/22)
Duplicating Variables: none
Reference Page: 360



Levene's Test (F-statistic):

Knot Size:

average p-value: 0.001*
median p-value: <0.001*

Knot Shape:

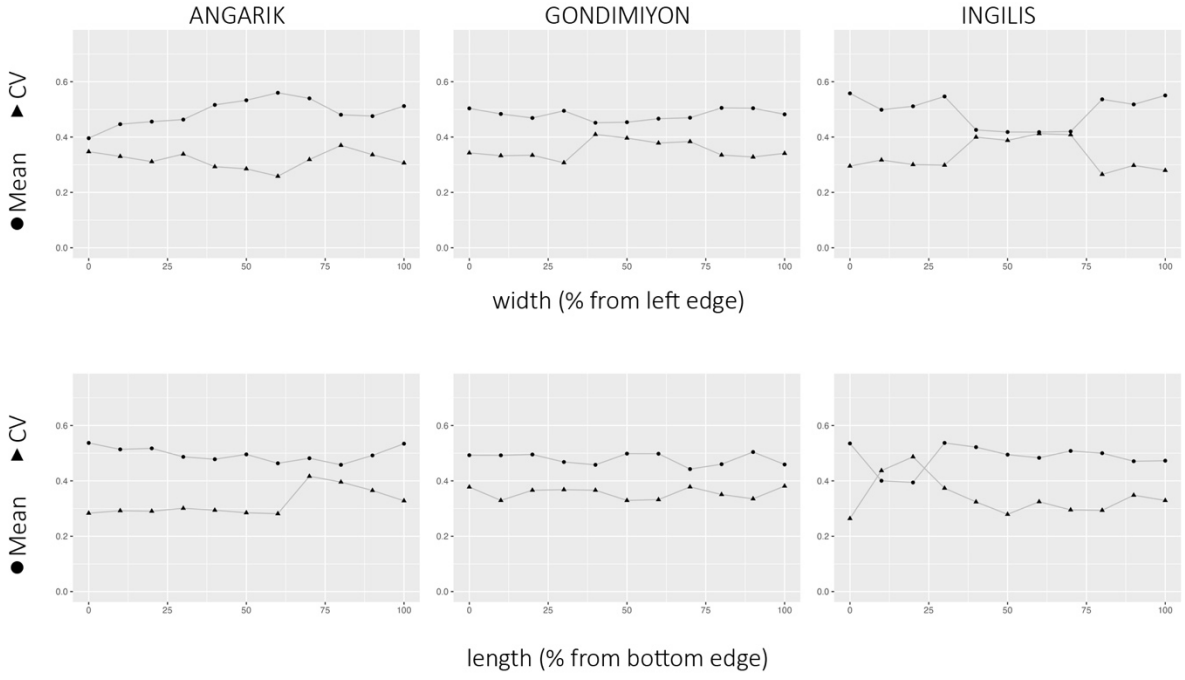
average p-value: <0.001*
median p-value: <0.001*

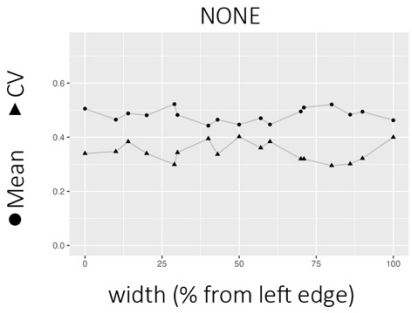
Student's Test (T-statistic) for Shape:

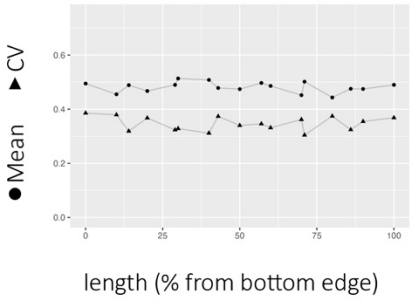
not applicable, unequal variances

Knot Size

Ethnographic Knot Size Means & CVs, by Carpet Width & Length

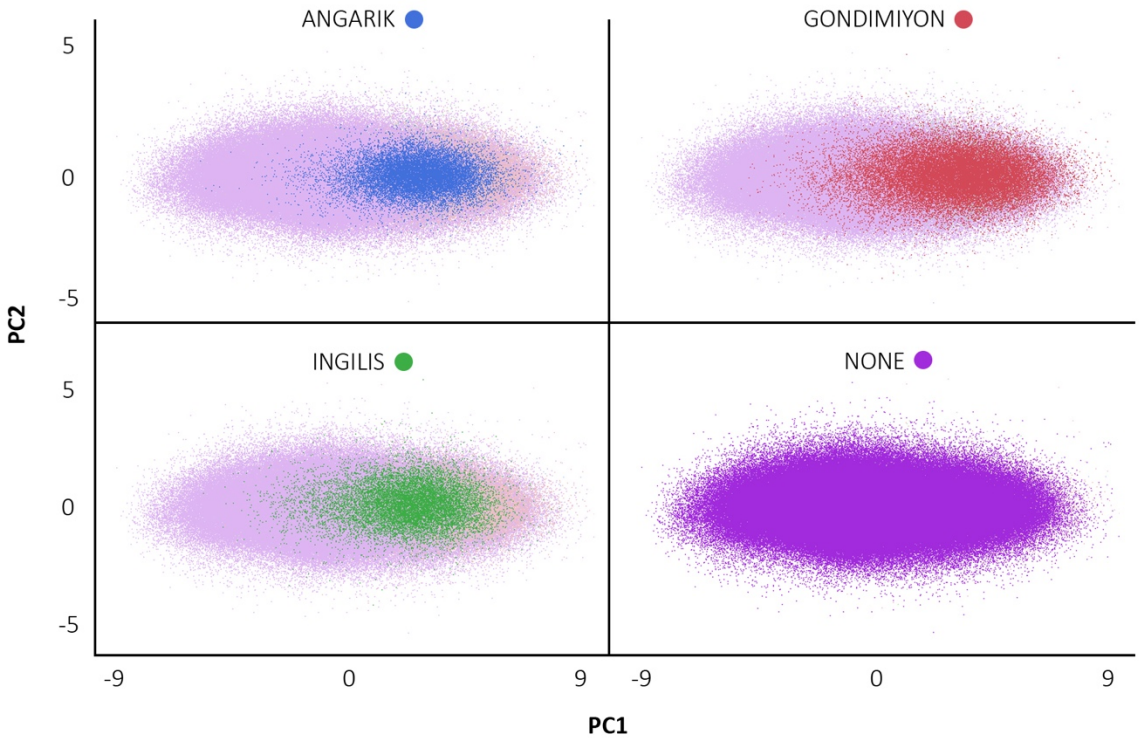






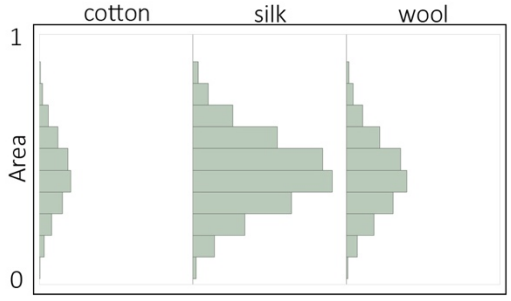
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



WARP MATERIAL

Variable Class: Structural
Variable Type: Categorical
Observations (n_k / n_c): Cotton (72,491/12); Silk (316,603/8); Wool (139,036/10)
Duplicating Variables: none
Reference Page: 313



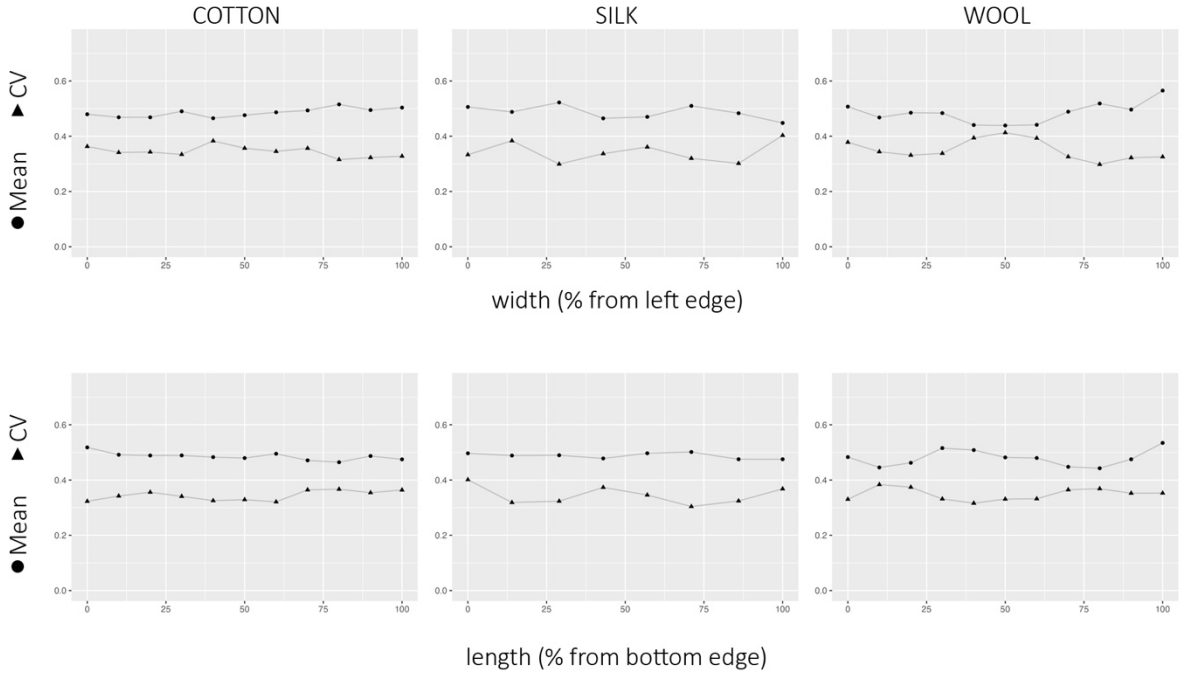
Levene's Test (F-statistic):
Knot Size:
F average p-value: 0.271
F median p-value: 0.208

Knot Shape:
F average p-value: <0.001*
F median p-value: <0.001*

Student's Test (T-statistic) for Shape:
not applicable, unequal variances

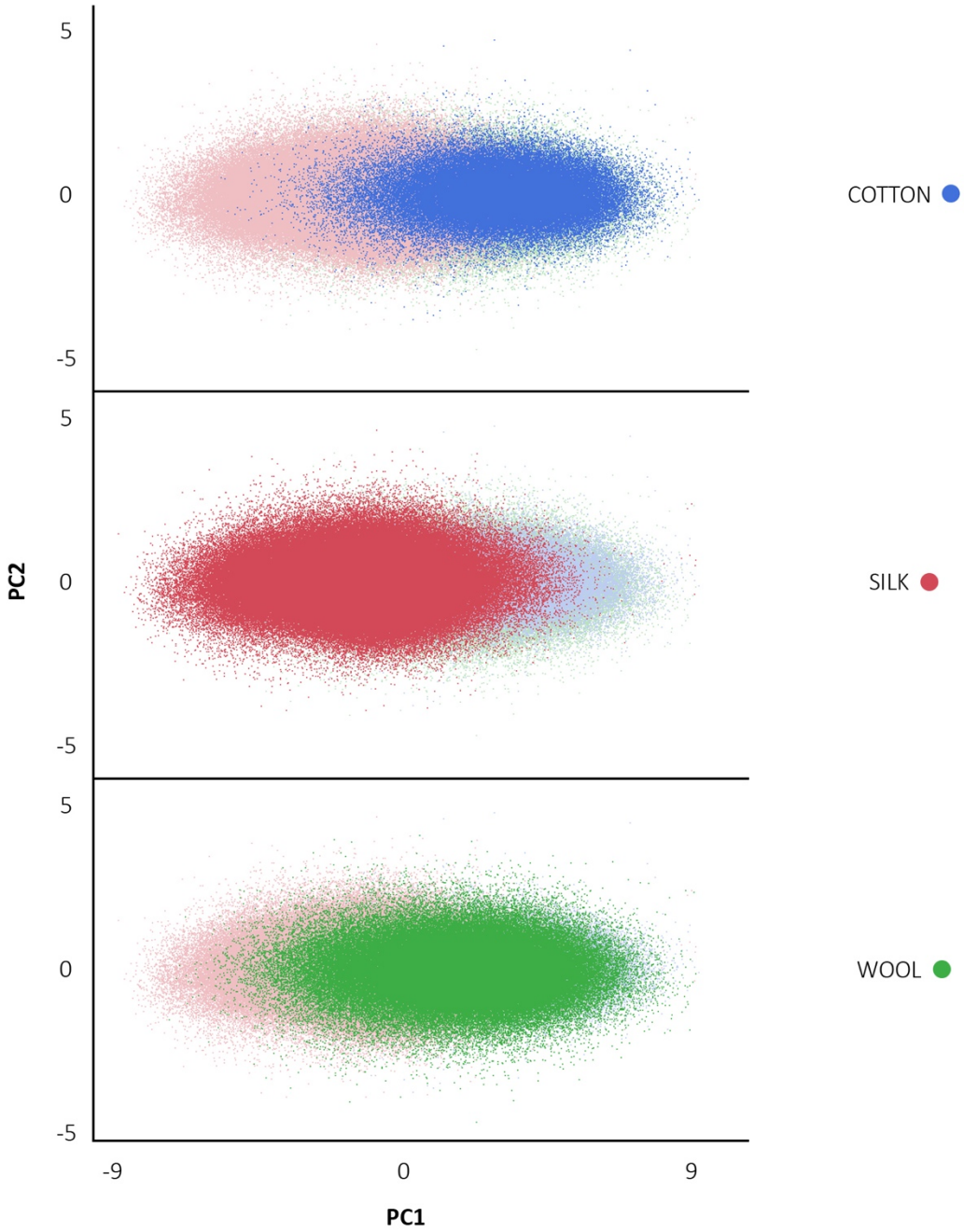
Knot Size

Ethnographic Knot Size Means & CVs, by Carpet Width & Length



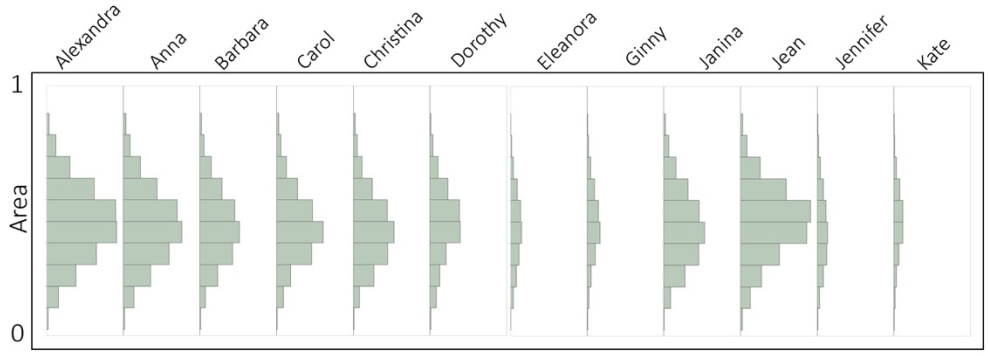
Knot Shape

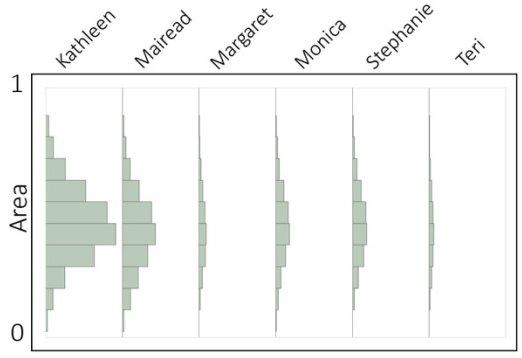
Ethnographic Knot Shapes, condensed to Two Principal Components



WEAVER (PSEUDONYM)

Variable Class: Idiosyncratic
Variable Type: Categorical
Observations (n_k / n_c): Alexandra (50,649/2); Anna (41,652/3); Barbara (27,598/2); Carol (28,236/1); Christina (27,247/2); Dorothy (19,883/1); Eleanora (15,515/1); Ginny (15,327/2); Janina (56,406/2); Jean (86,090/2); Jennifer (14,494/2); Kate (11,300/3); Kathleen (63,140/1); Mairead (32,082/1); Margaret (7,141/1); Monica (12,996/2); Stephanie (13,678/2); Teri (4,696/1)
Duplicating Variables: none
Reference Page: 356



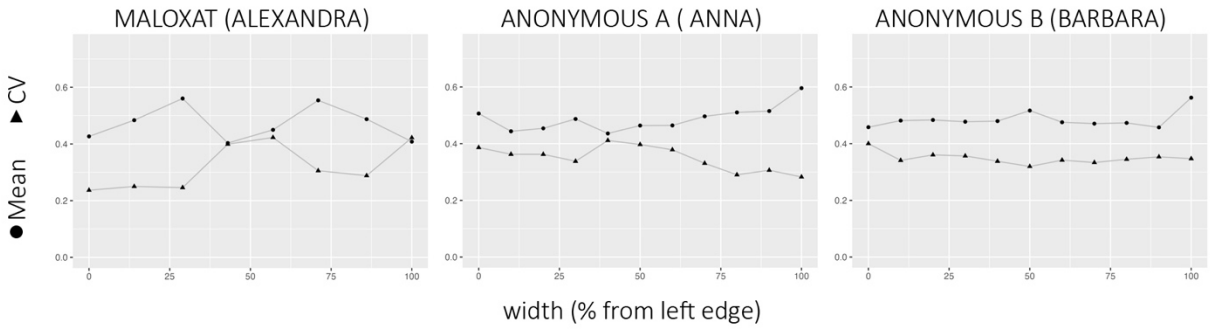


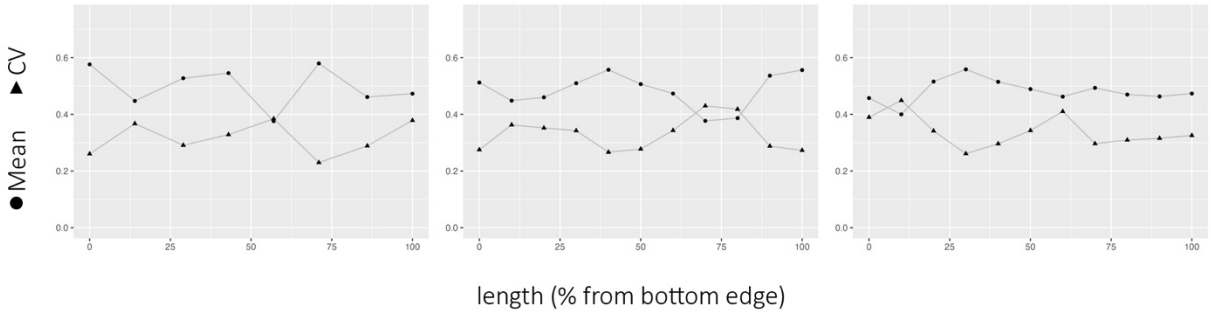
Levene's Test (F-statistic):
- Knot Size:
  - average p-value: <0.001*
  - median p-value: <0.001*
- Knot Shape:
  - average p-value: <0.001*
  - median p-value: <0.001*

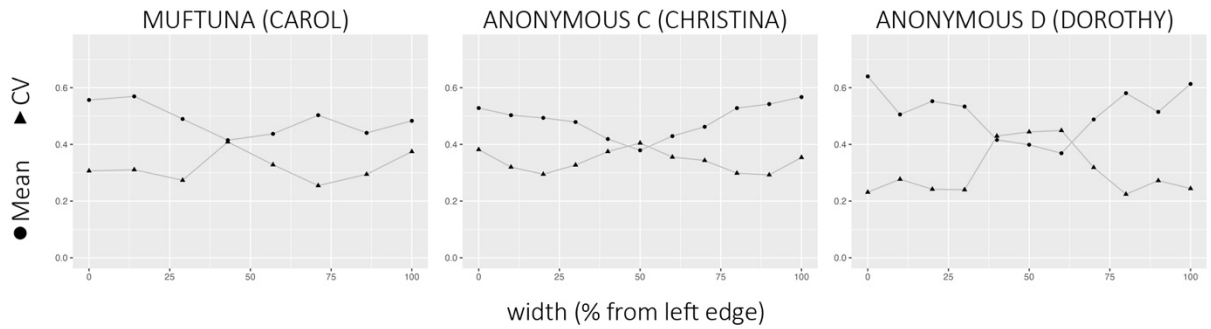
Student's Test (T-statistic) for Shape:
not applicable, unequal variances

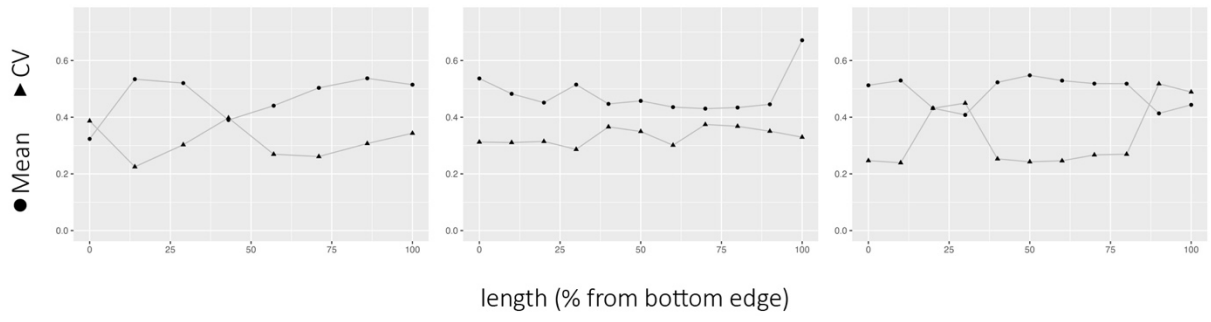
Knot Size

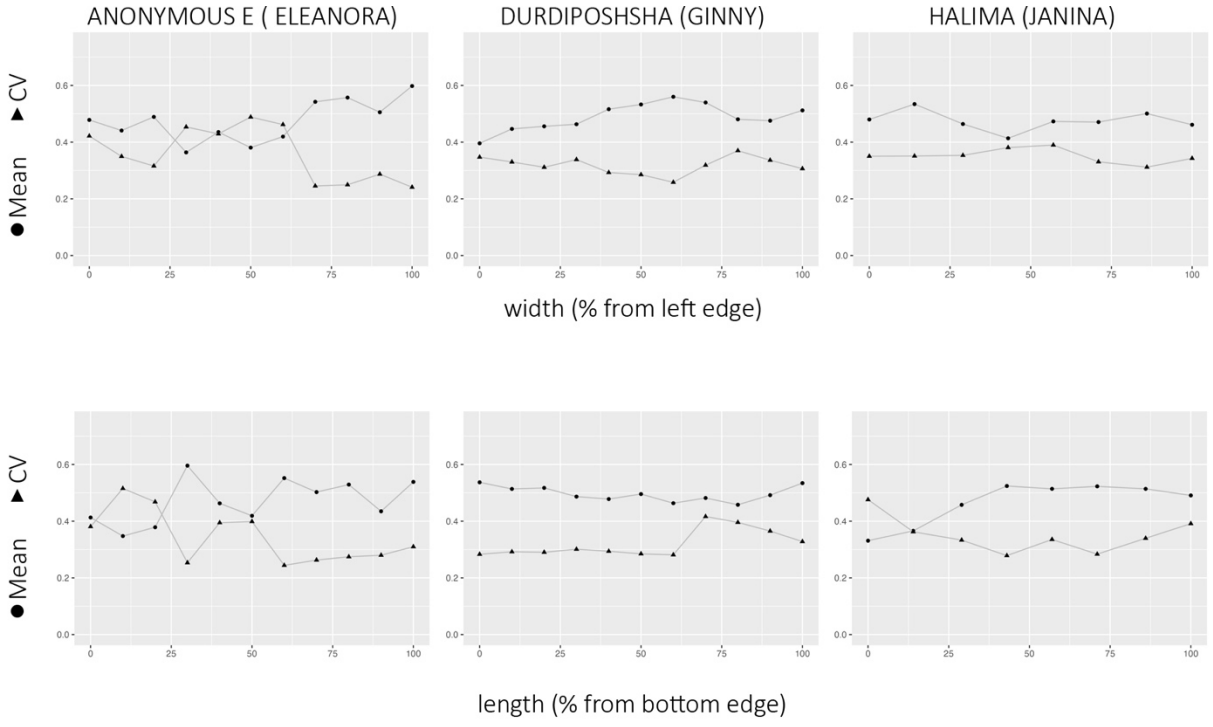
Ethnographic Knot Size Means & CVs, by Carpet Width & Length

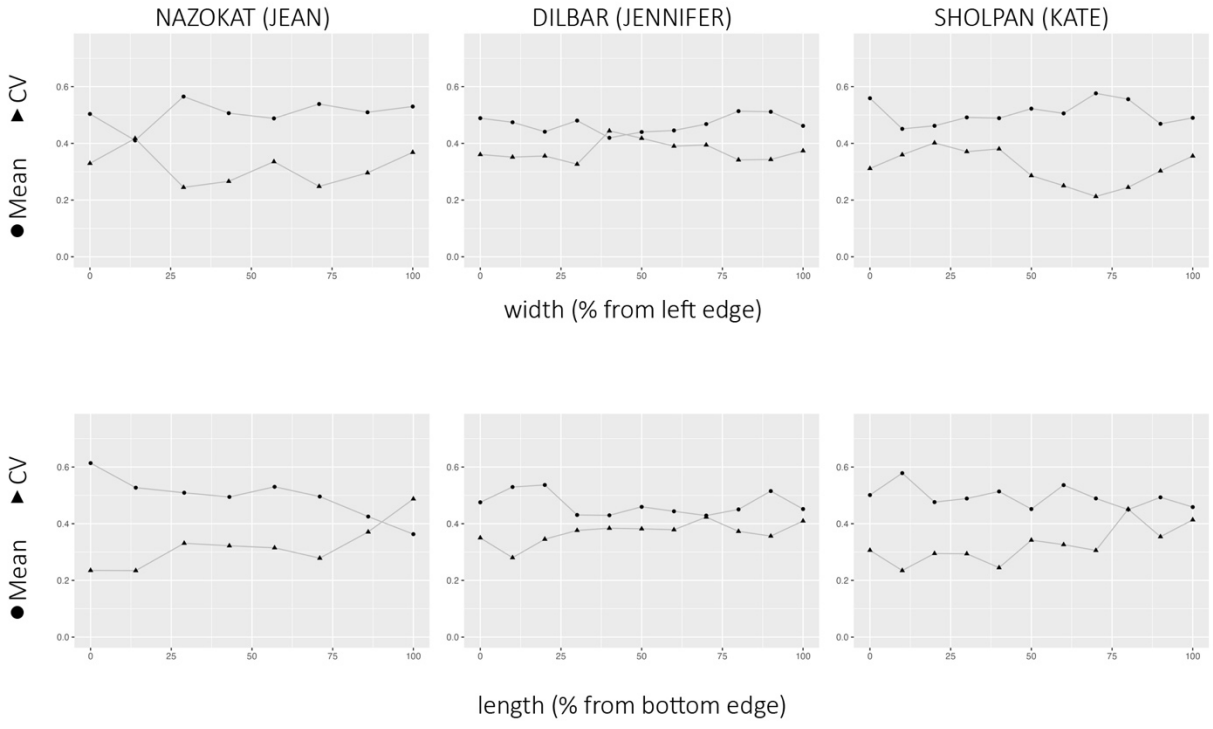


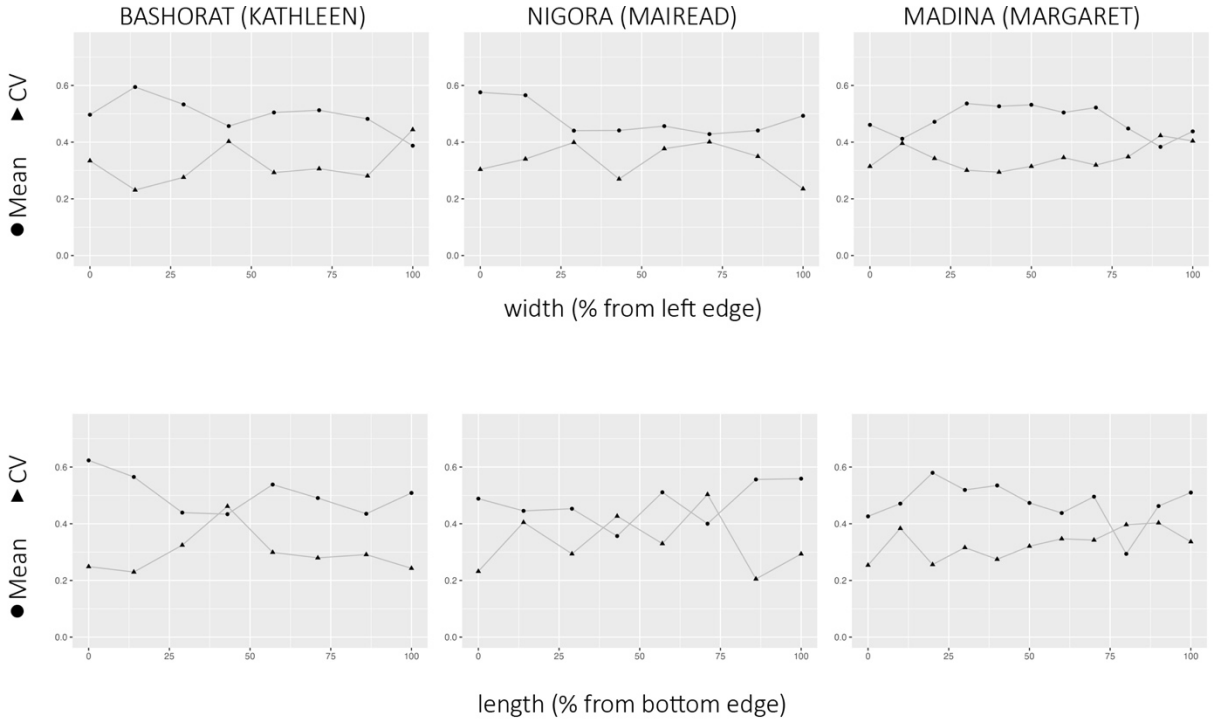


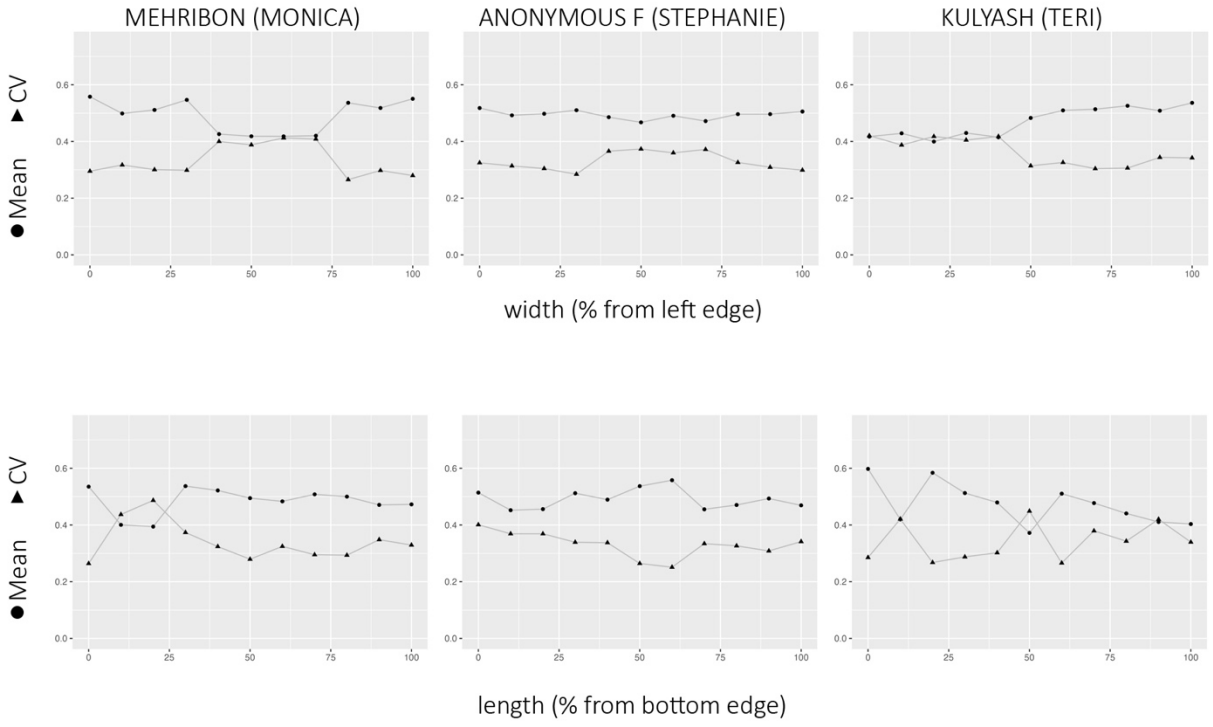





ANONYMOUS E (ELEANORA)
DURDIPOSHSHA (GINNY)
HALIMA (JANINA)
▲CV
●Mean
width (% from left edge)
length (% from bottom edge)

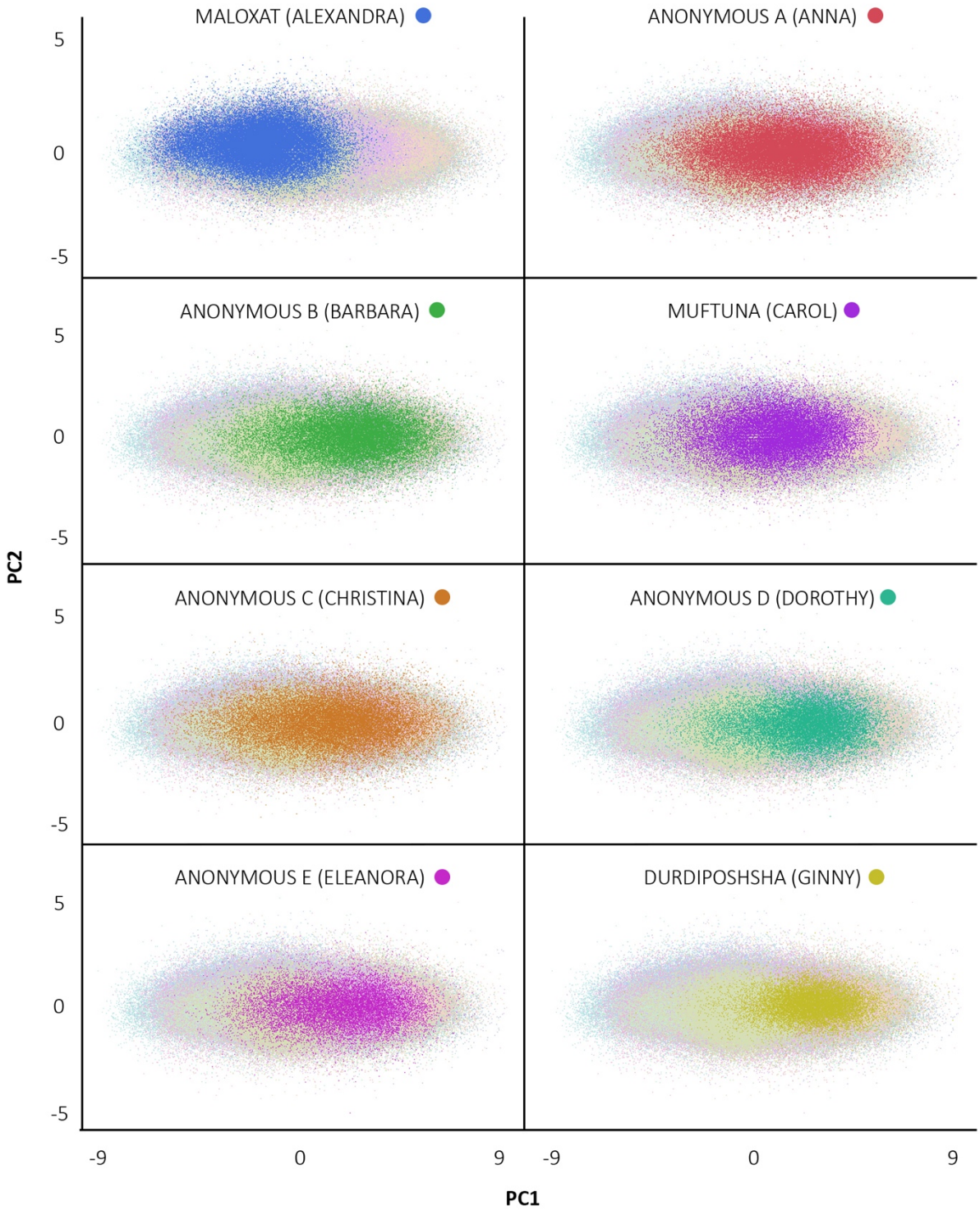

NAZOKAT (JEAN)
DILBAR (JENNIFER)
SHOLPAN (KATE)
▲CV
●Mean
width (% from left edge)
length (% from bottom edge)

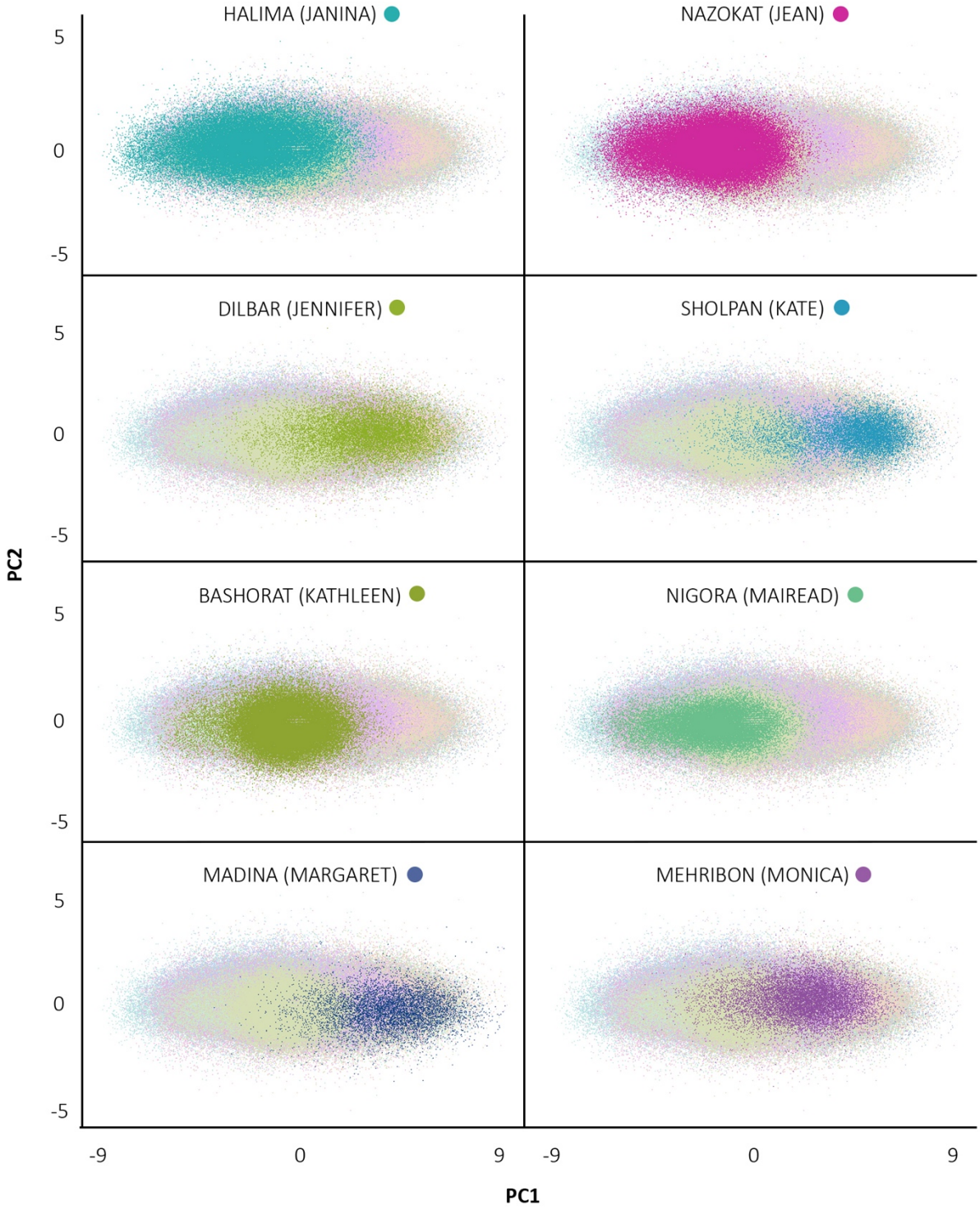

BASHORAT (KATHLEEN)
NIGORA (MAIREAD)
MADINA (MARGARET)
▲ CV
● Mean
width (% from left edge)
length (% from bottom edge)

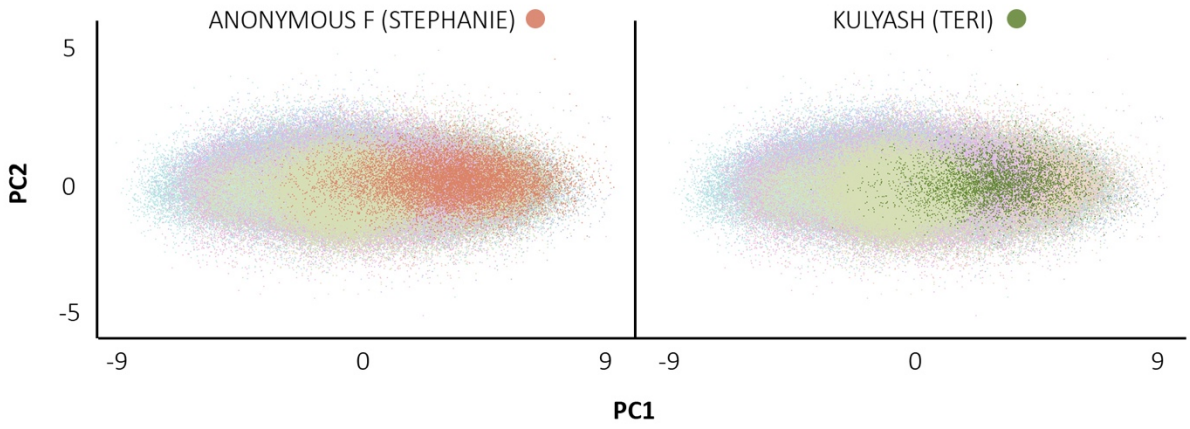

MEHRIBON (MONICA)
ANONYMOUS F (STEPHANIE)
KULYASH (TERI)
▲ CV
● Mean
width (% from left edge)
length (% from bottom edge)

Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components

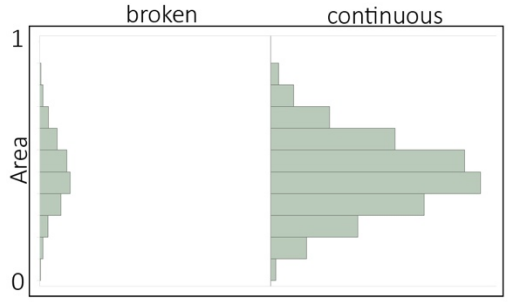



HALIMA (JANINA)
NAZOKAT (JEAN)
DILBAR (JENNIFER)
SHOLPAN (KATE)
BASHORAT (KATHLEEN)
NIGORA (MAIREAD)
MADINA (MARGARET)
MEHRIBON (MONICA)
5
0
-5
-9
0
9
PC1
PC2


ANONYMOUS F (STEPHANIE)
KULYASH (TERI)
5
0
-5
PC2
-9
0
9
-9
0
9
PC1

WEFT ADDITION RATE

Variable Class: Technological
Variable Type: Categorical
Observations (n_k / n_c): Broken (63,140/1); Continuous (464,990/29)
Duplicating Variables: none
Reference Page: 344



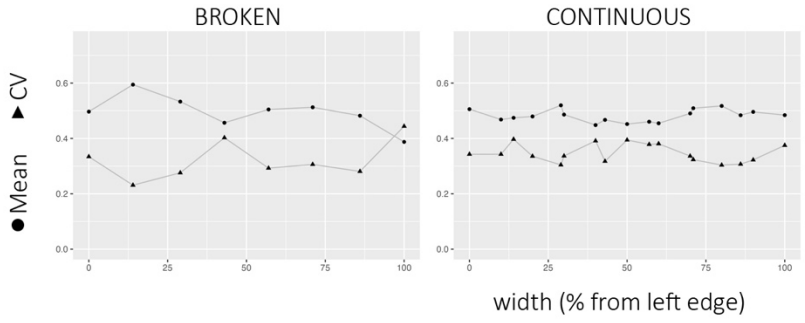
Levene's Test (F-statistic):
Knot Size:
average p-value: 0.070
median p-value: 0.004*

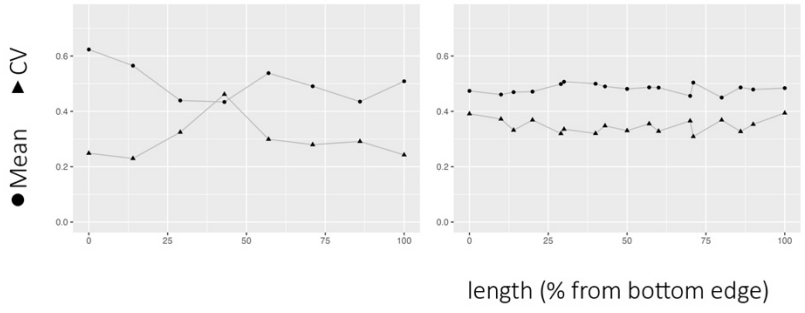
Knot Shape:
average p-value: <0.001*
median p-value: <0.001*

Student's Test (T-statistic) for Shape:
not applicable, unequal variances

Knot Size

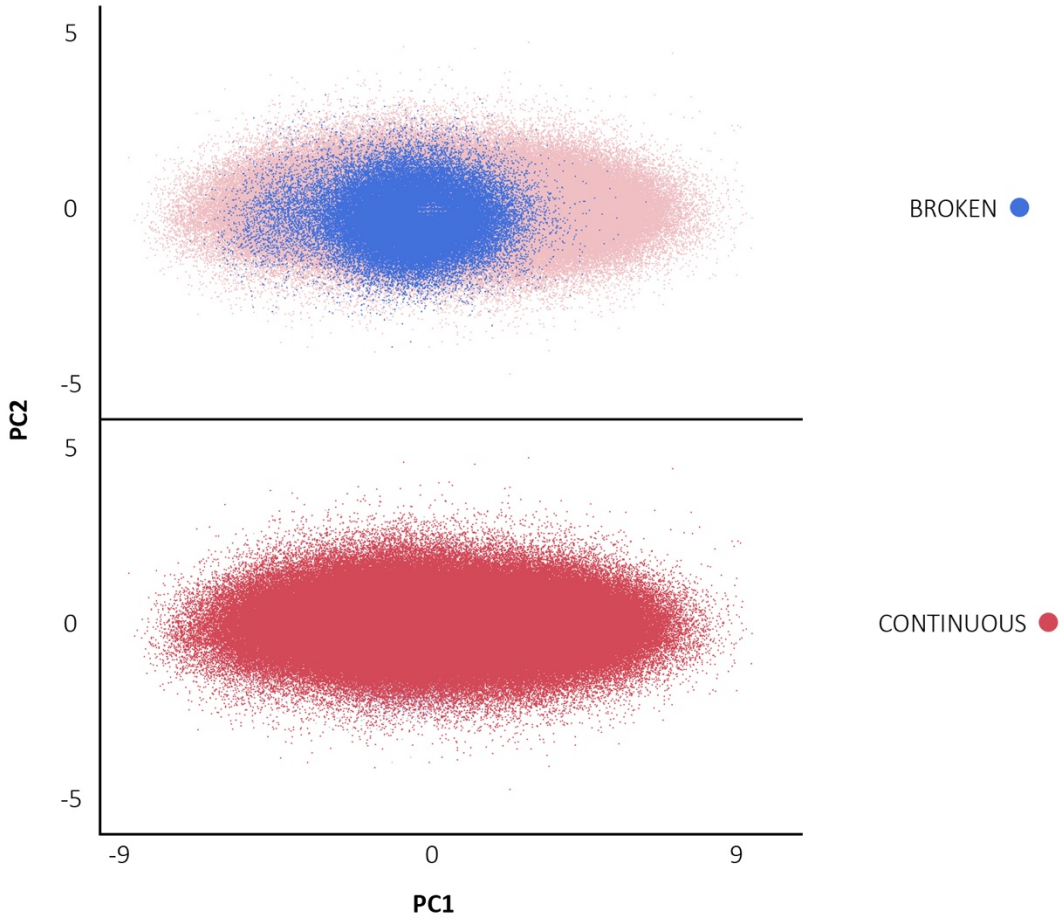
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





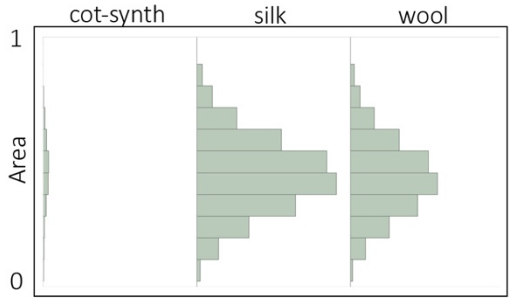
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



WEFT MATERIAL

Variable Class: Structural
Variable Type: Categorical
Observations (n_k / n_c): Cotton-Synthetic (11,300/3); Silk (316,603/8); Wool (200,227/18)
Duplicating Variables: none
Reference Page: 313



Levene's Test (F-statistic):

Knot Size:

average p-value:	<0.001*
median p-value:	<0.001*

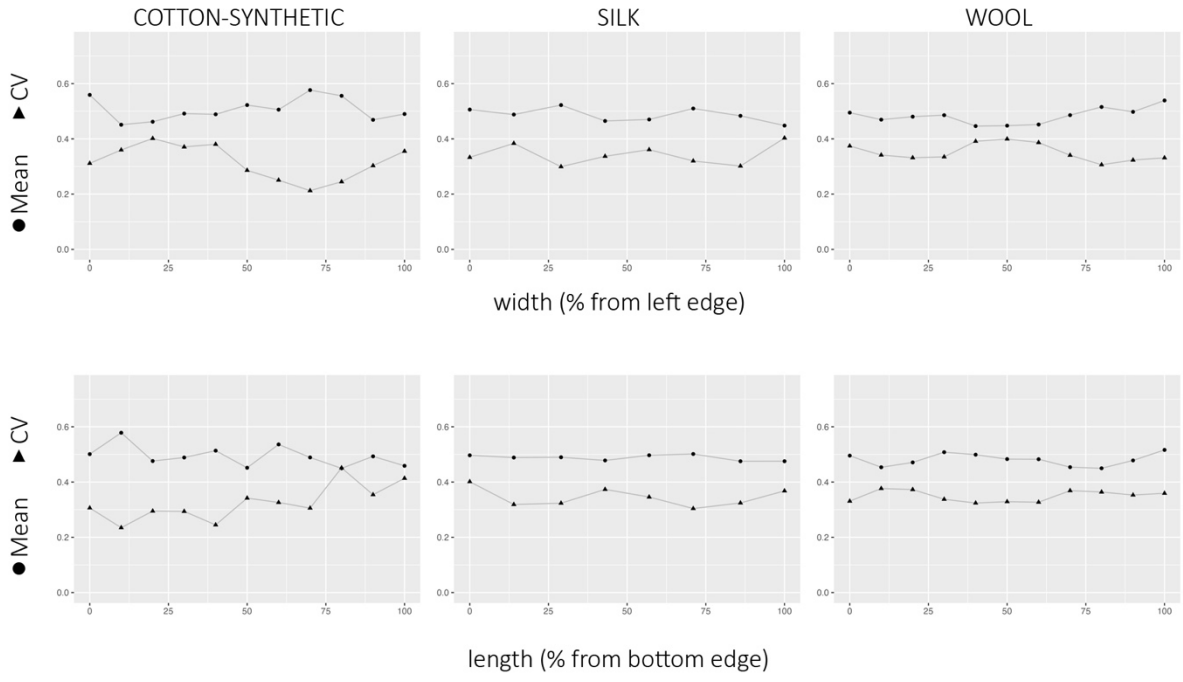
Knot Shape:

average p-value:	<0.001*
median p-value:	<0.001*

Student's Test (T-statistic) for Shape:
not applicable, unequal variances

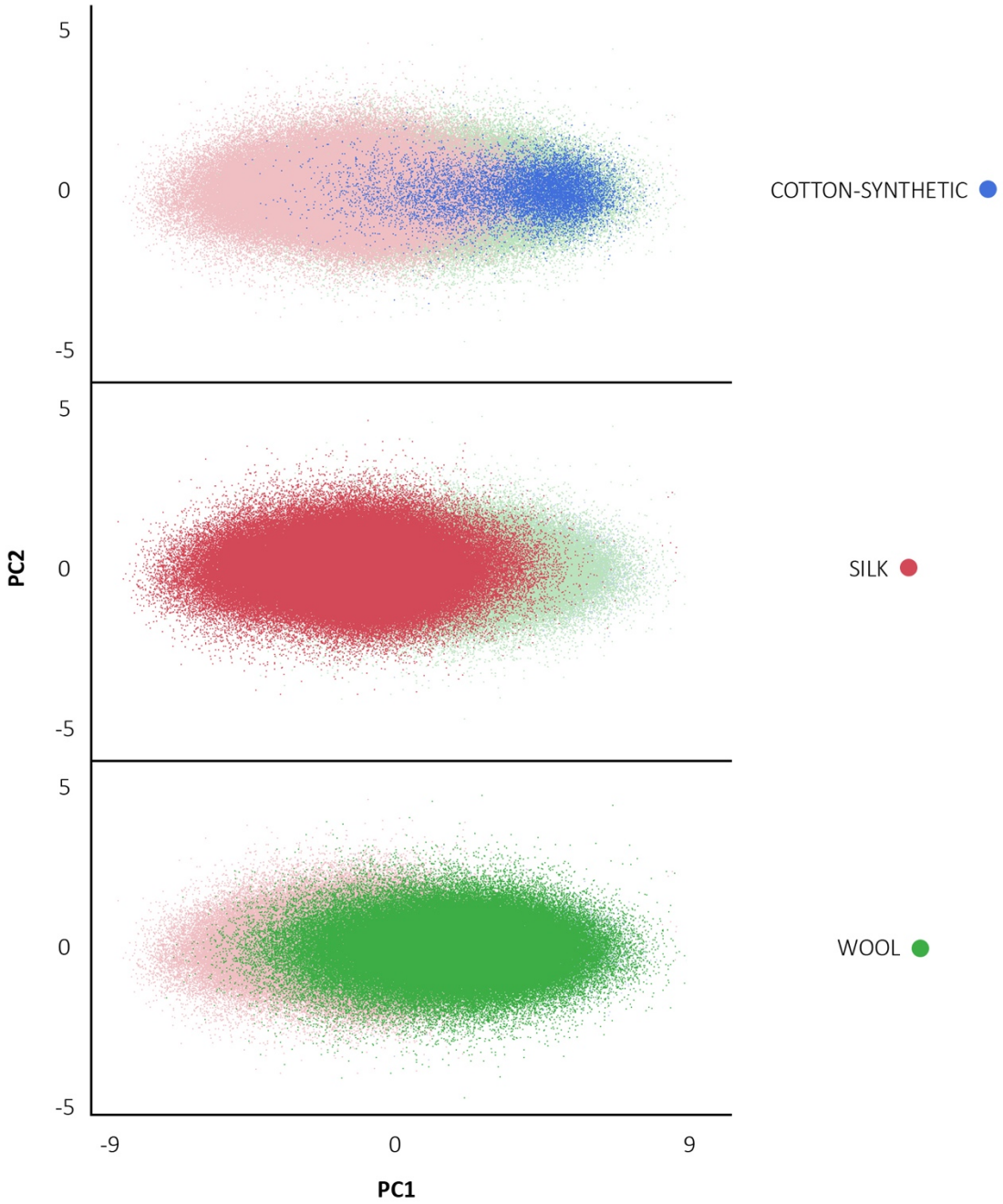
Knot Size

Ethnographic Knot Size Means & CVs, by Carpet Width & Length



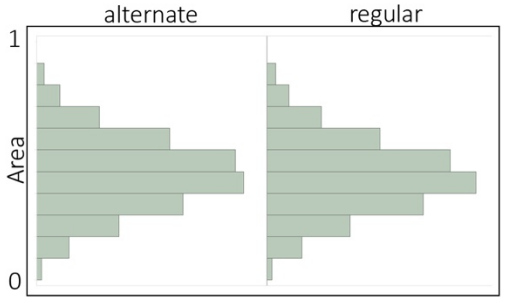
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



WEFT OFFSET PATTERN

Variable Class: Structural
Variable Type: Categorical
Observations (n_k / n_c): Alternate (268,081/17); Regular (260,049/13)
Duplicating Variables: none
Reference Page: 342



Levene's Test (F-statistic):

Knot Size:

average p-value: 0.526
median p-value: 0.639

Knot Shape:

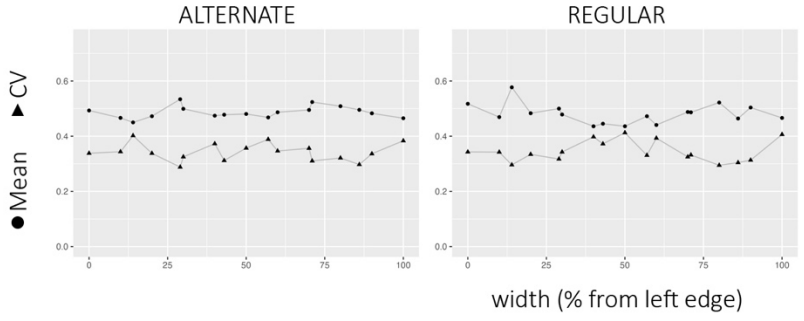
average p-value: <0.001*
median p-value: <0.001*

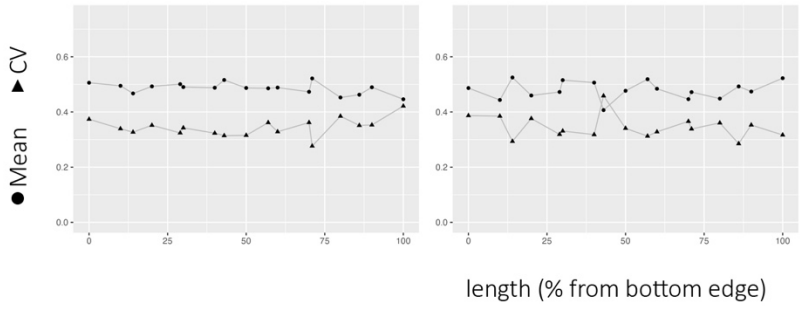
Student's Test (T-statistic) for Shape:

not applicable, unequal variances

Knot Size

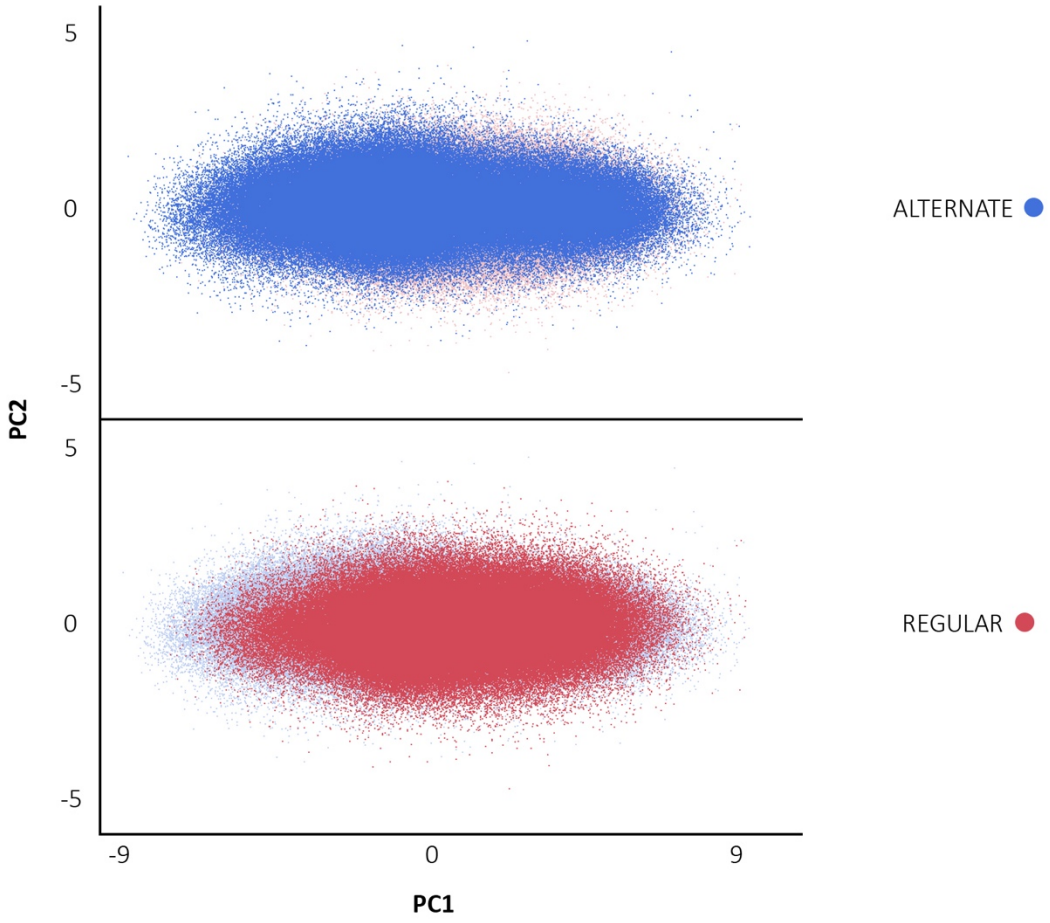
Ethnographic Knot Size Means & CVs, by Carpet Width & Length





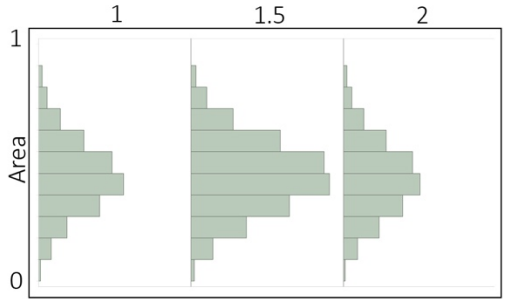
Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



WEFT SHOT PICK COUNT

Variable Class: Structural
Variable Type: Numeric-Discrete (functions like categorical-ordinal)
Observations (n_k / n_c): 1 Pick (141,899/7); 1.5 (249,640/13); 2 (136,591/10)
Duplicating Variables: none
Reference Page: 341



Levene's Test (F-statistic):

Knot Size:

average p-value:	0.144
median p-value:	0.033*

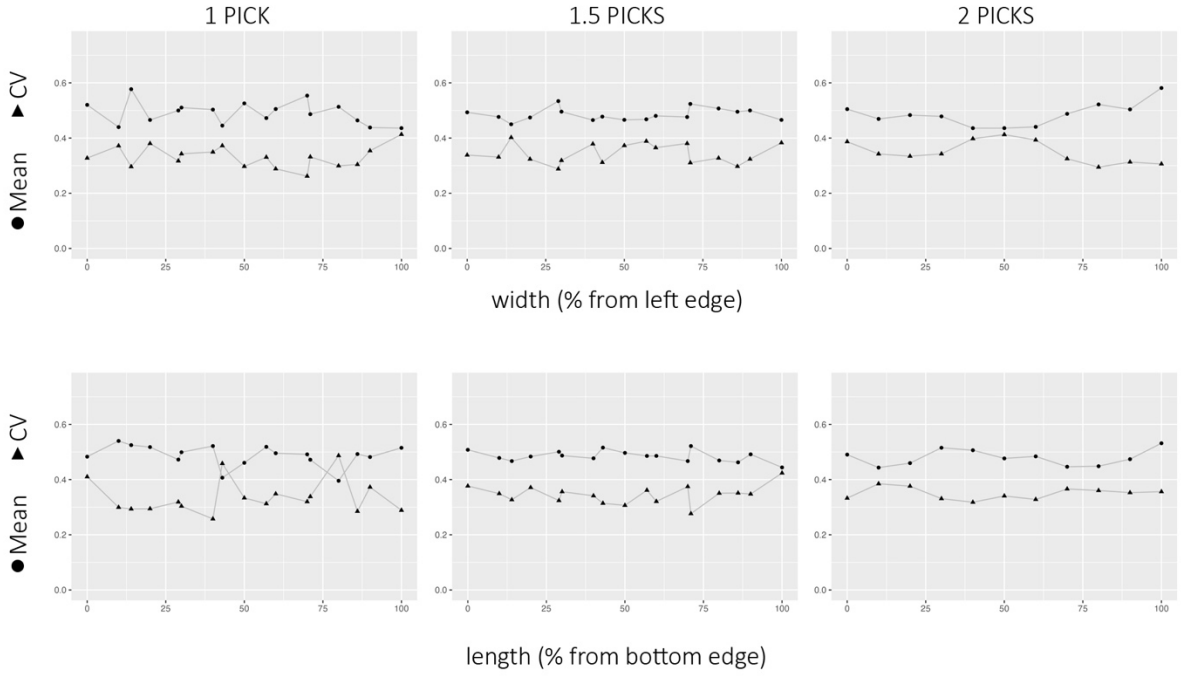
Knot Shape:

average p-value:	<0.001*
median p-value:	<0.001*

Student's Test (T-statistic) for Shape:
not applicable, unequal variances

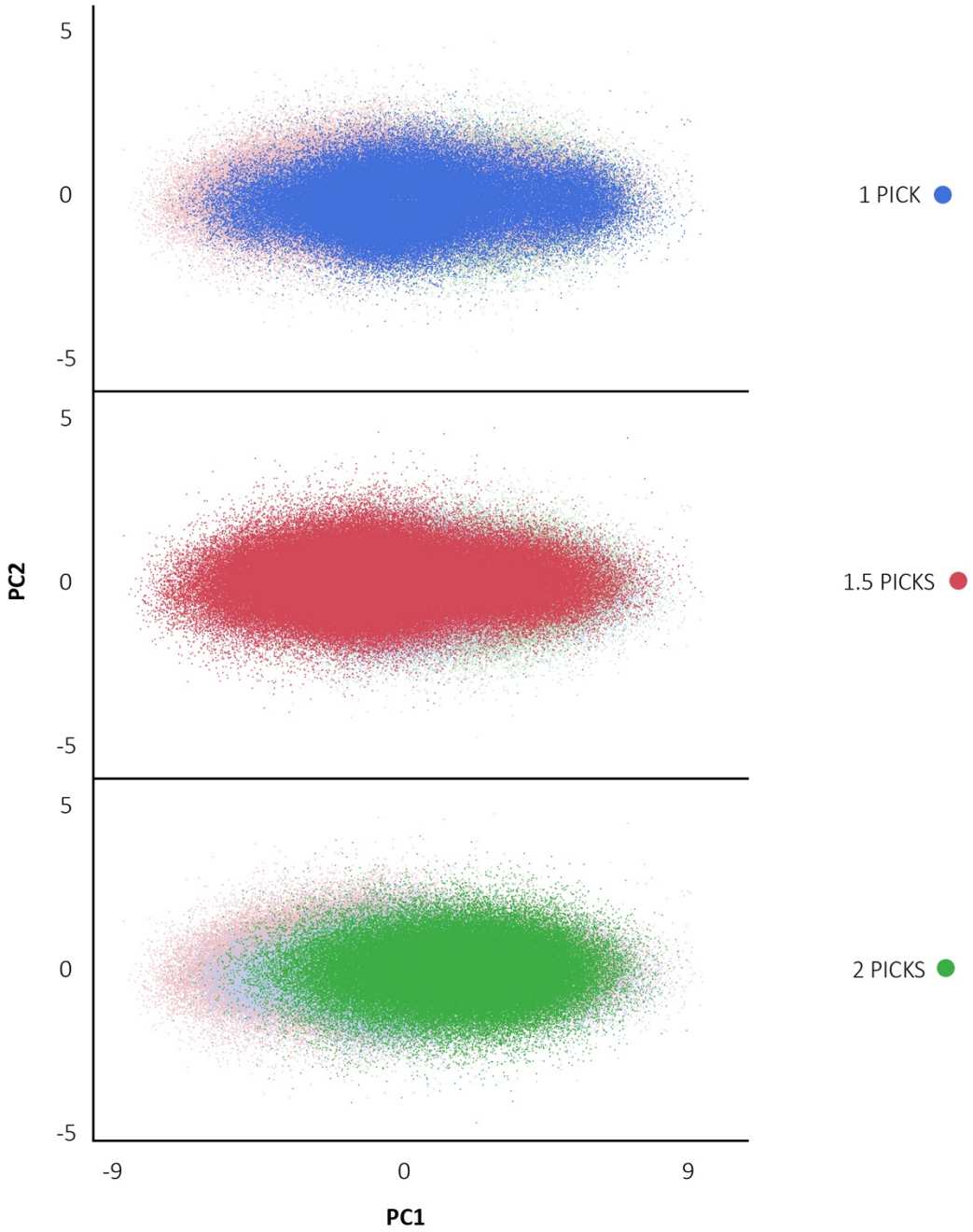
Knot Size

Ethnographic Knot Size Means & CVs, by Carpet Width & Length



Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



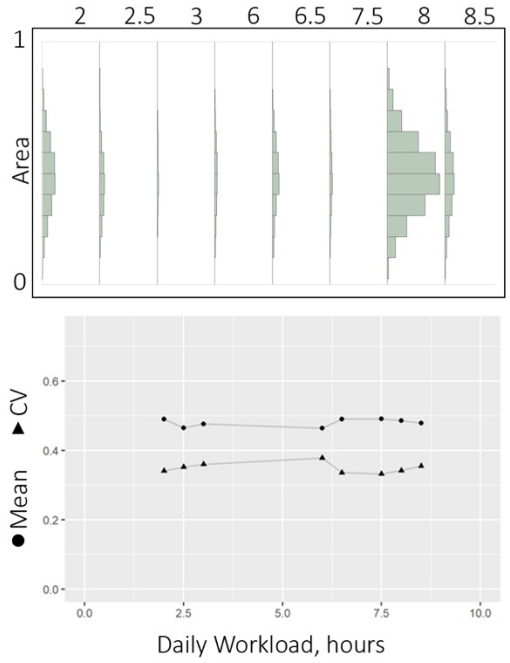
WORKLOAD

Variable Class: Idiosyncratic
Variable Type: Numeric-Continuous
Observations (n_k / n_c): 2 (77,596/6); 2.5 (27,247/2); 3 (7,141/1); 6 (15,515/1); 6.5 (35,210/3); 7.5 (13,678/2); 8 (297,095/11); 8.5 (54,648/5)
Duplicating Variables: none
Reference Page: 358

Levene's Test not applicable

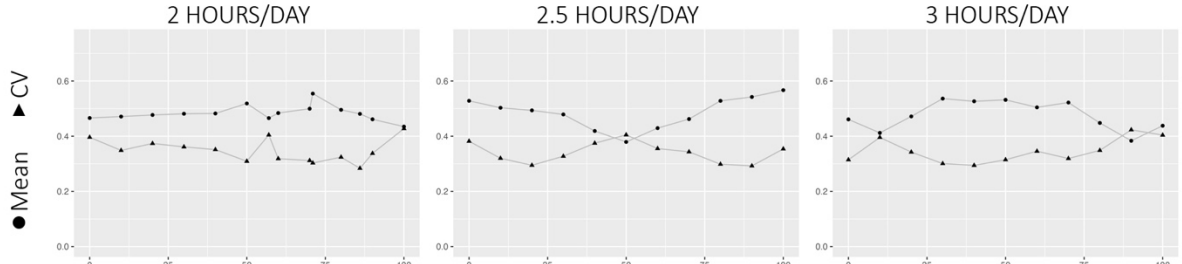
Linear Regression R^2:
Knot Size:
Mean: 0.067
CV: 0.020

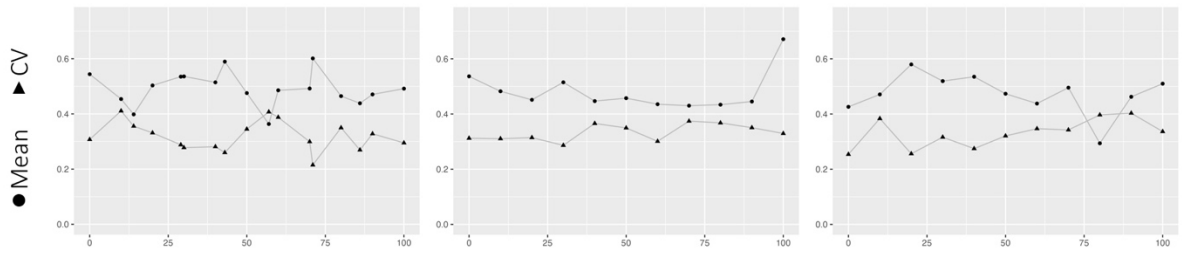
Knot Shape:
PC1: 0.001

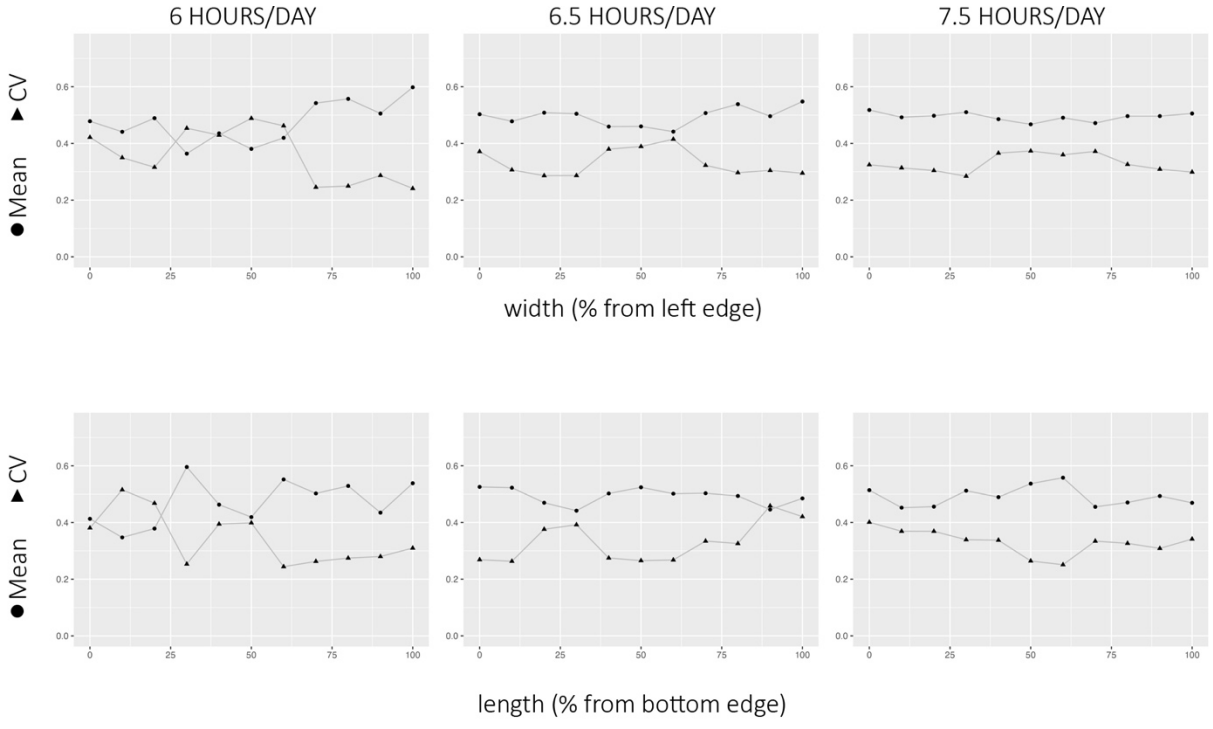


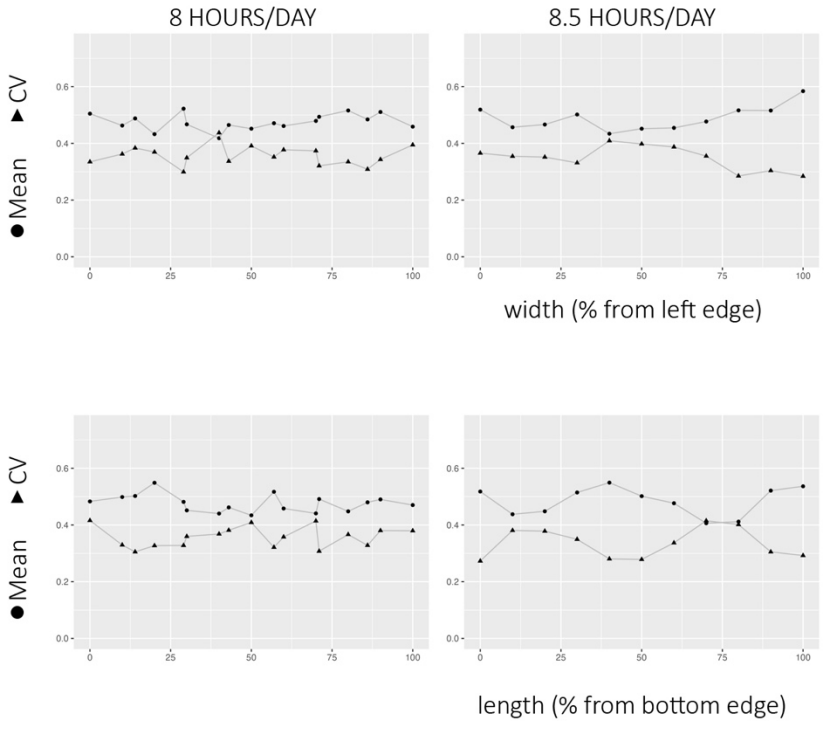
Knot Size

Ethnographic Knot Size Means & CVs, by Carpet Width & Length



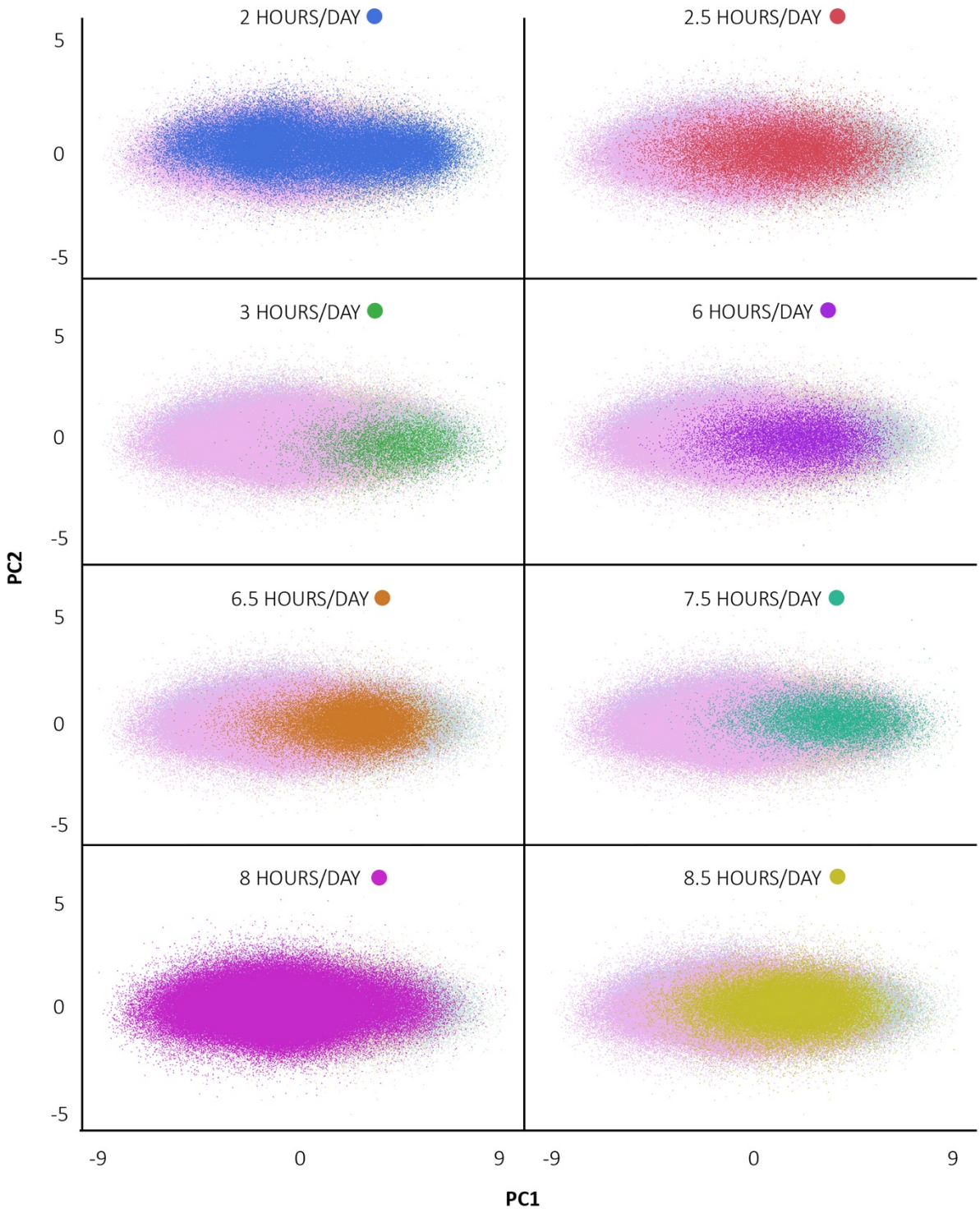



6 HOURS/DAY
6.5 HOURS/DAY
7.5 HOURS/DAY
● Mean ▲ CV
width (% from left edge)
length (% from bottom edge)


8 HOURS/DAY
8.5 HOURS/DAY
● Mean ▲ CV
width (% from left edge)
length (% from bottom edge)

Knot Shape

Ethnographic Knot Shapes, condensed to Two Principal Components



Appendix E. Historic Estimates

This section contains all of the estimates generated for the production characteristics of the historic sample. This includes estimates based on both the knot-size and knot-shape, where appropriate.

Historic Estimates Key

Size Comparisons:

Traits with the most similar distribution of mean knot size to the target carpet.

1: Most similar trait
2: Second most similar trait

Shape Comparisons:

Traits with the most similar distribution of knot shape (PC1/PC2) to the target carpet.

1: Most similar trait
2: Second most similar trait

Color Key:

estimated trait matches observed trait
estimated trait does not match observed trait
observed trait was not represented in ethnographic distributions*
estimated trait matches observed trait in a binary pair
invisible or unknown trait: estimate cannot be checked

** Observed trait given in footnotes for comparison*

Visible vs. Invisible Traits:

Visible traits are listed first, followed by invisible traits separated by dark border.

Other:

KSW = Khiva Silk Workshop
SSW = Samarkand Silk Workshop
Coll. = Collective
Dashes (-) used for fragmentary pieces where knot-size estimates are not appropriate

Refer to Appendix C for a table of all observed production characteristics for all carpets.

MU-AS-1 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R *	None
Knot Type	-	-	AS †	SY
Knot-Warp Pattern	-	-	II	I
Knot-Weft Pattern	-	-	D	A; D
Pile Material	-	-	Wool	Synthetic
Strands per Knot	-	-	2	4
Warp Material	-	-	Wool	Cotton
Weft Material	-	-	Wool	Silk
Weft Offset Pattern	-	-	Regular	Alternate
Weft Shot Pick Count	-	-	2	1.5
Cartoon Use	-	-	None	Sporadic
City	-	-	Mary	Khiva
Community	-	-	Coll. Khiva	Coll. Mary
Country	-	-	Turkmenistan	Uzbekistan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	1	0
Experience	-	-	9	20
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	Color	D/R-L
Knotting Shed Position	-	-	Partial	Closed
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Collective	Workshop
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	0	1
Single-Shed Heddles	-	-	0	1
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	2	1
Village	-	-	Ingilis	None
Weaver/Pseudonym	-	-	Jennifer	Ginny
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	8.5	6.5

* N/A, loop-wrap knot
† WR

MU-AS-2a (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R *	None
Knot Type	-	-	AS †	SY
Knot-Warp Pattern	-	-	II	III
Knot-Weft Pattern	-	-	A	D
Pile Material	-	-	Wool	Silk
Strands per Knot	-	-	2	1
Warp Material	-	-	Wool	Silk
Weft Material	-	-	Wool	Silk
Weft Offset Pattern	-	-	Regular	Alternate
Weft Shot Pick Count	-	-	2 ‡	1.5
Cartoon Use	-	-	Sporadic	None
City	-	-	Mary	Samarkand
Community	-	-	Coll. Mary	SSW
Country	-	-	Turkmenistan	Uzbekistan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	1	0
Experience	-	-	1	15
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	Pattern	Color
Knotting Shed Position	-	-	Partial	Open
Number of Weavers	-	-	1	2
Oversight	-	-	PS	None
Production Setting	-	-	Collective	Workshop
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	0	1
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	2	1
Village	-	-	None	Gondimiyon
Weaver/Pseudonym	-	-	Carol	Anna
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	2.5	8.5

* N/A, loop-wrap knot
† WR
‡ 4

MU-AS-2b (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R *	None
Knot Type	-	-	AS †	SY
Knot-Warp Pattern	-	-	II	III
Knot-Weft Pattern	-	-	D	A
Pile Material	-	-	Wool	Silk
Strands per Knot	-	-	2	1
Warp Material	-	-	Wool	Silk
Weft Material	-	-	Wool	Silk
Weft Offset Pattern	-	-	Regular	Alternate
Weft Shot Pick Count	-	-	2 ‡	1
Cartoon Use	-	-	Sporadic	None
City	-	-	Mary	Samarkand
Community	-	-	Coll. Mary	SSW
Country	-	-	Turkmenistan	Uzbekistan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	1	0
Experience	-	-	1.5	1
Hook	-	-	N	Y
Knife Type	-	-	Straight	Curve
Knotting Order	-	-	Color	Pattern
Knotting Shed Position	-	-	Partial	Open
Number of Weavers	-	-	1	2
Oversight	-	-	PS	None
Production Setting	-	-	Collective	Workshop
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	2	1
Village	-	-	None	Ingilis
Weaver/Pseudonym	-	-	Anna	Christina
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	8.5	2.5

* N/A, loop-wrap knot

† WR

‡ 3

MU-AS-3 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	None *	R
Knot Type	-	-	SY †	AS
Knot-Warp Pattern	-	-	III	II
Knot-Weft Pattern	-	-	A; D	A
Pile Material	-	-	Wool	Silk
Strands per Knot	-	-	1	2
Warp Material	-	-	Silk	Wool
Weft Material	-	-	Silk	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	1.5	2
Cartoon Use	-	-	Continuous	Sporadic
City	-	-	Khiva	Samarkand
Community	-	-	SSW	KSW
Country	-	-	Uzbekistan	Turkmenistan
Cutting Direction	-	-	N-S	NE-SW
Double-Shed Heddles	-	-	1	0
Experience	-	-	8	2
Hook	-	-	Y	N
Knife Type	-	-	Straight	Curve
Knotting Order	-	-	Color	Pattern
Knotting Shed Position	-	-	Open	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	PS	PR
Production Setting	-	-	Workshop	Collective
Scissor Type	-	-	Offset	Standard
Shed Rods	-	-	0	1
Single-Shed Heddles	-	-	0	1
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	2	1
Village	-	-	None	Gondimiyon
Weaver/Pseudonym	-	-	Christina	Kathleen
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	2	8

* Z
† WR

MU-AS-4a (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	None *	R
Knot Type	-	-	SY	AS
Knot-Warp Pattern	-	-	III	II
Knot-Weft Pattern	-	-	A; D	A
Pile Material	-	-	Silk	Wool
Strands per Knot	-	-	1	2
Warp Material	-	-	Silk	Wool
Weft Material	-	-	Silk	Wool
Weft Offset Pattern	-	-	Regular	Alternate
Weft Shot Pick Count	-	-	1.5	1
Cartoon Use	-	-	Sporadic	Continuous
City	-	-	Samarkand	Khiva
Community	-	-	SSW	KSW
Country	-	-	Uzbekistan	Turkmenistan
Cutting Direction	-	-	N-S	NE-SW
Double-Shed Heddles	-	-	1	0
Experience	-	-	15	2.5
Hook	-	-	Y	N
Knife Type	-	-	Straight	Curve
Knotting Order	-	-	Color	Pattern
Knotting Shed Position	-	-	Open	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	PR	PS
Production Setting	-	-	Workshop	Collective
Scissor Type	-	-	Offset	Standard
Shed Rods	-	-	0	1
Single-Shed Heddles	-	-	0	1
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	2	1
Village	-	-	None	Ingilis
Weaver/Pseudonym	-	-	Carol	Kathleen
Weft Addition Rate	-	-	Broken	Continuous
Workload	-	-	8	2.5

* L

MU-AS-4b (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R *	None
Knot Type	-	-	AS	SY
Knot-Warp Pattern	-	-	II	I
Knot-Weft Pattern	-	-	D	C; D
Pile Material	-	-	Wool	Synthetic
Strands per Knot	-	-	2	4
Warp Material	-	-	Wool	Cotton
Weft Material	-	-	Wool	Silk
Weft Offset Pattern	-	-	Regular	Alternate
Weft Shot Pick Count	-	-	2	1.5
Cartoon Use	-	-	None	Sporadic
City	-	-	Mary	Shymkent
Community	-	-	Coll. Mary	Coll. Khiva
Country	-	-	Turkmenistan	Kazakhstan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	1	0
Experience	-	-	20	48
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Partial	Closed
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Collective	Domestic
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	2	1
Village	-	-	Angarik	Ingilis
Weaver/Pseudonym	-	-	Eleanora	Dorothy
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	6.5	8.5

* L

MU-AS-4c (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	None *	R
Knot Type	-	-	SY	AS
Knot-Warp Pattern	-	-	III	II
Knot-Weft Pattern	-	-	A	D
Pile Material	-	-	Wool	Silk
Strands per Knot	-	-	1	2
Warp Material	-	-	Wool	Silk
Weft Material	-	-	Wool	Silk
Weft Offset Pattern	-	-	Regular	Alternate
Weft Shot Pick Count	-	-	2	1
Cartoon Use	-	-	Sporadic	Continuous
City	-	-	Samarkand	Mary
Community	-	-	SSW	Coll. Mary
Country	-	-	Uzbekistan	Turkmenistan
Cutting Direction	-	-	N-S	NE-SW
Double-Shed Heddles	-	-	1	0
Experience	-	-	15	2.5
Hook	-	-	Y	N
Knife Type	-	-	Straight	Curve
Knotting Order	-	-	Color	Pattern
Knotting Shed Position	-	-	Partial	Open
Number of Weavers	-	-	1	2
Oversight	-	-	PS	PR
Production Setting	-	-	Workshop	Collective
Scissor Type	-	-	Offset	Standard
Shed Rods	-	-	0	1
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	2	1
Village	-	-	None	Gondimiyon
Weaver/Pseudonym	-	-	Carol	Dorothy
Weft Addition Rate	-	-	Broken	Continuous
Workload	-	-	2.5	8.5

* L

MU-AS-5 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	None *	R
Knot Type	-	-	SY †	AS
Knot-Warp Pattern	-	-	III	II
Knot-Weft Pattern	-	-	A	A; D
Pile Material	-	-	Silk	Wool
Strands per Knot	-	-	1	2
Warp Material	-	-	Wool	Silk
Weft Material	-	-	Silk	Wool
Weft Offset Pattern	-	-	Regular	Alternate
Weft Shot Pick Count	-	-	1	1.5
Cartoon Use	-	-	Sporadic	Continuous
City	-	-	Samarkand	Khiva
Community	-	-	SSW	KSW
Country	-	-	Uzbekistan	Turkmenistan
Cutting Direction	-	-	N-S	NE-SW
Double-Shed Heddles	-	-	1	0
Experience	-	-	6	2.5
Hook	-	-	Y	N
Knife Type	-	-	Straight	Curve
Knotting Order	-	-	Color	Pattern
Knotting Shed Position	-	-	Partial	Open
Number of Weavers	-	-	1	2
Oversight	-	-	PS	PR
Production Setting	-	-	Workshop	Collective
Scissor Type	-	-	Offset	Standard
Shed Rods	-	-	0	1
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	2	1
Village	-	-	None	Ingilis
Weaver/Pseudonym	-	-	Kathleen	Carol
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	8	2

* S
† WR

MU-AS-6 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R	None
Knot Type	-	-	AS	SY
Knot-Warp Pattern	-	-	I	II
Knot-Weft Pattern	-	-	C [*]	C; D
Pile Material	-	-	Synthetic	Wool
Strands per Knot	-	-	2.5 [†]	4
Warp Material	-	-	Cotton	Wool
Weft Material	-	-	Wool	Cotton-Synthetic
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	2 [‡]	1.5
Cartoon Use	-	-	None	Sporadic
City	-	-	Shymkent	Shauldir
Community	-	-	Altyn Orda	Coll. Khiva
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	1	0
Experience	-	-	10	30
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Domestic	Collective
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	0	1
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	1	0
Trim Frequency	-	-	1	2
Village	-	-	Gondimiyon	Ingilis
Weaver/Pseudonym	-	-	Margaret	Stephanie
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	7.5	3

[*] Q; R; L; J

[†] 3

[‡] 4

MU-AS-7 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	None *	R
Knot Type	-	-	SY	AS
Knot-Warp Pattern	-	-	III	II
Knot-Weft Pattern	-	-	A; D	A
Pile Material	-	-	Silk	Wool
Strands per Knot	-	-	1 †	2
Warp Material	-	-	Silk	Wool
Weft Material	-	-	Silk	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	1.5	1
Cartoon Use	-	-	Continuous	Sporadic
City	-	-	Khiva	Samarkand
Community	-	-	KSW	SSW
Country	-	-	Uzbekistan	Turkmenistan
Cutting Direction	-	-	N-S	NE-SW
Double-Shed Heddles	-	-	1	0
Experience	-	-	5	3
Hook	-	-	Y	N
Knife Type	-	-	Straight	Curve
Knotting Order	-	-	Color	Pattern
Knotting Shed Position	-	-	Open	Partial
Number of Weavers	-	-	2	1
Oversight	-	-	PR	PS
Production Setting	-	-	Workshop	Collective
Scissor Type	-	-	Offset	Standard
Shed Rods	-	-	0	1
Single-Shed Heddles	-	-	0	1
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	1	2
Village	-	-	None	Gondimiyon
Weaver/Pseudonym	-	-	Jean	Alexandra
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	8	2

* L

† 3.5

MU-AS-8 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R	None
Knot Type	-	-	AS	SY
Knot-Warp Pattern	-	-	II	III
Knot-Weft Pattern	-	-	D	C
Pile Material	-	-	Wool	Synthetic
Strands per Knot	-	-	2 *	4
Warp Material	-	-	Wool	Cotton
Weft Material	-	-	Wool	Silk
Weft Offset Pattern	-	-	Regular	Alternate
Weft Shot Pick Count	-	-	2	1.5
Cartoon Use	-	-	None	Sporadic
City	-	-	Mary	Samarkand
Community	-	-	Coll. Mary	Coll. Khiva
Country	-	-	Turkmenistan	Kazakhstan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	1	0
Experience	-	-	48	15
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	Color	Pattern
Knotting Shed Position	-	-	Partial	Open
Number of Weavers	-	-	1	2
Oversight	-	-	PS	None
Production Setting	-	-	Collective	Workshop
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	2	1
Village	-	-	Ingilis	None
Weaver/Pseudonym	-	-	Ginny	Eleanora
Weft Addition Rate	-	-	Broken	Continuous
Workload	-	-	6	8.5

* 5

MU-AS-9ab (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R *	None
Knot Type	-	-	AS †	SY
Knot-Warp Pattern	-	-	I	II
Knot-Weft Pattern	-	-	C; D	C
Pile Material	-	-	Wool	Synthetic
Strands per Knot	-	-	2.5 ‡	2
Warp Material	-	-	Wool	Cotton
Weft Material	-	-	Cotton-Synthetic	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	1	1.5
Cartoon Use	-	-	None	Continuous
City	-	-	Shauldir	Shymkent
Community	-	-	None	Altyn Orda
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	0	1
Experience	-	-	10	20
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Domestic	Collective
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	1	0
Trim Frequency	-	-	1	2
Village	-	-	Angarik	Gondimiyon
Weaver/Pseudonym	-	-	Margaret	Teri
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	3	7.5

* L; Z

† AS; WR

‡ 3

MU-AS-9c (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R *	None
Knot Type	-	-	AS †	SY
Knot-Warp Pattern	-	-	I	II
Knot-Weft Pattern	-	-	C	C; D
Pile Material	-	-	Synthetic	Wool
Strands per Knot	-	-	2.5 ‡	4
Warp Material	-	-	Cotton	Wool
Weft Material	-	-	Cotton-Synthetic	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	1.5	2
Cartoon Use	-	-	None	Sporadic
City	-	-	Shymkent	Shauldir
Community	-	-	Altyn Orda	None
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	1	0
Experience	-	-	48	10
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Domestic	Collective
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	0	1
Single-Shed Heddles	-	-	0	1
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	1	0
Trim Frequency	-	-	2	1
Village	-	-	Gondimiyon	Angarik
Weaver/Pseudonym	-	-	Margaret	Kate
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	3	6.5

* L; Z

† AS; WR

‡ 3

MU-AS-9d (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R *	None
Knot Type	-	-	AS †	SY
Knot-Warp Pattern	-	-	II	I
Knot-Weft Pattern	-	-	D ‡	C
Pile Material	-	-	Wool	Synthetic
Strands per Knot	-	-	2 +	4
Warp Material	-	-	Wool	Cotton
Weft Material	-	-	Wool	Silk
Weft Offset Pattern	-	-	Regular	Alternate
Weft Shot Pick Count	-	-	2	1.5
Cartoon Use	-	-	None	Sporadic
City	-	-	Mary	Shymkent
Community	-	-	Coll. Mary	Coll. Khiva
Country	-	-	Turkmenistan	Kazakhstan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	1	0
Experience	-	-	20	48
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	Color	D/R-L
Knotting Shed Position	-	-	Partial	Closed
Number of Weavers	-	-	1	2
Oversight	-	-	PS	None
Production Setting	-	-	Collective	Workshop
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	0	1
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	2	1
Village	-	-	Ingilis	Angarik
Weaver/Pseudonym	-	-	Barbara	Dorothy
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	8.5	2.5

* L; Z
† AS; WR
‡ Similar result to actual structure (C; D)
+ 3

MU-AS-10

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	None *	R	None *	R
Knot Type	SY	AS	SY	AS
Knot-Warp Pattern	I	II	III	II
Knot-Weft Pattern	C	D	A; D	A
Pile Material	Wool	Silk	Silk	Wool
Strands per Knot	1 †	4	1 †	2
Warp Material	Wool	Cotton	Silk	Wool
Weft Material	Wool	Cotton-Synthetic	Silk	Wool
Weft Offset Pattern	Regular	Alternate	Alternate	Regular
Weft Shot Pick Count	2	1	1.5	1
Cartoon Use	Continuous	Sporadic	Continuous	Sporadic
City	Mary	Shauldir	Khiva	Samarkand
Community	Altyn Orda	Coll. Mary	KSW	SSW
Country	Kazakhstan	Uzbekistan	Uzbekistan	Turkmenistan
Cutting Direction	NE-SW	N-S	N-S	NE-SW
Double-Shed Heddles	0	1	1	0
Experience	1	10	5	3
Hook	Y	N	Y	N
Knife Type	Straight	Curve	Straight	Curve
Knotting Order	Color	Pattern	Color	Pattern
Knotting Shed Position	Closed	Partial	Open	Partial
Number of Weavers	1	2	2	1
Oversight	PS	None	PR	PS
Production Setting	Collective	Domestic	Workshop	Collective
Scissor Type	Standard	Offset	Offset	Standard
Shed Rods	0	1	0	1
Single-Shed Heddles	1	0	0	1
Tension Rods: Bottom	1	0	1	0
Tension Rods: Top	0	1	0	1
Trim Frequency	2	1	1	2
Village	Ingilis	Angarik	None	Gondimiyon
Weaver/Pseudonym	Anna	Teri	Jean	Janina
Weft Addition Rate	Continuous	Broken	Continuous	Broken
Workload	6	2.5	8	2

* L

† 3

MU-AS-11 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R	None
Knot Type	-	-	AS	SY
Knot-Warp Pattern	-	-	I	II
Knot-Weft Pattern	-	-	C; D	A; D
Pile Material	-	-	Synthetic	Wool
Strands per Knot	-	-	2.5 *	4
Warp Material	-	-	Cotton	Wool
Weft Material	-	-	Cotton-Synthetic	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	1	1.5
Cartoon Use	-	-	None	Sporadic
City	-	-	Shauldir	Shymkent
Community	-	-	None	Altyn Orda
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	N-S	NE-SW
Double-Shed Heddles	-	-	1	0
Experience	-	-	10	20
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Domestic	Collective
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	1	0
Trim Frequency	-	-	1	2
Village	-	-	Gondimiyon	None
Weaver/Pseudonym	-	-	Margaret	Teri
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	3	7.5

* 3

MU-AS-12 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	None *	R
Knot Type	-	-	SY	AS
Knot-Warp Pattern	-	-	III	II
Knot-Weft Pattern	-	-	A	A; D
Pile Material	-	-	Silk	Wool
Strands per Knot	-	-	1	2
Warp Material	-	-	Silk	Wool
Weft Material	-	-	Silk	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	1.5	1
Cartoon Use	-	-	Continuous	Sporadic
City	-	-	Samarkand	Khiva
Community	-	-	KSW	SSW
Country	-	-	Uzbekistan	Turkmenistan
Cutting Direction	-	-	N-S	NE-SW
Double-Shed Heddles	-	-	0	1
Experience	-	-	2.5	5
Hook	-	-	Y	N
Knife Type	-	-	Straight	Curve
Knotting Order	-	-	Pattern	Color
Knotting Shed Position	-	-	Open	Partial
Number of Weavers	-	-	2	1
Oversight	-	-	PR	PS
Production Setting	-	-	Workshop	Collective
Scissor Type	-	-	Offset	Standard
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	0	1
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	1	2
Village	-	-	None	Gondimiyon
Weaver/Pseudonym	-	-	Kathleen	Jean
Weft Addition Rate	-	-	Broken	Continuous
Workload	-	-	8	2

* L

MU-AS-13 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R *	None
Knot Type	-	-	AS	SY
Knot-Warp Pattern	-	-	I	II
Knot-Weft Pattern	-	-	C †	C; D
Pile Material	-	-	Synth	Wool
Strands per Knot	-	-	2.5	4
Warp Material	-	-	Cotton	Wool
Weft Material	-	-	Cotton-Synthetic	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	2 ‡	1.5
Cartoon Use	-	-	None	Sporadic
City	-	-	Shauldir	Shymkent
Community	-	-	None	Altyn Orda
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	1	0
Experience	-	-	10	48
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Domestic	Collective
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	0	1
Single-Shed Heddles	-	-	0	1
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	1	0
Trim Frequency	-	-	2	1
Village	-	-	Angarik	Ingilis
Weaver/Pseudonym	-	-	Teri	Margaret
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	3	7.5

* L; Z

† B

‡ 3

MU-AS-14 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R *	None
Knot Type	-	-	AS	SY
Knot-Warp Pattern	-	-	II	I
Knot-Weft Pattern	-	-	C; D	A; D
Pile Material	-	-	Synthetic	Wool
Strands per Knot	-	-	4	2
Warp Material	-	-	Cotton	Wool
Weft Material	-	-	Wool	Cotton-Synthetic
Weft Offset Pattern	-	-	Regular	Alternate
Weft Shot Pick Count	-	-	2	1.5
Cartoon Use	-	-	None	Continuous
City	-	-	Shymkent	Khiva
Community	-	-	Coll. Khiva	Altyn Orda
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	1	0
Experience	-	-	30	9
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Collective	Domestic
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	0	1
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	1	0
Trim Frequency	-	-	1	0
Village	-	-	Gondimiyon	Ingilis
Weaver/Pseudonym	-	-	Kate	Stephanie
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	6.5	6

* L

MU-AS-16 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	None	R
Knot Type	-	-	SY	AS
Knot-Warp Pattern	-	-	III	II
Knot-Weft Pattern	-	-	A; D [*]	A
Pile Material	-	-	Silk	Wool
Strands per Knot	-	-	1	2
Warp Material	-	-	Silk	Wool
Weft Material	-	-	Silk	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	1.5 [†]	1
Cartoon Use	-	-	Continuous	Sporadic
City	-	-	Khiva	Samarkand
Community	-	-	KSW	SSW
Country	-	-	Uzbekistan	Turkmenistan
Cutting Direction	-	-	N-S	NE-SW
Double-Shed Heddles	-	-	1	0
Experience	-	-	5	3
Hook	-	-	Y	N
Knife Type	-	-	Straight	Curve
Knotting Order	-	-	Pattern	Color
Knotting Shed Position	-	-	Open	Partial
Number of Weavers	-	-	2	1
Oversight	-	-	PR	PS
Production Setting	-	-	Workshop	Collective
Scissor Type	-	-	Offset	Standard
Shed Rods	-	-	0	1
Single-Shed Heddles	-	-	0	1
Tension Rods: Bottom	-	-	0	1
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	1	2
Village	-	-	None	Gondimiyon
Weaver/Pseudonym	-	-	Jean	Janina
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	8	2

[*] G; H
[†] 6

MU-AS-17ef (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R *	None
Knot Type	-	-	AS	SY
Knot-Warp Pattern	-	-	I	II
Knot-Weft Pattern	-	-	C; D	C
Pile Material	-	-	Synthetic	Wool
Strands per Knot	-	-	4 †	2.5
Warp Material	-	-	Cotton	Wool
Weft Material	-	-	Wool	Cotton-Synthetic
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	1.5	2
Cartoon Use	-	-	None	Continuous
City	-	-	Khiva	Shauldir
Community	-	-	Coll. Khiva	Altyn Orda
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	1	0
Experience	-	-	48	10
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Domestic	Collective
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	0	1
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	1	2
Village	-	-	Gondimiyon	Ingilis
Weaver/Pseudonym	-	-	Jennifer	Kate
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	7.5	3

* L
† 3

MU-AS-17g (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	None *	R
Knot Type	-	-	SY	AS
Knot-Warp Pattern	-	-	III	II
Knot-Weft Pattern	-	-	A	A; D
Pile Material	-	-	Wool	Silk
Strands per Knot	-	-	1 †	2
Warp Material	-	-	Wool	Silk
Weft Material	-	-	Wool	Silk
Weft Offset Pattern	-	-	Regular	Alternate
Weft Shot Pick Count	-	-	1	1.5
Cartoon Use	-	-	Continuous	Sporadic
City	-	-	Samarkand	Khiva
Community	-	-	SSW	KSW
Country	-	-	Uzbekistan	Turkmenistan
Cutting Direction	-	-	N-S	NE-SW
Double-Shed Heddles	-	-	0	1
Experience	-	-	2.5	15
Hook	-	-	Y	N
Knife Type	-	-	Straight	Curve
Knotting Order	-	-	Pattern	Color
Knotting Shed Position	-	-	Partial	Open
Number of Weavers	-	-	2	1
Oversight	-	-	PS	PR
Production Setting	-	-	Workshop	Collective
Scissor Type	-	-	Offset	Standard
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	0	1
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	2	1
Village	-	-	None	Ingilis
Weaver/Pseudonym	-	-	Kathleen	Carol
Weft Addition Rate	-	-	Broken	Continuous
Workload	-	-	2.5	8.5

* L
† 3

MU-AS-18 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R *	None
Knot Type	-	-	AS	SY
Knot-Warp Pattern	-	-	II	I
Knot-Weft Pattern	-	-	D	A; D
Pile Material	-	-	Wool	Synthetic
Strands per Knot	-	-	4 †	2
Warp Material	-	-	Wool	Cotton
Weft Material	-	-	Wool	Cotton-Synthetic
Weft Offset Pattern	-	-	Regular	Alternate
Weft Shot Pick Count	-	-	2	1.5
Cartoon Use	-	-	None	Sporadic
City	-	-	Mary	Shymkent
Community	-	-	Coll. Khiva	Coll. Mary
Country	-	-	Turkmenistan	Kazakhstan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	1	0
Experience	-	-	9	30
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Partial	Closed
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Collective	Domestic
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	2	1
Village	-	-	Gondimiyon	Ingilis
Weaver/Pseudonym	-	-	Barbara	Stephanie
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	8.5	2.5

* L
† 3

MU-CH-1

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	None	R	R	None
Knot Type	SY	AS	AS	SY
Knot-Warp Pattern	I	II	I	II
Knot-Weft Pattern	C *	A	C *	C; D
Pile Material	Wool	Silk	Synthetic	Wool
Strands per Knot	2.5	2	2.5	4
Warp Material	Wool	Cotton	Cotton	Wool
Weft Material	Cotton-Synthetic	Wool	Cotton-Synthetic	Wool
Weft Offset Pattern	Alternate	Regular	Alternate	Regular
Weft Shot Pick Count	2 †	1	2 †	1.5
Cartoon Use	Continuous	Sporadic	None	Sporadic
City	Samarkand	Shauldir	Shauldir	Shymkent
Community	Altyn Orda	SSW	None	Altyn Orda
Country	Turkmenistan	Kazakhstan	Kazakhstan	Turkmenistan
Cutting Direction	N-S	NE-SW	NE-SW	N-S
Double-Shed Heddles	0	1	1	0
Experience	15	5	10	48
Hook	Y	N	N	Y
Knife Type	Straight	Curve	Curve	Straight
Knotting Order	Pattern	Color	D/R-L	Color
Knotting Shed Position	Partial	Closed	Closed	Partial
Number of Weavers	2	1	1	2
Oversight	PS	None	None	PS
Production Setting	Workshop	Domestic	Domestic	Collective
Scissor Type	Offset	Standard	Standard	Offset
Shed Rods	0	1	0	1
Single-Shed Heddles	0	1	0	1
Tension Rods: Bottom	0	1	1	0
Tension Rods: Top	1	0	1	0
Trim Frequency	1	2	1	2
Village	Ingilis	Angarik	Angarik	Gondimiyon
Weaver/Pseudonym	Carol	Margaret	Margaret	Teri
Weft Addition Rate	Broken	Continuous	Continuous	Broken
Workload	3	7.5	3	7.5

* B
† 3

MU-CH-2

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	R	None	R	None
Knot Type	AS	SY	AS	SY
Knot-Warp Pattern	II	I	I	II
Knot-Weft Pattern	D *	A	C *	D
Pile Material	Wool	Synthetic	Synthetic	Wool
Strands per Knot	4	2	2.5	4
Warp Material	Wool	Silk	Cotton	Wool
Weft Material	Wool	Silk	Cotton-Synthetic	Wool
Weft Offset Pattern	Regular	Alternate	Alternate	Regular
Weft Shot Pick Count	2 †	1.5	2 †	1.5
Cartoon Use	Sporadic	Continuous	None	Sporadic
City	Mary	Samarkand	Shymkent	Shauldir
Community	Coll. Mary	Altyn Orda	None	Altyn Orda
Country	Turkmenistan	Kazakhstan	Kazakhstan	Turkmenistan
Cutting Direction	N-S	NE-SW	NE-SW	N-S
Double-Shed Heddles	1	0	1	0
Experience	3	1	48	10
Hook	N	Y	N	Y
Knife Type	Curve	Straight	Curve	Straight
Knotting Order	D/R-L	Color	D/R-L	Color
Knotting Shed Position	Partial	Open	Closed	Partial
Number of Weavers	1	2	1	2
Oversight	None	PS	None	PS
Production Setting	Collective	Domestic	Domestic	Collective
Scissor Type	Standard	Offset	Standard	Offset
Shed Rods	0	1	0	1
Single-Shed Heddles	0	1	0	1
Tension Rods: Bottom	0	1	1	0
Tension Rods: Top	0	1	1	0
Trim Frequency	2	1	1	2
Village	Ingilis	Gondimiyon	Angarik	Gondimiyon
Weaver/Pseudonym	Janina	Christina	Margaret	Teri
Weft Addition Rate	Continuous	Broken	Continuous	Broken
Workload	2.5	7.5	3	7.5

* B
† 3

MU-CH-3

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	R	None	R	None
Knot Type	AS	SY	AS	SY
Knot-Warp Pattern	II	III	I	II
Knot-Weft Pattern	D *	A; D	C *	D
Pile Material	Wool	Silk	Synthetic	Wool
Strands per Knot	2	4	2.5	4
Warp Material	Wool	Silk	Cotton	Wool
Weft Material	Wool	Silk	Cotton-Synthetic	Wool
Weft Offset Pattern	Alternate	Regular	Regular	Alternate
Weft Shot Pick Count	2 †	1.5	1 †	2
Cartoon Use	None	Sporadic	None	Sporadic
City	Mary	Khiva	Shauldir	Shymkent
Community	Coll. Mary	Coll. Khiva	Altyn Orda	None
Country	Turkmenistan	Kazakhstan	Kazakhstan	Turkmenistan
Cutting Direction	N-S	NE-SW	NE-SW	N-S
Double-Shed Heddles	1	0	1	0
Experience	3	20	10	30
Hook	N	Y	N	Y
Knife Type	Curve	Straight	Curve	Straight
Knotting Order	Color	D/R-L	D/R-L	Pattern
Knotting Shed Position	Open	Closed	Closed	Partial
Number of Weavers	1	2	1	2
Oversight	PR	PS	None	PS
Production Setting	Collective	Workshop	Domestic	Collective
Scissor Type	Offset	Standard	Standard	Offset
Shed Rods	0	1	1	0
Single-Shed Heddles	0	1	0	1
Tension Rods: Bottom	0	1	1	0
Tension Rods: Top	0	1	1	0
Trim Frequency	1	2	2	1
Village	None	Ingilis	Angarik	Gondimiyon
Weaver/Pseudonym	Janina	Monica	Margaret	Teri
Weft Addition Rate	Continuous	Broken	Continuous	Broken
Workload	2	8.5	3	7.5

* B
† 3

MU-CH-4

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	None	R	R	None
Knot Type	SY	AS	AS	SY
Knot-Warp Pattern	I	III	I	II
Knot-Weft Pattern	C; D	C	C	D
Pile Material	Wool	Synthetic	Synthetic	Wool
Strands per Knot	2.5	1	2.5	4
Warp Material	Cotton	Wool	Cotton	Wool
Weft Material	Wool	Cotton-Synthetic	Cotton-Synthetic	Wool
Weft Offset Pattern	Alternate	Regular	Alternate	Regular
Weft Shot Pick Count	1.5	1	2	1.5
Cartoon Use	Continuous	Sporadic	None	Sporadic
City	Shymkent	Shauldir	Shymkent	Shauldir
Community	Altyn Orda	KSW	Altyn Orda	None
Country	Kazakhstan	Uzbekistan	Kazakhstan	Turkmenistan
Cutting Direction	NE-SW	N-S	NE-SW	N-S
Double-Shed Heddles	0	1	1	0
Experience	3	48	10	48
Hook	Y	N	N	Y
Knife Type	Straight	Curve	Curve	Straight
Knotting Order	Pattern	D/R-L	D/R-L	Color
Knotting Shed Position	Closed	Open	Closed	Partial
Number of Weavers	1	2	1	2
Oversight	PS	None	None	PS
Production Setting	Collective	Domestic	Domestic	Collective
Scissor Type	Standard	Offset	Standard	Offset
Shed Rods	0	1	0	1
Single-Shed Heddles	1	0	0	1
Tension Rods: Bottom	1	0	1	0
Tension Rods: Top	1	0	1	0
Trim Frequency	1	2	1	2
Village	Angarik	None	Angarik	Gondimiyon
Weaver/Pseudonym	Janina	Jean	Teri	Margaret
Weft Addition Rate	Broken	Continuous	Continuous	Broken
Workload	3	6.5	3	7.5

MU-CH-5

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	R	None	None	R
Knot Type	AS	SY	SY	AS
Knot-Warp Pattern	II	III	III	II
Knot-Weft Pattern	D	A	A	A; D
Pile Material	Wool	Synthetic	Silk	Wool
Strands per Knot	4	2	1	2
Warp Material	Wool	Silk	Silk	Wool
Weft Material	Wool	Cotton-Synthetic	Silk	Wool
Weft Offset Pattern	Regular	Alternate	Alternate	Regular
Weft Shot Pick Count	2	1.5	1.5	1
Cartoon Use	Sporadic	Continuous	Continuous	Sporadic
City	Samarkand	Mary	Samarkand	Khiva
Community	Coll. Mary	SSW	KSW	SSW
Country	Turkmenistan	Uzbekistan	Uzbekistan	Turkmenistan
Cutting Direction	N-S	NE-SW	N-S	NE-SW
Double-Shed Heddles	1	0	1	0
Experience	3	15	5	3
Hook	N	Y	Y	N
Knife Type	Curve	Straight	Straight	Curve
Knotting Order	Color	D/R-L	Pattern	Color
Knotting Shed Position	Partial	Open	Open	Partial
Number of Weavers	1	2	2	1
Oversight	PR	PS	PR	PS
Production Setting	Collective	Domestic	Workshop	Collective
Scissor Type	Standard	Offset	Offset	Standard
Shed Rods	0	1	0	1
Single-Shed Heddles	0	1	0	1
Tension Rods: Bottom	1	0	0	1
Tension Rods: Top	1	0	0	1
Trim Frequency	2	1	1	2
Village	Gondimiyon	Ingilis	None	Ingilis
Weaver/Pseudonym	Janina	Mairead	Mairead	Alexandra
Weft Addition Rate	Broken	Continuous	Broken	Continuous
Workload	8.5	2.5	8	2

MU-CH-6

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	R	None	R	None
Knot Type	AS	SY	AS	SY
Knot-Warp Pattern	I	II	I	II
Knot-Weft Pattern	C; D	D	C	D
Pile Material	Wool	Synthetic	Synthetic	Wool
Strands per Knot	2	2.5	2.5	4
Warp Material	Wool	Silk	Cotton	Wool
Weft Material	Wool	Cotton-Synthetic	Cotton-Synthetic	Wool
Weft Offset Pattern	Alternate	Regular	Regular	Alternate
Weft Shot Pick Count	1.5	2	2	1
Cartoon Use	None	Continuous	None	Sporadic
City	Shauldir	Mary	Shauldir	Shymkent
Community	KSW	Coll. Mary	None	Altyn Orda
Country	Turkmenistan	Kazakhstan	Kazakhstan	Turkmenistan
Cutting Direction	N-S	NE-SW	NE-SW	N-S
Double-Shed Heddles	1	0	1	0
Experience	5	3	10	48
Hook	N	Y	N	Y
Knife Type	Curve	Straight	Curve	Straight
Knotting Order	Color	Pattern	D/R-L	Color
Knotting Shed Position	Closed	Open	Closed	Partial
Number of Weavers	2	1	1	2
Oversight	PR	PS	None	PR
Production Setting	Domestic	Collective	Domestic	Collective
Scissor Type	Standard	Offset	Standard	Offset
Shed Rods	0	1	0	1
Single-Shed Heddles	0	1	1	0
Tension Rods: Bottom	1	0	1	0
Tension Rods: Top	0	1	1	0
Trim Frequency	1	2	2	1
Village	Angarik	Gondimiyon	Angarik	Gondimiyon
Weaver/Pseudonym	Jean	Janina	Margaret	Teri
Weft Addition Rate	Continuous	Broken	Continuous	Broken
Workload	3	2	3	7.5

MU-CH-7

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	None	R	R	None
Knot Type	SY	AS	AS	SY
Knot-Warp Pattern	I	III	I	II
Knot-Weft Pattern	C; D	A; D	C	D
Pile Material	Silk	Synthetic	Synthetic	Wool
Strands per Knot	2.5	2	2.5	4
Warp Material	Silk	Cotton	Cotton	Wool
Weft Material	Cotton-Synthetic	Silk	Cotton-Synthetic	Wool
Weft Offset Pattern	Alternate	Regular	Regular	Alternate
Weft Shot Pick Count	1	1.5	2	1.5
Cartoon Use	None	Continuous	None	Sporadic
City	Shymkent	Shauldir	Shauldir	Shymkent
Community	KSW	Altyn Orda	None	Altyn Orda
Country	Kazakhstan	Uzbekistan	Kazakhstan	Turkmenistan
Cutting Direction	NE-SW	N-S	NE-SW	N-S
Double-Shed Heddles	0	1	1	0
Experience	3	5	10	48
Hook	Y	N	N	Y
Knife Type	Straight	Curve	Curve	Straight
Knotting Order	Pattern	D/R-L	D/R-L	Color
Knotting Shed Position	Closed	Open	Closed	Partial
Number of Weavers	2	1	1	2
Oversight	PR	PS	None	PS
Production Setting	Domestic	Workshop	Domestic	Collective
Scissor Type	Offset	Standard	Standard	Offset
Shed Rods	1	0	0	1
Single-Shed Heddles	1	0	0	1
Tension Rods: Bottom	0	1	1	0
Tension Rods: Top	1	0	1	0
Trim Frequency	1	2	2	1
Village	Angarik	None	Angarik	Ingilis
Weaver/Pseudonym	Jean	Janina	Teri	Margaret
Weft Addition Rate	Broken	Continuous	Continuous	Broken
Workload	2	3	3	7.5

MU-DY-1a (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R	None
Knot Type	-	-	AS	SY
Knot-Warp Pattern	-	-	I	II
Knot-Weft Pattern	-	-	C	D
Pile Material	-	-	Synthetic	Wool
Strands per Knot	-	-	2.5	2
Warp Material	-	-	Cotton	Wool
Weft Material	-	-	Cotton-Synthetic	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	1	1.5
Cartoon Use	-	-	None	Continuous
City	-	-	Shauldir	Shymkent
Community	-	-	None	Altyn Orda
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	N-S	NE-SW
Double-Shed Heddles	-	-	1	0
Experience	-	-	10	30
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Domestic	Collective
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	1	0
Trim Frequency	-	-	2	1
Village	-	-	Gondimiyon	None
Weaver/Pseudonym	-	-	Margaret	Teri
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	3	7.5

MU-DY-1b (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R	None
Knot Type	-	-	AS	SY
Knot-Warp Pattern	-	-	I	II
Knot-Weft Pattern	-	-	C	C; D
Pile Material	-	-	Synthetic	Wool
Strands per Knot	-	-	2.5	4
Warp Material	-	-	Cotton	Wool
Weft Material	-	-	Cotton-Synthetic	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	1.5	2
Cartoon Use	-	-	None	Sporadic
City	-	-	Shauldir	Shymkent
Community	-	-	Altyn Orda	None
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	1	0
Experience	-	-	10	20
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Domestic	Collective
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	0	1
Single-Shed Heddles	-	-	0	1
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	1	0
Trim Frequency	-	-	1	2
Village	-	-	Ingilis	Angarik
Weaver/Pseudonym	-	-	Margaret	Teri
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	3	7.5

MU-DY-1c (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R	None
Knot Type	-	-	AS	SY
Knot-Warp Pattern	-	-	I	II
Knot-Weft Pattern	-	-	C	C; D
Pile Material	-	-	Synthetic	Wool
Strands per Knot	-	-	2.5	4
Warp Material	-	-	Cotton	Wool
Weft Material	-	-	Cotton-Synthetic	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	1	1.5
Cartoon Use	-	-	None	Continuous
City	-	-	Shauldir	Shymkent
Community	-	-	None	Altyn Orda
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	N-S	NE-SW
Double-Shed Heddles	-	-	0	1
Experience	-	-	10	30
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Domestic	Collective
Scissor Type	-	-	Offset	Standard
Shed Rods	-	-	0	1
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	1	0
Trim Frequency	-	-	1	2
Village	-	-	Gondimiyon	None
Weaver/Pseudonym	-	-	Margaret	Teri
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	3	7.5

MU-DY-1d (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	None	R
Knot Type	-	-	SY	AS
Knot-Warp Pattern	-	-	I	II
Knot-Weft Pattern	-	-	C	D
Pile Material	-	-	Synthetic	Wool
Strands per Knot	-	-	2	2.5
Warp Material	-	-	Cotton	Wool
Weft Material	-	-	Cotton-Synthetic	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	1.5	1
Cartoon Use	-	-	None	Continuous
City	-	-	Shauldir	Shymkent
Community	-	-	None	Altyn Orda
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	N-S	NE-SW
Double-Shed Heddles	-	-	1	0
Experience	-	-	30	10
Hook	-	-	Y	N
Knife Type	-	-	Straight	Curve
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Domestic	Collective
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	1	0
Trim Frequency	-	-	1	2
Village	-	-	Gondimiyon	None
Weaver/Pseudonym	-	-	Margaret	Kate
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	3	7.5

MU-DY-2a (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R	None
Knot Type	-	-	AS	SY
Knot-Warp Pattern	-	-	II	I
Knot-Weft Pattern	-	-	C; D	D
Pile Material	-	-	Wool	Synthetic
Strands per Knot	-	-	4	2
Warp Material	-	-	Wool	Cotton
Weft Material	-	-	Wool	Cotton-Synthetic
Weft Offset Pattern	-	-	Regular	Alternate
Weft Shot Pick Count	-	-	2 *	1.5
Cartoon Use	-	-	None	Sporadic
City	-	-	Shymkent	Mary
Community	-	-	Coll. Khiva	Coll. Mary
Country	-	-	Turkmenistan	Kazakhstan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	1	0
Experience	-	-	30	9
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Collective	Workshop
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	2	1
Village	-	-	Gondimiyon	Ingilis
Weaver/Pseudonym	-	-	Jennifer	Eleanora
Weft Addition Rate	-	-	Broken	Continuous
Workload	-	-	6.5	6

* 4

MU-DY-2b (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	R	None
Knot Type	-	-	AS	SY
Knot-Warp Pattern	-	-	II	I
Knot-Weft Pattern	-	-	C; D	C
Pile Material	-	-	Synthetic	Wool
Strands per Knot	-	-	4	2.5
Warp Material	-	-	Cotton	Wool
Weft Material	-	-	Wool	Synthetic
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	2 *	1.5
Cartoon Use	-	-	None	Sporadic
City	-	-	Shymkent	Shauldir
Community	-	-	Coll. Khiva	Altyn Orda
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	1	0
Experience	-	-	30	20
Hook	-	-	N	Y
Knife Type	-	-	Curve	Straight
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Collective	Domestic
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	1	0
Trim Frequency	-	-	2	1
Village	-	-	Gondimiyon	Ingilis
Weaver/Pseudonym	-	-	Stephanie	Jennifer
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	6.5	7.5

* 4

MU-DY-2c (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	None	R
Knot Type	-	-	SY	AS
Knot-Warp Pattern	-	-	III	II
Knot-Weft Pattern	-	-	A	A; D
Pile Material	-	-	Silk	Wool
Strands per Knot	-	-	1	2
Warp Material	-	-	Silk	Wool
Weft Material	-	-	Silk	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	1.5 *	1
Cartoon Use	-	-	Continuous	Sporadic
City	-	-	Samarkand	Khiva
Community	-	-	KSW	SSW
Country	-	-	Uzbekistan	Turkmenistan
Cutting Direction	-	-	N-S	NE-SW
Double-Shed Heddles	-	-	0	1
Experience	-	-	2.5	5
Hook	-	-	Y	N
Knife Type	-	-	Straight	Curve
Knotting Order	-	-	Pattern	Color
Knotting Shed Position	-	-	Open	Partial
Number of Weavers	-	-	2	1
Oversight	-	-	PR	PS
Production Setting	-	-	Workshop	Collective
Scissor Type	-	-	Offset	Standard
Shed Rods	-	-	0	1
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	0	1
Trim Frequency	-	-	1	2
Village	-	-	None	Ingilis
Weaver/Pseudonym	-	-	Kathleen	Jean
Weft Addition Rate	-	-	Broken	Continuous
Workload	-	-	8	2

* 4

MU-IN-1

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	None	R	R	None
Knot Type	SY	AS	AS	SY
Knot-Warp Pattern	III	I	I	II
Knot-Weft Pattern	C; D *	A	C	C; D *
Pile Material	Silk	Wool	Synthetic	Wool
Strands per Knot	1.5	2	2.5	4
Warp Material	Wool	Silk	Cotton	Wool
Weft Material	Silk	Wool	Cotton-Synthetic	Wool
Weft Offset Pattern	Regular	Alternate	Alternate	Regular
Weft Shot Pick Count	1	2	2	1.5
Cartoon Use	Sporadic	None	None	Continuous
City	Shymkent	Samarkand	Shymkent	Shauldir
Community	KSW	Altyn Orda	None	Altyn Orda
Country	Kazakhstan	Uzbekistan	Kazakhstan	Turkmenistan
Cutting Direction	NE-SW	N-S	N-S	NE-SW
Double-Shed Heddles	0	1	1	0
Experience	5	3	10	48
Hook	N	Y	N	Y
Knife Type	Curve	Straight	Curve	Straight
Knotting Order	Pattern	D/R-L	D/R-L	Color
Knotting Shed Position	Open	Closed	Closed	Partial
Number of Weavers	2	1	1	2
Oversight	PS	PR	None	PS
Production Setting	Workshop	Domestic	Domestic	Collective
Scissor Type	Offset	Standard	Standard	Offset
Shed Rods	0	1	0	1
Single-Shed Heddles	0	1	0	1
Tension Rods: Bottom	0	1	1	0
Tension Rods: Top	0	1	1	0
Trim Frequency	1	2	1	2
Village	Ingilis	Angarik	Angarik	Ingilis
Weaver/Pseudonym	Janina	Margaret	Teri	Margaret
Weft Addition Rate	Broken	Continuous	Continuous	Broken
Workload	8.5	3	3	7.5

* Similar result to actual structure (D)

MU-IN-2

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	R *	None	R *	None
Knot Type	AS	SY	AS	SY
Knot-Warp Pattern	III	I	I	II
Knot-Weft Pattern	A	C; D	C	C; D
Pile Material	Silk	Wool	Synthetic	Wool
Strands per Knot	4	2	2.5	4
Warp Material	Wool	Silk	Cotton	Wool
Weft Material	Silk	Wool	Cotton-Synthetic	Wool
Weft Offset Pattern	Regular	Alternate	Alternate	Regular
Weft Shot Pick Count	2	1.5	1.5	2
Cartoon Use	Sporadic	Continuous	Continuous	None
City	Samarkand	Shymkent	Shauldir	Shymkent
Community	Coll. Mary	SSW	Altyn Orda	None
Country	Uzbekistan	Kazakhstan	Kazakhstan	Turkmenistan
Cutting Direction	N-S	NE-SW	N-S	NE-SW
Double-Shed Heddles	1	0	1	0
Experience	3	15	10	30
Hook	Y	N	Y	N
Knife Type	Straight	Curve	Straight	Curve
Knotting Order	Pattern	Color	D/R-L	Color
Knotting Shed Position	Open	Partial	Closed	Partial
Number of Weavers	1	2	1	2
Oversight	PR	None	None	PS
Production Setting	Workshop	Collective	Domestic	Collective
Scissor Type	Standard	Offset	Standard	Offset
Shed Rods	0	1	0	1
Single-Shed Heddles	1	0	1	0
Tension Rods: Bottom	1	0	1	0
Tension Rods: Top	1	0	1	0
Trim Frequency	2	1	1	2
Village	Ingilis	Gondimiyon	None	Ingilis
Weaver/Pseudonym	Carol	Kathleen	Teri	Margaret
Weft Addition Rate	Broken	Continuous	Continuous	Broken
Workload	2.5	7.5	3	7.5

* L

MU-IN-3

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	R *	None	R *	None
Knot Type	AS	SY	AS	SY
Knot-Warp Pattern	I	III	II	III
Knot-Weft Pattern	C; D	C	D	A; D
Pile Material	Wool	Silk	Wool	Synthetic
Strands per Knot	2	2.5	2	4
Warp Material	Wool	Silk	Wool	Cotton
Weft Material	Cotton-Synthetic	Wool	Wool	Silk
Weft Offset Pattern	Regular	Alternate	Regular	Alternate
Weft Shot Pick Count	1	2	2	1
Cartoon Use	Continuous	Sporadic	Sporadic	Continuous
City	Shauldir	Mary	Mary	Samarkand
Community	None	Coll. Mary	Coll. Khiva	Coll. Mary
Country	Kazakhstan	Turkmenistan	Turkmenistan	Uzbekistan
Cutting Direction	NE-SW	N-S	NE-SW	N-S
Double-Shed Heddles	0	1	0	1
Experience	5	2.5	15	1
Hook	N	Y	N	Y
Knife Type	Curve	Straight	Curve	Straight
Knotting Order	Pattern	Color	Pattern	Color
Knotting Shed Position	Partial	Closed	Partial	Open
Number of Weavers	2	1	1	2
Oversight	PR	None	PS	None
Production Setting	Collective	Domestic	Collective	Workshop
Scissor Type	Standard	Offset	Standard	Offset
Shed Rods	1	0	1	0
Single-Shed Heddles	1	0	1	0
Tension Rods: Bottom	1	0	1	0
Tension Rods: Top	1	0	0	1
Trim Frequency	1	2	2	1
Village	Ingilis	None	None	Ingilis
Weaver/Pseudonym	Alexandra	Anna	Carol	Christina
Weft Addition Rate	Broken	Continuous	Continuous	Broken
Workload	8.5	2	2.5	6

* L

MU-IN-4

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	R	None	None	R
Knot Type	AS	SY	SY	AS
Knot-Warp Pattern	II	III	I	II
Knot-Weft Pattern	A	C; D *	C	C; D *
Pile Material	Wool	Silk	Synthetic	Wool
Strands per Knot	4	1	2.5	2
Warp Material	Wool	Silk	Cotton	Wool
Weft Material	Cotton-Synthetic	Wool	Cotton-Synthetic	Wool
Weft Offset Pattern	Regular	Alternate	Alternate	Regular
Weft Shot Pick Count	1	2	1	2
Cartoon Use	Continuous	Sporadic	None	Continuous
City	Samarkand	Shauldir	Shauldir	Shymkent
Community	Altyn Orda	SSW	None	Altyn Orda
Country	Kazakhstan	Turkmenistan	Kazakhstan	Turkmenistan
Cutting Direction	NE-SW	N-S	NE-SW	N-S
Double-Shed Heddles	0	1	1	0
Experience	15	1	10	48
Hook	N	Y	N	Y
Knife Type	Curve	Straight	Curve	Straight
Knotting Order	Pattern	D/R-L	D/R-L	Color
Knotting Shed Position	Closed	Open	Closed	Partial
Number of Weavers	2	1	1	2
Oversight	None	PS	None	PS
Production Setting	Domestic	Collective	Domestic	Collective
Scissor Type	Offset	Standard	Standard	Offset
Shed Rods	1	0	0	1
Single-Shed Heddles	1	0	0	1
Tension Rods: Bottom	0	1	1	0
Tension Rods: Top	1	0	1	0
Trim Frequency	2	1	2	1
Village	Ingilis	Gondimiyon	Gondimiyon	None
Weaver/Pseudonym	Mairead	Janina	Margaret	Teri
Weft Addition Rate	Broken	Continuous	Continuous	Broken
Workload	2.5	6	3	7.5

* Similar result to actual structure (D)

MU-IN-5

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	R	None	R	None
Knot Type	AS	SY	AS	SY
Knot-Warp Pattern	II	I	I	II
Knot-Weft Pattern	A	D	C	C; D
Pile Material	Wool	Synthetic	Synthetic	Wool
Strands per Knot	2	4	2.5	2
Warp Material	Wool	Cotton	Cotton	Wool
Weft Material	Wool	Silk	Cotton-Synthetic	Wool
Weft Offset Pattern	Alternate	Regular	Alternate	Regular
Weft Shot Pick Count	2	1	1.5	2
Cartoon Use	Continuous	None	Continuous	None
City	Samarkand	Mary	Shauldir	Shymkent
Community	KSW	Coll. Mary	None	Altyn Orda
Country	Turkmenistan	Uzbekistan	Kazakhstan	Turkmenistan
Cutting Direction	N-S	NE-SW	NE-SW	N-S
Double-Shed Heddles	0	1	1	0
Experience	2.5	15	10	48
Hook	N	Y	Y	N
Knife Type	Curve	Straight	Straight	Curve
Knotting Order	D/R-L	Pattern	D/R-L	Color
Knotting Shed Position	Open	Partial	Closed	Partial
Number of Weavers	2	1	1	2
Oversight	None	PS	None	PS
Production Setting	Collective	Workshop	Domestic	Collective
Scissor Type	Standard	Offset	Standard	Offset
Shed Rods	0	1	1	0
Single-Shed Heddles	1	0	1	0
Tension Rods: Bottom	1	2	1	0
Tension Rods: Top	0	1	1	0
Trim Frequency	1	2	1	2
Village	Gondimiyon	Ingilis	Gondimiyon	None
Weaver/Pseudonym	Jean	Carol	Margaret	Teri
Weft Addition Rate	Broken	Continuous	Continuous	Broken
Workload	6.5	7.5	3	7.5

MU-IN-6

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	None *	R	None *	R
Knot Type	SY	AS	SY	AS
Knot-Warp Pattern	I	II	I	II
Knot-Weft Pattern	A	C	C	C; D
Pile Material	Wool	Silk	Synthetic	Wool
Strands per Knot	1	2.5	2.5	2
Warp Material	Wool	Silk	Cotton	Wool
Weft Material	Cotton-Synthetic	Silk	Cotton-Synthetic	Wool
Weft Offset Pattern	Regular	Alternate	Alternate	Regular
Weft Shot Pick Count	1	1.5	1.5	2
Cartoon Use	Continuous	Sporadic	Continuous	None
City	Samarkand	Shymkent	Shymkent	Shauldir
Community	SSW	Altyn Orda	None	Altyn Orda
Country	Kazakhstan	Turkmenistan	Kazakhstan	Turkmenistan
Cutting Direction	NE-SW	N-S	N-S	NE-SW
Double-Shed Heddles	0	1	1	0
Experience	2.5	15	10	48
Hook	Y	N	Y	N
Knife Type	Straight	Curve	Straight	Curve
Knotting Order	Pattern	D/R-L	D/R-L	Color
Knotting Shed Position	Closed	Partial	Closed	Partial
Number of Weavers	2	1	1	2
Oversight	None	PS	None	PS
Production Setting	Workshop	Domestic	Domestic	Collective
Scissor Type	Offset	Standard	Offset	Standard
Shed Rods	1	0	1	0
Single-Shed Heddles	1	0	1	0
Tension Rods: Bottom	0	1	1	0
Tension Rods: Top	1	0	1	0
Trim Frequency	2	1	1	2
Village	Gondimiyon	None	Gondimiyon	None
Weaver/Pseudonym	Kathleen	Carol	Margaret	Teri
Weft Addition Rate	Broken	Continuous	Continuous	Broken
Workload	2.5	8.5	3	7.5

* L

MU-IN-7

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	None *	R	None *	R
Knot Type	SY	AS	SY	AS
Knot-Warp Pattern	I	II	I	II
Knot-Weft Pattern	A	C	C	C; D
Pile Material	Synthetic	Silk	Synthetic	Wool
Strands per Knot	4	2.5	2.5	2
Warp Material	Wool	Silk	Cotton	Wool
Weft Material	Cotton-Synthetic †	Wool	Cotton-Synthetic †	Wool
Weft Offset Pattern	Regular	Alternate	Alternate	Regular
Weft Shot Pick Count	1	2	1.5	2
Cartoon Use	Continuous	Sporadic	Continuous	None
City	Shauldir	Samarkand	Shauldir	Shymkent
Community	None	SSW	None	Altyn Orda
Country	Kazakhstan	Turkmenistan	Kazakhstan	Turkmenistan
Cutting Direction	NE-SW	N-S	N-S	NE-SW
Double-Shed Heddles	0	1	1	0
Experience	1	2.5	10	48
Hook	Y	N	Y	N
Knife Type	Straight	Curve	Straight	Curve
Knotting Order	Pattern	D/R-L	D/R-L	Pattern
Knotting Shed Position	Closed	Partial	Closed	Partial
Number of Weavers	2	1	1	2
Oversight	PR	None	None	PS
Production Setting	Domestic	Workshop	Domestic	Collective
Scissor Type	Offset	Standard	Standard	Offset
Shed Rods	1	0	1	0
Single-Shed Heddles	1	0	0	1
Tension Rods: Bottom	0	1	1	0
Tension Rods: Top	1	0	1	0
Trim Frequency	2	1	1	2
Village	Gondimiyon	Ingilis	Angarik	Ingilis
Weaver/Pseudonym	Janina	Christina	Teri	Margaret
Weft Addition Rate	Broken	Continuous	Continuous	Broken
Workload	2.5	8	3	7.5

* L

† Wool-Silk

MU-SO-1

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	R	None	R	None
Knot Type	AS	SY	AS	SY
Knot-Warp Pattern	III	II	I	II
Knot-Weft Pattern	C; D	A	C	C; D
Pile Material	Silk	Wool	Synthetic	Wool
Strands per Knot	2	4	2.5	4
Warp Material	Wool	Silk	Cotton	Wool
Weft Material	Wool	Silk	Cotton-Synthetic	Wool
Weft Offset Pattern	Regular	Alternate	Regular	Alternate
Weft Shot Pick Count	2	1	1.5	2
Cartoon Use	Sporadic	Continuous	None	Sporadic
City	Samarkand	Mary	Shauldir	Shymkent
Community	KSW	SSW	None	Altyn Orda
Country	Turkmenistan	Uzbekistan	Kazakhstan	Turkmenistan
Cutting Direction	N-S	NE-SW	NE-SW	N-S
Double-Shed Heddles	1	0	1	0
Experience	2.5	20	48	10
Hook	N	Y	N	Y
Knife Type	Curve	Straight	Curve	Straight
Knotting Order	Color	Pattern	D/R-L	Color
Knotting Shed Position	Partial	Open	Closed	Partial
Number of Weavers	2	1	1	2
Oversight	PR	PS	None	PS
Production Setting	Collective	Workshop	Domestic	Collective
Scissor Type	Offset	Standard	Standard	Offset
Shed Rods	0	1	0	1
Single-Shed Heddles	0	1	0	1
Tension Rods: Bottom	1	0	1	0
Tension Rods: Top	0	1	1	0
Trim Frequency	2	1	2	1
Village	None	Ingilis	Angarik	Ingilis
Weaver/Pseudonym	Jean	Alexandra	Margaret	Teri
Weft Addition Rate	Broken	Continuous	Continuous	Broken
Workload	8.5	6.5	3	7.5

MU-SO-2

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	None	R	R	None
Knot Type	SY	AS	AS	SY
Knot-Warp Pattern	I	III	I	II
Knot-Weft Pattern	C; D *	A; D	C *	C; D
Pile Material	Silk	Synthetic	Synthetic	Wool
Strands per Knot	2.5	2	2.5	4
Warp Material	Cotton	Silk	Cotton	Wool
Weft Material	Cotton-Synthetic	Silk	Cotton-Synthetic	Wool
Weft Offset Pattern	Alternate	Regular	Alternate	Regular
Weft Shot Pick Count	1 †	1.5	1.5 †	1
Cartoon Use	None	Sporadic	None	Continuous
City	Shymkent	Shauldir	Shymkent	Shauldir
Community	KSW	Altyn Orda	None	Altyn Orda
Country	Kazakhstan	Uzbekistan	Kazakhstan	Turkmenistan
Cutting Direction	N-S	NE-SW	NE-SW	N-S
Double-Shed Heddles	0	1	1	0
Experience	48	3	10	48
Hook	Y	N	N	Y
Knife Type	Straight	Curve	Curve	Straight
Knotting Order	Pattern	D/R-L	D/R-L	Color
Knotting Shed Position	Closed	Open	Closed	Partial
Number of Weavers	1	2	1	2
Oversight	PS	None	None	PS
Production Setting	Domestic	Collective	Domestic	Collective
Scissor Type	Offset	Standard	Standard	Offset
Shed Rods	0	1	0	1
Single-Shed Heddles	0	1	1	0
Tension Rods: Bottom	0	1	1	0
Tension Rods: Top	1	0	1	0
Trim Frequency	1	2	2	1
Village	Angarik	Gondimiyon	Gondimiyon	Ingilis
Weaver/Pseudonym	Jean	Janina	Teri	Margaret
Weft Addition Rate	Broken	Continuous	Continuous	Broken
Workload	7.5	6.5	3	7.5

* B
† 3

MU-SO-3

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	R	None	None	R
Knot Type	AS	SY	SY	AS
Knot-Warp Pattern	III	II	I	II
Knot-Weft Pattern	A	C	C	C; D
Pile Material	Synthetic	Wool	Wool	Synthetic
Strands per Knot	4	2	2.5	4
Warp Material	Wool	Cotton	Cotton	Wool
Weft Material	Silk	Wool	Cotton-Synthetic	Wool
Weft Offset Pattern	Regular	Alternate	Alternate	Regular
Weft Shot Pick Count	2	1.5	1.5	2
Cartoon Use	Continuous	Sporadic	Continuous	Sporadic
City	Samarkand	Mary	Shauldir	Shymkent
Community	SSW	KSW	None	Altyn Order
Country	Kazakhstan	Turkmenistan	Kazakhstan	Turkmenistan
Cutting Direction	NE-SW	N-S	N-S	NE-SW
Double-Shed Heddles	0	1	1	0
Experience	2.5	3	10	48
Hook	N	Y	Y	N
Knife Type	Curve	Straight	Straight	Curve
Knotting Order	D/R-L	Color	Color	Pattern
Knotting Shed Position	Open	Partial	Closed	Partial
Number of Weavers	1	2	1	2
Oversight	PR	PS	None	PS
Production Setting	Collective	Domestic	Domestic	Collective
Scissor Type	Standard	Offset	Standard	Offset
Shed Rods	1	0	0	1
Single-Shed Heddles	1	0	1	0
Tension Rods: Bottom	1	0	1	0
Tension Rods: Top	1	0	1	0
Trim Frequency	2	1	1	2
Village	Gondimiyon	None	Gondimiyon	Angarik
Weaver/Pseudonym	Kathleen	Janina	Teri	Margaret
Weft Addition Rate	Broken	Continuous	Continuous	Broken
Workload	7.5	2.5	3	7.5

MU-SO-4

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	R	None	R	None
Knot Type	AS	SY	AS	SY
Knot-Warp Pattern	III	I	I	II
Knot-Weft Pattern	A *	C; D	C *	C; D
Pile Material	Silk	Wool	Synthetic	Wool
Strands per Knot	4	2	2.5	4
Warp Material	Silk	Wool	Cotton	Wool
Weft Material	Silk	Wool	Cotton-Synthetic	Wool
Weft Offset Pattern	Alternate	Regular	Regular	Alternate
Weft Shot Pick Count	1 †	2	2 †	1.5
Cartoon Use	Sporadic	Continuous	None	Sporadic
City	Samarkand	Shauldir	Shauldir	Shymkent
Community	KSW	SSW	None	Altyn Order
Country	Kazakhstan	Turkmenistan	Kazakhstan	Turkmenistan
Cutting Direction	NE-SW	N-S	NE-SW	N-S
Double-Shed Heddles	0	1	1	0
Experience	2.5	3	10	48
Hook	N	Y	N	Y
Knife Type	Curve	Straight	Curve	Straight
Knotting Order	Color	Pattern	D/R-L	Color
Knotting Shed Position	Open	Closed	Closed	Partial
Number of Weavers	2	1	1	2
Oversight	PR	None	None	PS
Production Setting	Domestic	Collective	Domestic	Collective
Scissor Type	Offset	Standard	Standard	Offset
Shed Rods	0	1	0	1
Single-Shed Heddles	1	0	1	0
Tension Rods: Bottom	0	1	1	0
Tension Rods: Top	1	0	1	0
Trim Frequency	2	1	2	1
Village	Gondimiyon	Angarik	Angarik	Ingilis
Weaver/Pseudonym	Kathleen	Janina	Margaret	Teri
Weft Addition Rate	Broken	Continuous	Continuous	Broken
Workload	6.5	8	3	7.5

* B
† 3

MU-VA-1 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	None	R
Knot Type	-	-	SY	AS
Knot-Warp Pattern	-	-	I	II
Knot-Weft Pattern	-	-	C	C; D
Pile Material	-	-	Synthetic	Wool
Strands per Knot	-	-	2.5	2
Warp Material	-	-	Cotton	Wool
Weft Material	-	-	Cotton-Synthetic	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	1	1.5
Cartoon Use	-	-	Continuous	None
City	-	-	Shauldir	Shymkent
Community	-	-	None	Altyn Orda
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	0	1
Experience	-	-	10	30
Hook	-	-	Y	N
Knife Type	-	-	Straight	Curved
Knotting Order	-	-	D/R-L	Pattern
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Domestic	Collective
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	1	0
Trim Frequency	-	-	1	2
Village	-	-	None	Gondimiyon
Weaver/Pseudonym	-	-	Teri	Margaret
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	3	7.5

MU-VA-2 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	None *	R
Knot Type	-	-	SY	AS
Knot-Warp Pattern	-	-	I	II
Knot-Weft Pattern	-	-	C †	C; D
Pile Material	-	-	Synthetic	Wool
Strands per Knot	-	-	2.5	4
Warp Material	-	-	Cotton	Wool
Weft Material	-	-	Cotton-Synthetic ‡	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	2 +	1.5
Cartoon Use	-	-	None	Continuous
City	-	-	Shymkent	Shauldir
Community	-	-	None	Altyn Orda
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	0	1
Experience	-	-	10	48
Hook	-	-	N	Y
Knife Type	-	-	Curved	Straight
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Domestic	Collective
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	1	0
Trim Frequency	-	-	1	2
Village	-	-	None	Gondimiyon
Weaver/Pseudonym	-	-	Teri	Margaret
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	3	7.5

* L ‡ Cotton † B + 3

MU-VA-3 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	None	R
Knot Type	-	-	SY	AS
Knot-Warp Pattern	-	-	I	II
Knot-Weft Pattern	-	-	C	C; D
Pile Material	-	-	Synthetic	Wool
Strands per Knot	-	-	2.5	2
Warp Material	-	-	Cotton	Wool
Weft Material	-	-	Cotton-Synthetic	Wool
Weft Offset Pattern	-	-	Alternate	Regular
Weft Shot Pick Count	-	-	1 *	1.5
Cartoon Use	-	-	None	Continuous
City	-	-	Shauldir	Shymkent
Community	-	-	None	Altyn Orda
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	NE-SW	N-S
Double-Shed Heddles	-	-	0	1
Experience	-	-	10	30
Hook	-	-	Y	N
Knife Type	-	-	Straight	Curved
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Domestic	Collective
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	0	1
Single-Shed Heddles	-	-	1	0
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	1	0
Trim Frequency	-	-	2	1
Village	-	-	None	Gondimiyon
Weaver/Pseudonym	-	-	Teri	Margaret
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	7.5	3

* 6:7

MU-VA-4 (fragment)

	Size Comparison	Size Comparison	Shape Comparison	Shape Comparison
Production Characteristic	Best Fit	Second-Best Fit	Best Fit	Second-Best Fit
Knot Direction	-	-	None	R
Knot Type	-	-	SY	AS
Knot-Warp Pattern	-	-	I	II
Knot-Weft Pattern	-	-	C	C; D
Pile Material	-	-	Synthetic	Wool
Strands per Knot	-	-	2.5	2
Warp Material	-	-	Cotton	Wool
Weft Material	-	-	Cotton-Synthetic	Wool
Weft Offset Pattern	-	-	Alternate *	Regular
Weft Shot Pick Count	-	-	1.5 †	2
Cartoon Use	-	-	Continuous	None
City	-	-	Shauldir	Shymkent
Community	-	-	None	Altyn Orda
Country	-	-	Kazakhstan	Turkmenistan
Cutting Direction	-	-	N-S	NE-SW
Double-Shed Heddles	-	-	1	0
Experience	-	-	30	10
Hook	-	-	Y	N
Knife Type	-	-	Straight	Curved
Knotting Order	-	-	D/R-L	Color
Knotting Shed Position	-	-	Closed	Partial
Number of Weavers	-	-	1	2
Oversight	-	-	None	PS
Production Setting	-	-	Domestic	Collective
Scissor Type	-	-	Standard	Offset
Shed Rods	-	-	1	0
Single-Shed Heddles	-	-	0	1
Tension Rods: Bottom	-	-	1	0
Tension Rods: Top	-	-	1	0
Trim Frequency	-	-	1	2
Village	-	-	None	Gondimiyon
Weaver/Pseudonym	-	-	Teri	Margaret
Weft Addition Rate	-	-	Continuous	Broken
Workload	-	-	3	7.5

* Random
† 7

Appendix F. Glossary & Foreign Language Terms

This section includes definitions of English weaving terms used in the text, as well as foreign-language translations where available. A summary of the references is given at the end of the glossary; full citations are given in the Bibliography. Uncited translations are provided by the author through personal experience or were given by project weavers. Unless otherwise specified, the weaving terms represent 21st century English usage.

asymmetric knot (n)

a common knot form tied around two consecutive warps, where the body of the knot sits around one warp and the two loose ends stick out around the other warp. Occurs in left-opening and right-opening varieties.
See *Persian Knot* and *Senneh Knot*

yarachitme [1, 2, 3]	Turkmen, Uzbek

beater (n)

a rigid instrument used to compact successive rows of weaving into a coherent, study textile. Come in types such as sword, comb, heddle, and reed.

тарақ [taraq] *	Kazakh
тоқпақ [toqpaq]	Kazakh
darak *	Turkmen
kilich † [2, 3]	Uzbek
taroq *	Uzbek

* comb-style beater
† sword-style beater

[side] binding (n)

a section of weaving at the vertical left and right sides of a carpet that creates a neat, sturdy, finished edge and protects the knots from wear. May be woven or wrapped, with or without an additional core.

gerasarmah [3]	Turkmen
pugtama * [3]	Turkmen

* also *selvedge*

carpet (n)

a pile-woven textile used as a floor covering.

anspāk [4]	Sogdian (4-10th c. CE)
fsp [4]	Sogdian (4-10th c. CE)
prštrn [4]	Sogdian (4-10th c. CE)
gahāvara [5]	Saka-Khotanese (4th c. BCE - 3rd c. CE)

“rug with long hair”	kojava, kōjava [4, 5]	Saka-Khotanese (4th c. BCE - 3rd c. CE)
	tavastaga [5]	Saka-Khotanese (4th c. BCE - 3rd c. CE)
	thauracaihä [5]	Saka-Khotanese (4th – 11th c. CE)
	tapast, tapastak [4]	Pahlavi (3rd c. BCE - 8th c. CE)
	farasp [4]	Persian (from 8th c. CE)
	gilīm [4]	Persian (from 8th c. CE)
	ḵẖālī, ġẖālī, qālī [4]	Persian (from 8th c. CE)
“carpet with a shaggy pil”	ṭanfasat [4]	Persian (from 8th c. CE)
	غالی [ghali] *	Pashto
	قالین [qalin] *	Pashto
	қолин [qolin] *	Tajik
	julhirs ‡ [2]	Tajik
	kiviz [4, 5]	Turkic (8-11th c. CE)
	tavrattï [5]	Turkic (8-11th c. CE)
	吉里雅木 [giliyam] [4]	Xinjiang Turkic (18th c. CE)
	帕拉斯 [palasi] [4]	Xinjiang Turkic (18th c. CE)
	кілем [kilem] *	Kazakh
	тоқылатын кілем [toqilatin kilem] †	Kazakh
	жұлқышы [zhylkishi] ‡	Kazakh
	gilam *	Kyrgyz, Uzbek
	julkhir ‡ [3]	Kyrgyz, Uzbek
	kalyn	Uzbek
	haly	Turkmen
	گلەم [glenm] [4]	Uyghur
	氆氇 [tadeng] [5]	Chinese (300 BCE - 13th c. CE)
“woven skin/leather”	织皮 [zhīpí] [4]	Chinese (500 BCE – 900 CE)

* could also be translated as *rug*
† with modifier *knotted*
‡ long-haired carpets

cartoon (n) — a drawn diagram of a knotted carpet pattern, where the design is drawn over a grid and each grid square represents one knot.

nakish, nagish [3]	Arabic, Turkmen, Uzbek
nuska, nusga [3]	Kyrgyz, Turkmen, Uzbek

	chizma [2]	Uzbek
“draftsperson”	chizmachi [2]	Uzbek

cloth bar (n)
cloth beam (n)
a specialized warp bar that can be wound to take up finished textile; sometimes also used for the near or lower warp bar, even if not windable.
See *Warp Bar*

cut pile (n)
a technique for creating pile where a weft is not pulled taught, and the excess yarn is allowed to pool in individual loops between warps. These loops are then cut to create a flat, even plush surface. Velvet is an example.
See *Woven Pile* and *Looped Pile*.

embroidery (n)
a decorative technique where designs are stitched to the surface of a woven textile.

end (n)
a single thread of warp that can be traced across the full length of a textile, usually used in reference to density (e.g., X ends per centimeter).

uch [3]	Turkmen, Uzbek

felt (n)
a pseudo-textile where wool is matted together into a solid mass using pressure, heat, and liquid.

koshma [3]	Turkmen, Uzbek
киіз [kyiz]	Kazakh
кийиз [kyyiz]	Kyrgyz

float (n)
a section of weft that skips many warps, usually on the back to keep the weft out of sight for a particular section of the design.

frame (n)
structural components that hold the warp bars, cloth bars, heddles, and other loom components in a fixed position.

fringe (n) — the ends of the warps where the carpet is cut from the loom. Fringes may be left loose, braided, knotted, or otherwise secured.

kesalin erish [3]	Turkmen

Ghiordes knot (n) — a misleading alternate name for symmetric knots, referencing the town of Gördes in western Turkey.
See *Symmetric Knot*

grandrelle (n)
grandrelle yarn (n) — a type of yarn where two or more colors are plied together, resulting in a heathered or dimensional textile when used.

gul (n) — a motif, from the Persian-Turkic word meaning flower. Commonly used in carpet studies in place of 'motif'.

гүл [gul]	Kazakh
gül	Turkmen
gul	Uzbek

heddle (n) — a loom component that allows for the mechanical opening of pre-determined sheds; warp threads pass through a rigid heddle, or are individually attached to a string heddle.

бел ағаш [bel agash]	
күзу ағаш [kuzoo aghash]	
күзу жіп [kuzoo zhip] *	Kazakh

* threads that attach the warps to the heddle

hook (n) — a tool with a miniature hook that allows for the quick separation of individual warp threads, speeding up the knotting process. Often integrated into the carpet knife.

крючок [kryochok]	Kazakh
çeňňek	Turkmen
ilgak	Uzbek

jufti knot (n)

a less-common knot form tied across four consecutive warps, occurring in both symmetric and asymmetric varieties.
See *Symmetric Knot* and *Asymmetric Knot*

kaunakes (n)

[1] a shaggy wrap or mantle often depicted in Mesopotamian art, possibly an early pile textile.

[2] a knotted textile or carpet with large gaps between rows of knots, many picks of weft, and very long pile.

жұлқышы [zhylkishi] *	Kazakh
rytu [7]	North Caucasus
kiiz [7]	North Caucasus
rya, rye	Scandinavia
filikli [7]	Turkic (derivation unclear)
tulu [7]	Turkish
гуня [gunya] [7]	Ukrainian, Belarussian, Transcarpathian, and other
julkhir * [3]	Uzbek

* also used for long-pile carpets without gaps between rows

[carpet] knife (n)

a specialty knife or blade used to cut individual knots off the skein during production of a knotted carpet.

кілем пышағы [kilem pishacghi] *	Kazakh
пышақ [pishaq]	Kazakh
keser	Turkmen
gilam pichog'I	Uzbek
pichoq	Uzbek

* with modifier *carpet*

knot (n)
to knot (v)
knotted (adj)

a single unit of pile in a knotted textile, a short length of yarn tied around a single warp or several consecutive warps to create pile. This is a distinct system from woven pile, where the pile and weft are the same yarns.
See *Asymmetric Knot, Symmetric Knot,* and *Wrap Knot.*

n.	түйін [tuyin]	Kazakh
n.	түкті [tukti] *	Kazakh
v.	chitme * [3]	Turkmen
n.	ilmek [3]	Turkmen
n.	shtim †	Uzbek (Khorezm)

* could also be translated as *pile*
† translation uncertain; provided by weaver

loom (n) — a mechanical system for the weaving of textiles, where warp threads are held under tension and weft threads are interlaced between them.

"weaving equipment"		
	kөzək [4]	Turkic (pre-13th c. CE)
	қалып [qalip]	Kazakh
	станоқ [stanoq]	Kazakh
	тоқыма станогы [toqima stanogi] *	Kazakh
	urmak, ormok [2, 3]	Kyrgyz, Uzbek
	dastgoh	Uzbek
	to'qish dastgohi *	Uzbek

* with modifier *weaving*

looped pile (n) — a technique for creating pile where a weft is not pulled taught, and the excess yarn is allowed to pool in individual loops between warps. These may be left as loops, or may be cut to create *cut pile*. Toweling is an example.
See *Woven Pile* and *Cut Pile*.

native shed (n) — a non-mechanized shed that is created by the structure of the

natural shed (n) — loom, the warp winding route, or the use of tension rods.

Oriental carpet (n) — a misleading and outdated generic name for knotted carpets, referencing the historic origin of many carpets.
See *Carpet*

Persian carpet (n) — a misleading generic name for knotted carpets, referencing a major historic producer.
See *Carpet*

Persian knot (n) — a misleading alternate name for asymmetric knots, referencing the historic association of this knot form with Iran.
See *Asymmetric Knot*

pick (n) — a single thread of weft that can be traced across the full width of a textile, usually used in reference to density (e.g., X picks per centimeter).

pile (n) — yarns that stand upright in the z-axis to create a raised, three-dimensional surface on conjunction with the warp and weft.

түкті [tukti] *	Kazakh
chitme * [3]	Turkmen

* could also be translated as *knot*

pile textile (n) — a cloth or fabric that has a pile. Examples include knotted carpets, velvet, corduroy, and toweling.

plain weave (n) — the simplest and most common weaving pattern, the basic type of tabby weave where single wefts pass over and under successive warps in regular sequence.
See *Tabby*

row (n) — many knots sitting side-by-side on top of and underneath the same weft picks.

rug (n) — a flat-woven textile used as a floor covering.

кілем [kilem] *	Kazakh
килем [kilem] *	Kyrgyz

gilam	Turkmen, Uzbek

* also used for *carpet*

scissors (n) a tool used to cut pile ends to a standard length during and after weaving. Scissors are in-line, meaning the weaver's hand may hinder the ability to cut flush along the plane of the textile. See *Shears*

қайшы [qaishi] *	Kazakh
gaýçy *	Turkmen
qaychi *	Uzbek

* also used for *shears*

selvedge (n) a section of weaving at the horizontal top and bottom sides of a carpet that creates a neat, sturdy, finished edge and protects the knots from wear. Usually plain-woven and without decorative elements.

pugtama * [3]	Turkmen
elem [2, 3]	Turkmen, Uzbek
labaki †	Uzbek

* also *binding* translation uncertain
† translation uncertain; provided by weaver

Senneh knot (n) a misleading alternate name for asymmetric knots, referencing the historic name for the town of Sanandaj in western Iran.
See *Asymmetric Knot*

shears (n) a tool used to cut pile ends to a standard length during and after weaving. Shears are off-set, meaning the weaver's hand is held away from the textile surface and it is easier to achieve a flush cut along the textile's plane.
See *Scissors*

қайшы [qaishi] *	Kazakh

gaýçy *	Turkmen
qaychi *	Uzbek

* also used for *scissors*

shed (n) the gap between warps through which a weft pick is passed. The use of different sheds in sequence creates the structure and design of a textile. Can be picked out by hand or opened mechanically.

shed rod (n) a cylindrical dowel inserted between warps to force them apart and open a shed. Moving the rod away from the weaving zone closes the shed, and bringing it closer to the weaving zone opens the shed by parallax.

адырғы [adirghi]	Kazakh
қылыш [qilish]	Kazakh

soumak (n) a weaving technique where supplementary wefts are wrapped or knotted around warps in a decorative pattern to create a 3D texture.

Spanish knot (n) an uncommon pseudo-knot tied around a single warp; used almost exclusively in the Iberian peninsula and Egypt.
See *Wrap Knot*

symmetric knot (n) a common knot form tied around two consecutive warps, where the body of the knot is split between the two warps and the loose ends stick out between them.
See *Turkish Knot* and *Ghiordes Knot*

duochitme [1, 2, 3]	Turkmen, Uzbek

tabby (n) — one of three basic weave patterns, where the weft passes over and under the same number of warps in sequence, and the subsequent weft inverts the route. Occurs in plain (aka balanced) and basketweave variations.
See *Plain Weave*

ta'lim (n) — a written sequence of knot colors, which can be read or said aloud in the order of knotting.

tapestry (n) — a weaving technique where wefts of many colors are woven side-by-side rather than full-width, creating images and designs in the textile.

tension rod (n) — a cylindrical dowel inserted between warps to achieve one of several non-mechanical goals: 1) to take up slack in the warp, 2) to reposition a cross-point in a figure-8 warp, 3) to bring to sections of warp together in a single weaving plane, or 4) to change the width of a native shed.

textile (n) — an object created by the interlacing of fibers, including by weaving, knotting, knitting, crocheting, tatting, braiding, and sometimes felting and basketry.

to trim (v) — the process by which knot-ends are trimmed as a group after knotting. Often occurs after one or two rows of weaving is complete, and usually done with scissors or shears. Not to be confused with the process by which individual knots are cut from the skein using a knife.

gyorm [3] — Turkmen

tufting (n)
tufted pile (n) — a technique for producing pile where bundles of yarn are pushed between the warp/weft threads and are held in place by tension or by the application of an adhesive to the back. This system is distinct from both woven and knotted pile, as the pile is added after the underlying fabric is created.

Turkish knot (n) — a misleading alternate name for symmetric knots, referencing the historic association of this knot form with Turkey.
See *Symmetric Knot*

twill (n) — one of three basic weave patterns, where the weft passes over and under a different number of warps in sequence, and subsequent wefts shift the pattern sideways a prescribed number of warps.

warp (n) — the collective name for the threads that are held in tension by the loom, usually running vertically (y-axis). By the interweaving of the weft (x-axis), a textile is created.
See *End*

желі [zheli]	Kazakh
жіп [zhip]	Kazakh
erish, irish [3]	Kyrgyz, Turkmen, Uzbek
tor	Uzbek
ilish	Uzbek (Khorezm)

warp bar (n)
the **warp beam** (n) — one of two beams in a loom around which the warp is wrapped, distance between which holds the warp in tension.
See *Cloth Bar*

to weave (v)
woven (adj)
weaver (n) — interlacing threads by passing them over and under each other at a right angle.

	n.	išparu [4]	Neo-Assyrian (9th c. BCE)
"felt maker, carpet maker"	*n.*	kāmidu [4]	Neo-Assyrian (9th c. BCE)
	v.	gyah [4]	Saka-Khotanese (4-11th c. CE)
"to twist, weave, spin"	*v.*	tānīdan [4]	Persian (from 8th c. CE)
"to twist, weave, spin"	*v.*	tavrattï [4]	Turkic (pre-13th c. CE)
	n.	тоқымашы [toqimashi]	Kazakh
"carpet weaver"	*n.*	кілемші [kilemshi]	Kazakh

v.	току [toku]	Kazakh
+n.	токуучу [tokuchu]	Kyrgyz
n.	бофанда [bofanda]	Tajik
n.	dokmaçy	Turkmen
v.	dokamek [3]	Turkmen
v.	to'qmoq	Uzbek
v.	to'quvchi	Uzbek
v, adj.	tukimachilik [2]	Uzbek

weft (n) the collective name for the threads that are interwoven into the warp (y-axis), and which are not held in tension by the loom. Usually run horizontally (x-axis).
See *Pick*

арқау (жіп) [arqau (zhip)]	Kazakh
arkak [3]	Kyrgyz
yek argach * [3]	Turkmen
argoch, argach [3], argatch [6]	Turkmen, Uzbek
fut † [3]	Turkmen, Uzbek
bofta †	
sarg'a ‡	Uzbek

* specifically the thicker, primary yarn used in every weft shot
† terms specifically for a secondary, smaller weft added for strength in alternate weft shots
‡ translation uncertain; provided by weaver

weft shot (n) the collective name for all weft picks between consecutive rows of knots.

woven pile (n) a technique for creating pile where a weft is woven loosely and manipulated to create a pile. This is a distinct system from knotted pile, where the pile and weft are separate yarns.
See *Cut Pile* and *Looped Pile*

wrap knot (n) a pseudo-knot form wrapped around individual warps. Can occur with an *s*- or *z*-twist.

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