Continued from Book 199: [specimens] 25921-25923. No. 200 1897

U. S. GEOLOGICAL SURVEY

FIELD SECTION BOOK

9-891

LAKE SUPERIOR DIVISION.

INSTRUCTIONS.

1. Ordinarily at least two pages of this book will be devoted to one section. On the left-hand page, place a map of as much of the section as has *actually been seen*. Denote rivers, lakes, marshes, etc., by the usual topographical signs. Denote the ledges of rock, when no structure is made out, by cross-hatching, making the cross-hatching cover as nearly as possible the areas occupied by the exposures. If the rock is a massive one, but still more or less plainly bedded, use the same sign with a dip arrow and number attached, showing the direction and amount of the dip. Denote a shaly or other very plainly bedded ledge by right parallel lines, and a ledge having a secondary structure by wavy parallel lines running in the direction of the strike, with dip arrow and number attached as before. The greatest care must be taken to avoid confusing slaty or schistose structure with bedding, and in all cases where there is the least doubt about the true bedding direction, indicate it by a query. To each exposure on the face of the map attach the number of the specimen representing it. In mapping the section count each of the spaces between the blue lines as 100 paces, and twenty of these spaces to one mile, or 2,000 paces. Usually the southeast corner will be placed at the bottom of the page, or at the first black line above the bottom of the page, and at the right-hand side. If, however, for any reason, it is desirable to show portions of an adjoining section, the southeast corner may be shifted up, or the map may be turned around and the north placed at the left-hand side of the page. The ruling of the left-hand pages is also arranged so that, if desirable, a larger or a smaller scale can be used, eight inches, two inches, one inch, or one-half inch to the mile. With the two-inch scale, the squares outlined in black represent sections, and those in red, quarter sections and "forties," while the space between the blue lines is 200 paces.

2. On the right-hand page place the notes descriptive of the exposures. Begin in each case with the number of the specimen, placing the number on the left-hand side of the red line, after which give in order on the right of the same red line the position of the ledges as reckoned in paces from the southeast corner of the section and the dip and strike when observable, the latter always being expressed from the north; for instance 4025, 250 *N.*, 300 *W.*, *Strike*, *N.* 78° *E.*, *Dip* 50° *S.* Then follow with a full description of the ledge. When topographical maps are used for locations this paragraph applies only in part.

3. Collect a specimen from every ledge, or wherever there is a change of rock on any one ledge, taking care to get fresh material, unless for a special purpose the weathered surface is desired. In case of trips made on foot or in canoes, for long distances, neighboring ledges, unquestionably of one kind of rock, need not be specimened. The position and extent of the ledges not specimened should be marked on the map, with notes that each is of a rock identical with specimen so-and-so. Under the same conditions small-sized specimens, trimmed to a uniform size of 2 x 2½ x ¾ inches will be allowed, but in all other cases *large-sized specimens*, trimmed to a size of 3 x 4 x 1 inches, must be selected, in accordance with section 3, chapter IV, p. 44, Regulations of the U. S. Geological Survey. Specimens should not be placed together without protection in the collecting bag, as the fresh surfaces, important in determining the character of rocks, are thus destroyed. They should be damaged by no temporary mark, but the numbers should be at once marked in at least two places upon the inclosing paper or cloth bags. Specimens may be permanently marked in camp by painting the numbers upon them in white upon a black background, using Silver White and Ivory Black oil tubes for color, with turpentine as a diluent.

4. On the last twenty-five pages of the book give, as may seem desirable, a general account of the examination of the region mapped in the previous pages, correlation of observations, sketches, cross sections, etc.

5. Forward this note book as soon as filled as registered mail matter to C. R. Van Hise, U. S. Geologist, Madison, Wis.

#200

Continued from Book 199

(Sierra Nevada)

From the foregoing pages, and by an examination of the drainage of the map, it appears that the rectangular sets of joints gradually vary in direction in passing from the Merced to the Tuolumne. This gradual changes is especially marked in the course of Yosemite Creek. In the course of the Tuolumne below Tuolumne Meadows there is an inclined set of joints which is very marked. This system strikes NE - SW and dips SE at angles estimated from 35° to 45°. Parallel to this set of joints are numerous flattened inclusions, and to some extent a parallel arrangement of the mineral particles. This, then, was the direction of the ancient schistosity, and explains the prominence of this set of joints.

The typical forms of the

topography of the granite area of the Sierras seems clearly dependent upon the system of jointing. The dome forms — the roof or pinnacle forms and the flat-topped rectangular or buttressed forms, - everywhere are dominant. The dome forms are due to the horizontal or nearly horizontal jointing combined with exfoliation. The roof form is dependent upon the intersection of the inclined sets, and is beautifully illustrated by Cathedral Peak. The pinnacles of the peak are a result of the vertical joints producing rectangular chimneys.

The Tuolumne from the Meadows runs in a series of rapids and cascades for 4 or 5 miles through a rounded glacial formed depression, in which the stream

is just beginning to cut a notch into a deep canyon with flat meadows. Below the meadow is a coarse reef and below this is another meadow.

Saturday Aug. 28, 1897

From Meadow on Dana Creek went up creek to top of divide between the West and the Great Basin. Ascended Mt. Dana. Came down Mt. in southwesterly course over the talus and cliffs to the E. end of the Mt.

From the divide and from the Mt. had a most extended and instructive view of the Great Basin, the Basin Ranges, Mono lake, and numerous other Basin Lakes and glided up Lake Tahoe. Of the topography of the high

Sierra, and especially of the Mt. Warren mass, the Mts. ------ and Lyell and Ritter and of a great group much farther S which projects E. farther than these.

One of the first beauties which attracts the eye is the greater abundance of snow on the western part of the high Sierra than on the eastern part. Evidently the water is chiefly precipitated before the upthrown eastern masses are reached. Going with this change is a change in color, the less watered areas being of brown and the more watered ones being green. These colors are of course modified by the color of the rocks, whether dark gray bedded rocks, red volcanics or light gray granites. Of course other rocks than these have their colors, but these are the

rocks which seem to give the dominant rock tints to the various masses.

However, the most interesting thing is the topography. All the large valleys are exactly like that of the Tuolumne mentioned yesterday, i.e., each stream follows a series of very flat meadows, separated by areas of rapid fall, either over smooth glacial rock faces or over moraines. This applies to the streams from the highest source in a little creek, to the larger ones. Way up on the higher elevations 11,000 or 12,000 ft up, may be seen the meadows containing numerous little glacial lakes - - - - and a meandering stream. Such benches will be separated in most cases from the next meadow below by rapids

and cascades. In most cases the dams which result in the meadows, some of which have been occupied by lakes, as in the case of the Tuolumne in which former found lake deposits and terraces — are glacial moraines, but in some cases at least a rock reef runs across or nearly across the meadows and this makes it easy for the moraines to dam the valleys, just at the N. foot of Mt. Dana. Solomons says the lower meadows of the Tuolumne between the falls and rapids mentioned are largely separated by a rock reef, by means of which one meadow is about 80 ft above the other.

These features are beautifully expressed in Willard Johnson's map of Mono lake and vicinity

The above gives an idea of the longitudinal character of the valleys. Transversely they are wide U-shaped valleys almost without exception, in which the streams have cut a barely perceptible notch in the floors of rapids, and in which the streams are at work on the moraines and lake silts in the meadows. Ordinarily the valleys are several times as broad as deep. Higher in the mountains the ratio may not be more than 2 or 3 to 1, as in the present Dana Glacier valley. Lower down in the lower streams, they are many to one. These wide, flat-bottomed steep-sided U-shaped valleys are so different from those ordinarily produced by streams that one cannot doubt that the valleys have been greatly widened by the glaciers and somewhat deepened, - how much in this respect we cannot tell

but the various levels suggest considerable modification.

There can be no doubt that the widening of the valley has been greatly assisted by the vertical joint systems, one of the other of which are followed. The side quarrying in this joint-systemed country would be very easy.

Moreover the process is plain in this region. Each main valley is joined by numerous side valleys at right angles, following the other system of jointing. Each of these side valleys, like the main valley, was occupied by a glacier. Tertiary to these secondary valleys is a third system of still smaller valleys occupied by smaller glaciers. If one starts with the larger streams, like the Merced, this would require one to go to the fourth order. Each of the valley heads is a cirque.

Many of these amphitheatres are as perfect as in the Alps. By this rectangular arrangement of the glaciers - the same as the streams - the vertical side quarrying of each glacier is assisted greatly by the help of the numerous side glaciers. All this is beautifully illustrated by the Tuolumne - Dana system. Dana Creek valley is almost straight, parallel to one system of joints. Within this the river itself meanders. On either side of Dana are several glacial valleys, - the higher of which are occupied by snow. One or two of the larger of the tributaries has many glacial tributaries of the 4th order.

Many small glacial lakes were observed in the various meadows, high and low.

The old lake basin of Mono - the rows of terraces in the distant mountains - the eskers, etc,

as ~~seen~~ described by Russell were beautifully seen.

Mt. Dana itself is constituted by a series of tedded rocks which near the top are very flat, - which on the S side in going down have higher and higher dips, many up to 60° or more in places, - which also on the SW crest have higher and higher dips. One may see layers curve about from a course nearly parallel the Dana valley to a course at least 45° away from it. This suggests that Dana is a synclinal basin. At one place from the valley of the side glacier the curved course of the beds may be beautifully followed; thus showing finely that complex folding is the same as torsion. As one would expect the harder of these layers have two beautiful systems of joints at right angles to ~~those~~ joints each other. Moreover

these joints are closer together where they beds are more closely folded. It thus seems very probable that these joints are tension joints.

The layers of the series comprise a peculiar chiastolite banded rock, which appears to be a metarhyolite or metarhyolite tuff; a coarse grits or tuffs, of schist and schist conglomerate, the pebbles of which are flattened parallel to the schistosity — a peculiar mottled black slate, etc.

Both the slate and schist conglomerate have taken on a slaty cleavage. This cleavage, as one would expect, has a steeper dip than the beds. When in the zone of fracture the joints have followed this schistosity for this rock, and a course diagonal to it, the strike of the joints being that of the ------

Thus the schist layers by its jointing differ from the more massive beds which have not taken a schistosity.

Below the Dana series is a series of red igneous rocks which appear to cut across the Dana series diagonally, probably by intrusion, but possibly the Dana series overlies this series unconformably. Evidence was not seen to decide this. The igneous series has a well-developed schistose structure, and possibly the pebbles of the schist conglomerate were derived from these rocks. Of course both the Dana series and these underlying rocks are cut by various dikes of porphyry, etc..

My best guess is that the igneous series is older because in it schistosity is general, while the massive beds of the Dana series are not schistose.

From my observations of the day I have no doubt that the High Sierra was almost covered by a great complex system of glaciers, above which protruded the higher peaks, almost as a series of ----

We now have the topography characteristic of such a glacial country preserved in this country of ancient glaciers much more than in the Alps, - where the glaciers are still large, and where we cannot therefore see the topography. Moreover, the elevation of the country by the glaciers has been so rapid that the topography is scarcely affected by the subsequent stream erosion. In a word, what I saw below the Rhone Glacier in Switzerland is typical of the High Sierra.

Sunday, Aug. 29, 1897.

Crossed from Daraner to the Tuolumne river, just below the rocky divide between the two, then followed the Tuolumne to near its head under Mt. Lyell passed over the divide and came about ten miles down Rush Creek.

As we rounded the rocky ridge between the Creek and river, we passed over a wide high medial moraine, - the product of the lateral moraines of the Dana and Tuolumne river glaciers.

Once in the valley of this river, we find it to be a wide flat rock-bottomed valley, in which the river has not made any gash whatever. The valley bottom, with but little slope, is about ½ mile wide. The walls are about 500 feet high. Thus the ratio between walls and bottom is

about 1 to 5. As we go up the stream the same topography continues, only the walls become higher and the floor narrower and less level, but still strongly contrasting with the very steep walls.

As one gains the higher elevations near the divide we can clearly see on the right that the ice has cut a horizontal terrace nearest the top of the slope, above which a few points of Kuna crest project. All below is rounded and glaciated and reflects light from polished surfaces. The Kuna crest points are rounded and may have been glaciated, but if so, long enough ago so as to have become broken by weathering.

Sept 9. On train crossing Mohave desert between Mohave station and Needles, Cal.

Upon this part of the desert the vegetation is very scanty. The dusty colored sage bush grows sparsely, between the bushes there being considerable spaces. The giant tree cacti are numerous between Mohave and Barstow. As looked at from the train across the desert, they appear to be very close together, so little appreciation does one have of distance. However, as we pass through them, we find them to be separated by wide intervals. Many other forms of cacti are seen, but the tree forms resembling stunted oaks are the ones which most impress one.

The sand of the desert is coarse - so coarse in places that it might be called fine gravel. The material if transported would make a fine conglomerate. Notwithstanding the coarseness of the desert sands & gravels, everywhere may be seen

wind riffle-marks.

At various places beds of ephemeral lakes were seen. Some of these are of considerable width, at least 8 or 10 or more miles. The sediment of these lakes is mainly the fine material selected from the coarse desert sands. Of course with this is mingled more or less of saline deposits. The Ry crosses both of the larger of these lakes shortly after leaving Mohave. Here there was a perfect mirage effect. As the train began to pass over the lake bed I had no doubt whatever that the other apparently lower side was occupied by water. As the train went along the apparent water remained at the same distance until the farther side of the lake was reached it was plain that no water at this time was in the lake basin.

The desert is studded with mountains. These appear mainly to be volcanic. Some of them

however, have been much
reached by the erosive forces, so
as to take on the ordinary topo-
graphic forms of eroded mountains
or mountain groups. Others are
perfect volcanic cones which show
not sign whatever of reaching
These cones are often grouped, indi-
cating an important volcanic dis-
trict. Some of the cones are
mainly composed of lavas. Others
of them are very plainly ash
cones. Lava flows were distinctly
seen at various places on the
slopes of the mountains, and for
some distance out on the plain.
Some of the lava flows almost
reach the R.R. track. In passing
through it appeared to me, that
this would be one of the best
regions I had seen for the study
of volcanic phenomena, the volcanic
mountains showing various degrees
of dissection, and being almost
wholly devoid of vegetation. For the
most part the volcanic rocks are
black. The contrast in colors

between the black igneous rocks, the yellow brownish sands, and the dun colored sage bush make a scene of rare beauty.

The water which falls on the mountains is ~~distributed~~ evaporated on the plains, so that we have in the mountain and desert country the union of water into larger and larger streams, until the base of the mountain is reached, and then the dispersion of the water into smaller and smaller streams, until it is evaporated, or reaches one of the ephemeral lakes. The mountains therefore show the ordinary forms of sculpture. However, at the base of every gulch or canyon is a great alluvial cone, which may be steep, but which often spreads in a fan-like area with a very gentle slope for a long way from the base of the canyon. The laws of the deposit of the alluvial cones are those of deltas. That is, the streams instead of uniting, separate and migrate, then being upbuilding

instead of erosion. The streams themselves occupy the ridges - not the hollows. If by breaking a dam they migrate to one of the lower plains, as they frequently do, this plain is built up to the highest ground - when another rupture may take place, and migration again occur. As a result of the deposition of all the material eroded from the mountains upon the desert, it results that the lower parts of the mountain masses are buried in their own debris. The desert debris is the transported material of the present and past mountain systems. We have here in these western mountains both the erosion and deposition of material as a process occurring upon land, rather than (erosion) as a process of land, and deposition as a process of the sea.

Sept. 14
Went from rim of Grand Canyon at Tourist down Red canyon to about ½ mile below bend of river.

Sept. 15
Went down river one day's journey by horseback winding around side canyons, about half way between Paint and Bright Angel Creeks.

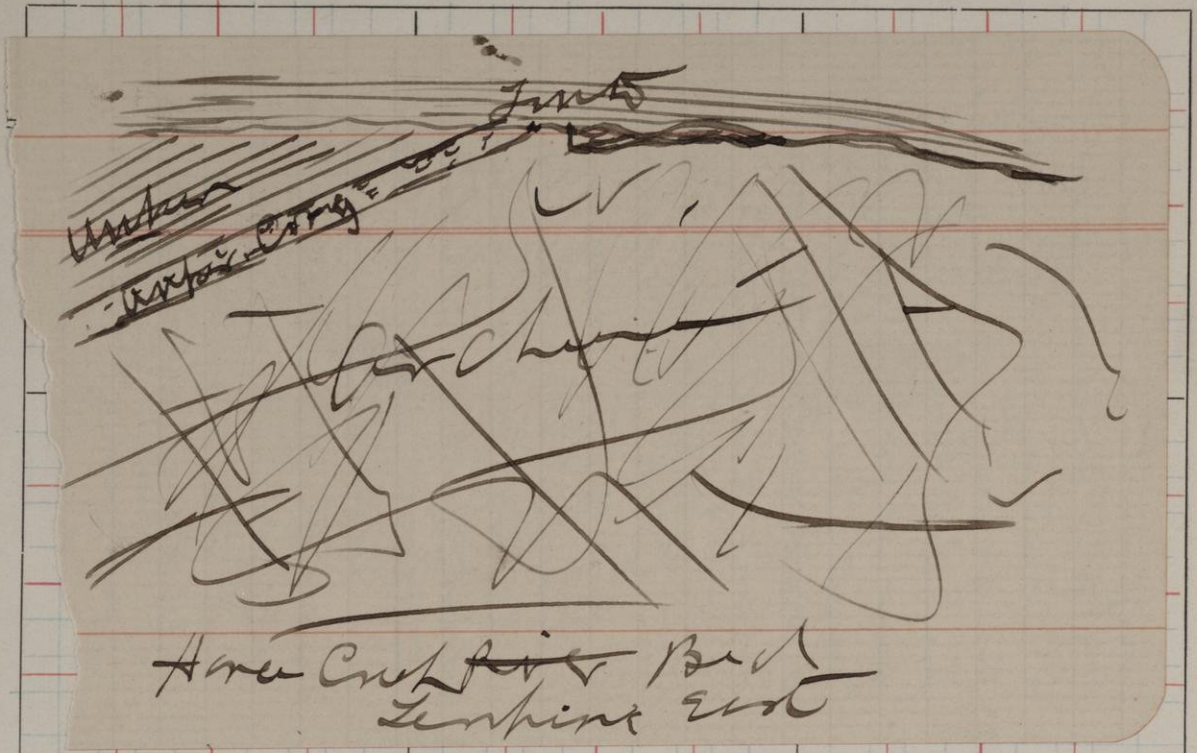
Sept. 16
Returned to camp by river.

Sept. 17
Returned to Tourist.

Sept. 18 & 19.
Went along rim to Grand Point about 8 miles E. of Tourist in a straight line.

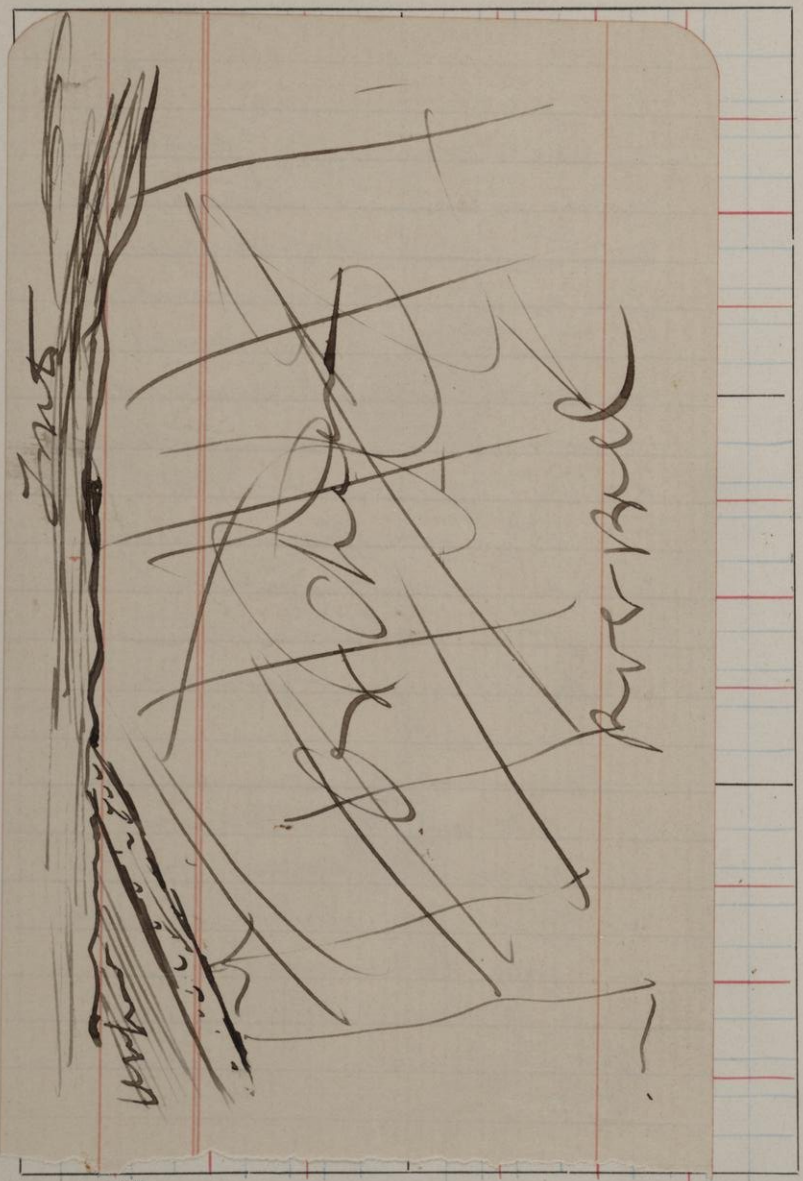
The different systems of rocks, as described by Powell, Walcott, and Dutton were seen, from the Aubrey to the Archean. In the course

S. T. R.



up and down Red Canyon no intrusive rocks were noted in the Unkar. A few basic dikes are seen, but the majority of these are small. Some are as much as 20 or 30 feet across. The igneous rocks mapped by Walcott at the base of the Unkar extend across the river and some distance down the north side, just as indicated by him. This igneous rock clearly seems to be an intrusive either a diabase or basalt. Its
7592/ central part is coarse 7592/
7592 Its upper part 7592 is fine grained, almost aphanitic, and very dense. There is no vesicular structure of any kind, nor any other indications of an intrusive rock. This intrusive follows the bedding approximately, but at places appears to cut diagonally across it. This diabase or basalt is intrusive in the limestone, ~~bed~~ at this bed of which underlies it. Below this is a persistent basal conglomerate having an average thickness of 20

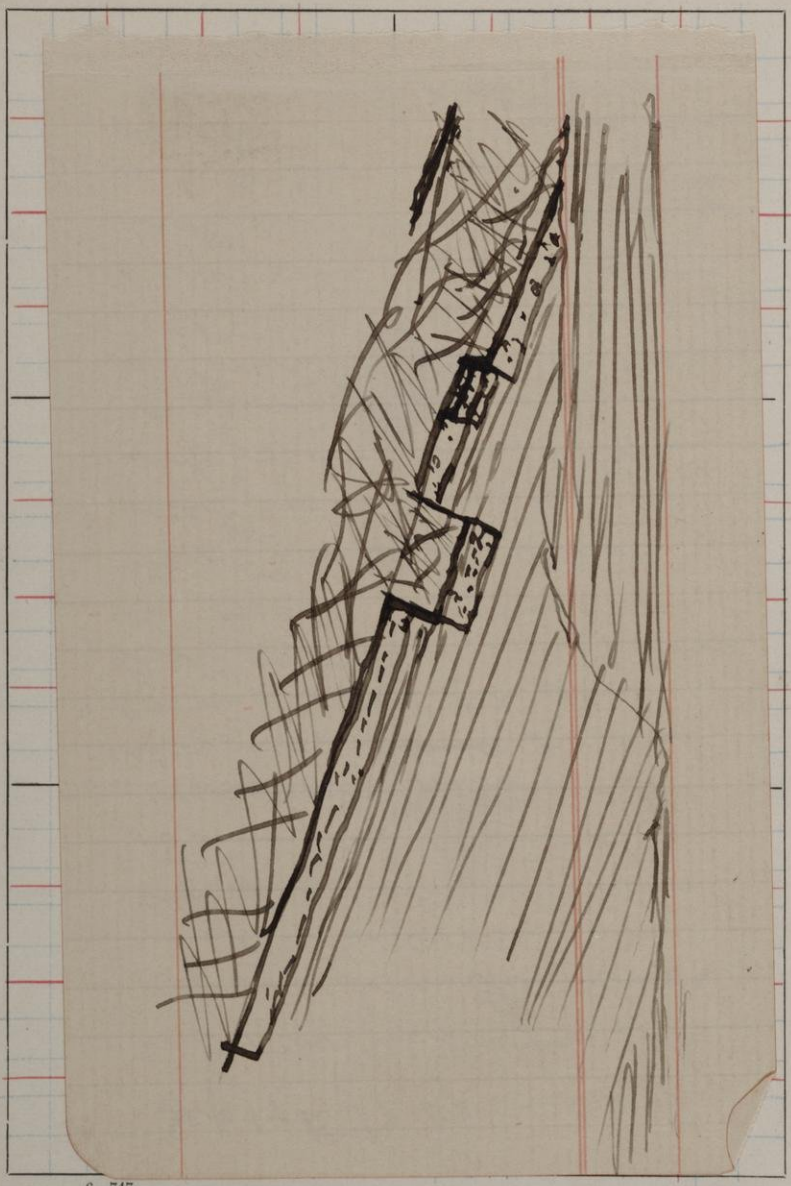
S. T. R.



fact. In places it is thinner and thicker than this. The part of the limestone below the igneous rocks is from 5 to 10 ft. thick.

The Unkar series consists of conglomerates, cherty limestone shales, slates, indurated sandstones approaching quartzites. The lower part of the series, that below Red Canyon creek, consists from the base upward of a persistent conglomerate bed - a bed in which greenish cherty limestone 30 to 50 ft. thick, predominates; above this a very considerable thickness of rock in which dark colored cherty-limestone predominates 50 to 75 ft. thick; and above this sandstones and shales. Where the limestones were crossed on Congress Canyon (Hays canyon) between the two limestones is a second belt of conglomerate. The series is everywhere stained with oxide of iron. The shales have the bright color of finely powdered

S. T. R.



juroxide. The limestone and sandstone have brown hues. In some these hues are so dark as to approach black. The conglomerate at the bottom of the Unkar contains many bands of pebbles and boulders. The bed is as beautiful an example of basal conglomerate as I have seen. It persists with wonderful uniformity of width down the Colorado to Red Canyon for the 4 or 5 miles we went. From a point of vantage at the junction of Colorado and Cotton creek, it was seen to extend with the same regularity for 4 or 5 miles farther. In the side canyons such as Cotton, Hance, and others, this conglomerate is seen to have the same persistent character. The pebbles of the conglomerate comprise the greatest variety of granites, gneisses and schists and also numerous
25923 ones of quartzite 25923 This must mean that somewhere is a pre-Unkar sedimentary series

from which the quartzite was derived. I know of no such quartzite nearer than the Uncompahgre Mts. of S.W. Colorado. The Uinkaret series lies upon the truncated edges of the Archean in its typical development. The Archean, notwithstanding the great variety of rocks which compose it, seems to have been almost absolutely base-leveled - at least for the district where we saw it. Above this plane is Uinkaret conglomerate of uniform thickness, and above this the other Uinkaret beds. The contact between the conglomerate and the Archean is regular, as the bedding of the Uinkaret seems to be absolutely parallel with it. Various measurements of the dip of the contact plane of the Uinkaret beds were taken, the results varying from 10° to 12° to the NE.

Considering the great variety of rocks in the Archean, this almost perfect inclined plane of contact with its uniform basal

conglomerate, fucuits an unique appearance.

It has been said that the Archean is typical. The descriptions written for the Lake Superior region and the general descriptions of the Archean in Bull. 86, would apply equally to the Colorado Archean. Black hornblende gneiss and light colored gneissoid granite are all abundant. In many cases these were interlaminated. In some cases the gneiss was distinctly ~~corrugated~~ banded, in others are distinctly foliated or schistose. The gneiss are cut by various granites in the most complex manner. Great exposures show the dikes ramifying and coming together in the most fantastic manner. This indicates that before the granites were intruded the old gneisses had been most completely deformed. None of the granite dikes penetrate the Archean. The only dikes found

in the Unkar were basic, and similar dikes were found cutting the Archean. The later intrusive granites are not schistose, and in place show a somewhat regular system of jointing. For instance the uppermost joint along the river where the Archean first appears below the Unkar, there are two sets of vertical joints at right angles to one set of horizontal joints. At a distance this rock looks like quartzite; yet when one gets to the same, he sees that it is a granite. (except in this newest granite, the jointing was so complex and varied that no law was made out. So far as I could see the old law holds that the dark colored gneisses are the oldest rocks of the Archean. The older gneisses are banded and contorted in both a major and a minor way - in short, exhibit the old story of complex deep seated deformation

modified by subsequent de-
formation of fracturing when
near the surface.

The general character of the
Archean is magnificently seen
at the junction of the Colton and
the Colorado, the view here extend-
ing both up and down the river.
From this point one can perhaps
see a distance of 9 miles along
its course. Scarcely less
splendid exposures are seen on
the side gulches. The Archean
at the point mentioned, and
for all the distance below the
point where the Unkar series
disappears, rises 1000 to 1100 ft
above the river. At this place
the river and side cuts have
cut the wildest of gorges. Rough,
ragged, V-shaped canyons are
here found. The walls are
intricately irregular; here is a
salient then a recentrant, one
may pass into the other either
laterally or vertically. The only
gorge which I have saw com-

paring with it in wildness and ruggedness is the Yellowstone. All this wildness is the more impressive, because below appears the regular, majestic, square buttressed and castellated system of the horizontal Paleozoic and Archean rocks.

Resting unconformably upon the Archean and Unkar is the Torto sandstone. The latter is horizontal, and is seen for miles to lie upon the same uneven surface of the two previous formations. Along the river and side ravines and as far down the river as we could see from the lowest point, and as far up the river as we could see from Grand Point, the Torto sandstone was seen in this attitude. This unconformity was thus followed with the eye for 20 or 30 or more miles. The plane between the Torto and the underlying formations has not the same marvelous evenness as

that between the Unkar and Archean. However for the distance observed the Archean could hardly have varied in altitude more than 200 ft when overridden by the Toroto. On passing from below up the river the Toroto we turn first upon the Archean, on all the truncated beds of the Unkar from the lowest to the highest, and then again upon the truncated edges of the Chuar.

The great Grand Canyon group, as a result of its gentle dip to the NE of 10° or 12°, has had its entire thickness truncated. At no place the two unconformable planes already described come together at an angle of 10° or 12°, the inclined plane being that between the Unkar and the Archean. It is perfectly clear that the Archean and all its complex parts and the Unkar have shared as a unit in the deformation being

tilted together at the gentle angle described. Both old and new, weak and strong, simple and complex, have been gently inclined 10° or 12°, with comparatively little differential movement within the mass. Where the two unconformities come together, we have a magnificent illustration of the principle that one unconformity and perhaps the apparently less important one, may be equally equal in length to two other unconformities, and the deposition of an intermediate series. In this case the uneven erosion line of the Torto stands as the equivalent of the two leveling periods of the Archean and Cincan deposition and the truncation of this great series of rocks 12,000 ft. thick. And yet this lower unconformity might appear to be of little importance. The Torto simply rests on the uneven surface of the Archean.

The conglomerate at the base of the Tonto has no such regular thickness as that at the base of the Unkar. Indeed, at some places it can almost be said to be absent. A mere film of schist rock separates the fine grained sandstone or fine grained conglomerate from the truncated edges of the Archean. Wherever seen the conglomerate was rather inconspicuous, and nowhere was it found to make a belt recognizable at a distance. This may mean that the Cambrian transgression was much more rapid than the Unkar transgression. It may be that the remarkably uniform Unkar conglomerate means that the sea was slowly advancing, cutting a terrane as it advanced, while in the case of the Tonto, there may have been a somewhat rapidly subsiding land. The rapid subsidence and advance

of the sea in Lower time did not permit of the formation of a marked conglomerate bed, while the slow, steady advance of the Unkar permitted the sawing away of all elevations, and the formation of a layer of conglomerate of definite thickness. The fact that granite pebbles occur in the upper conglomerate in the Unkar series suggests that in some region not far distant there may have been areas of Archean which have not been worn out into a terrane.

Resting on the top of what is supposed to be the Trenton ~~limestone~~ is a conglomerate, the pebbles of which are largely chert. This conglomerate is supposed to be at the base of the Red Wall and to mark the unconformity which should exist to explain the absence of the Silurian and Devonian. This conglomerate is 70 or more feet in thickness. Being composed so largely of chert fragments, it must mark a considerable time interval. For the Trenton limestone must have been modified so as to have become an ordinary cherty limestone, then eroded by solution etc., so as to give to the advancing sea a bed of chert conglomerate. The top of the Carboniferous limestone as seen on the plateau, is strewn with a surface of loose material composed largely of chert. Everywhere the ground is paved with these chert fragments. If the sea should now advance

over this Cantonment deposit the conditions would be such as to form on the eroded, but little tilted Paleozoic of the plateau, a basal conglomerate in all respects similar to that at the bottom of the Red Wall.

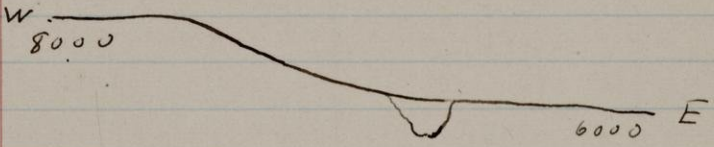
All the igneous rocks of the Unkar shrewd along Red Rock Canyon between the base of the Tonto and the river, and down the river, are intrusive basic dikes, some of which follow the bedding for some distance. As the dip of the Unkar is to the ~~SE~~ NE, and the canyon goes N., no very great thickness of this series is seen in going down the canyon. While the igneous rocks were seen along Red Rock Canyon, and down the Colorado, up the Colorado as far as we went, that is, for a

distance of about three miles, no igneous rocks whatever were seen. These intrusive igneous rocks seem to be particularly characteristic of the lower horizons of the formation.

From Grand Point our most extended view was obtained. Here the eye was able to stretch far down the river. Many miles of the Archean were seen. The eye swept over the entire thickness of the Unkar from its very base to its top, no layer being missed. The great intrusive at the base of the series stood out with perfect clearness. The rocks described as lavas in the upper part of the formation by Walcott were easily discriminated. Above the Unkar nearly the entire thickness of the Chuar is seen. The only beds which were beyond our vision were the very highest beds of the formation constituting the upper part of Nankoweap Butte.

Above the Chuar was seen the full thickness of Toroweap Red Wall and Aubrey. Not only was their full thickness seen, but the outcrops of their layers were followed for many miles. The eye sweeps north as far as Lee's ferry 50 or 60 miles north, and as far west as Powell's plateau. Here there is exposed to view at this one point, without moving, at least 15,000 ft. of strata, besides the great masses of Archean. All the formations, and for much of the area all the exposures of all the rocks mapped by Walcott in his 14th. Ann. Rept. could be seen. Far to the north the Kaibib plateau which has an elevation of about 8000 ft was seen to pass by a great monochinal flexure into the plateau east of the river, only about 6000 ft. high. The same great Aubrey formation constitutes the top of the Kaibib plateau

and the town plateau to the east. - Thus



This great plateau is upland to the S. by Walcott's fault, by means of which the Aubrey is dropped down against the Chuar. Thus we have a magnificent illustration of the principle that the same kind of deformation may be accomplished both by folding and by faulting. The displacement at one place for many miles N. of the great bend of the Colorado is by fracture and the rocks, now 3000 ft. from one another, come into juxtaposition. Farther north the same relative positions of the plateaus east and west of the Colorado are maintained, but in another manner, by monoclinal

pleasure.

The view from Grand Point is one of the most extensive which it has been my good fortune to see. To the north the eye stretches to Vermilion Cliffs and to Lee's Ferry. To the N.E. are Echo Cliffs. Beyond Echo Cliffs may be seen Navahoe Mt., which is probably 150 miles away. To the N.W. the limit of vision is ~~Boobis~~ Powell's plateau and beyond this are seen a few peaks, evidently high, but the points only appearing above the plateau. To the S.E. one sees the beginning of the great volcanic district which extends to near San Francisco Mt.

Sept. 20. On stage from Tourist to Flagstaff.

Sept. 21. Ascended San Francisco Peak.

As mapped by the Wheeler Survey, the great lower mass of this mountain and of the adjacent peaks is composed of a white rock supposed to be trachyte. Higher up on the Mt. are found a great variety of rocks, including various basalts, andesites, obsidians, and indurated tuffs. The relations of the rocks to one another were not made out. However, it was evident that when the history of this Mt. is understood, it will be found to give a complex story, as in the case of most other important volcanic peaks, there having issued from it basic, acid, and intermediate rocks.

San Francisco Peak is evidently a somewhat old vol-

S. T. R.

From the top of San Francisco Peaks a great view is obtained of the region. The country is spread before one for 100 to 150 miles in every direction

canic Mt. As a result of erosive forces it is now much breached, there being deep ravines and gulches upon its sides. The peak is not simple, but complex. One of the minor peaks seems to have been somewhat regular and probably marks the close of the complex volcanic period.

Sept. 17. Visited the volcanic region immediately east of the San Francisco Mts. This is an area of very recent volcanic activity, in which there are a large number of almost perfect volcanic cones, as yet unbreached in any way. The forests have not even advanced over the district although it is a humid one. The volcanic products are apparently as fresh as if they had been thrown out but yesterday. Indeed, one must believe that this volcanic activity was at its

height, within a few centuries, or perhaps within a century. In the western part of the field the last important event was the issuance of lava from the bases of some of the cones. Here is a great lava field which exhibits all the characteristics of such flows. Its surface is of extraordinary roughness. As the lava has moved on, the hardened crust has been turned and broken by the lava pushing from behind. In some places, after the surface lava has solidified, the liquid material below has passed onward, and the surface crust has sunken in, leaving huge cracks between the separated parts. Everywhere shrinkage cracks may be seen. At some places these seem to be in two systems at right angles to each other, parallel and transverse to the lava stream.

The event immediately preceding these lava flows was

a great volcanic explosion or series of volcanic explosions, by which the country for miles about was covered with dust ashes, lapilli and bombs. This seems not to have been a single explosion, but a series of explosions from a number of craters. In both the Black crater and Sunset crater, into which we went, the hard rock was almost entirely hidden by a thick layer of tuff. Upon the lower slopes of Sunset crater, the bombs were present by millions from those of small size to those 1½ to 2 ft. in diameter. The entire country round about was strewn with these bombs. In many of the bombs are pieces of sedimentary rocks through which the eruption came. The rim of the Black crater does not rise much above the level of the plateau, on its lower side perhaps not more than 150 to 200 ft. Its depth

on its lower side is estimated to be 250 to 300. On its higher side from 500 to 600 ft. Its breadth is probably a half mile or more. From the lower part of the crater one is unable to see any of the surrounding features of the country. The summit crater is probably 100 ft. high. Its outer slope are of loose tuff, lying so steep that at a touch of the foot, the material rolls. This inclination was not measured but was estimated to be 30 to 35°. The slope is steepest near the bottom and very gradually becomes less steep near its top thus its curve being a slightly convex one from top to bottom. Notwithstanding the lesser steepness at the top, the bombs hyc started would roll to the bottom of the Mt.

The event preceding the great outburst of tuff were great lava flows, not very

different from the latest lava flows. These beds are for the most part buried beneath the tuff, but protrude here and there. They are, however, sufficiently covered so that one can make his way over these earlier beds with the greatest ease, while the last beds are traversed, if at all, with the greatest difficulty and with exceeding slowness.

From Sunset Peak about 90 craters were counted - which included every crater we knew to be certainly such. But there are many smaller ones which probably contain craters.

This volcanic district covers an area some miles in

breadth and 20 or 30 miles in length, judging roughly from the top of Sunset Peak.

The tuffs seem not to be all of the same age. The tuff of Black Crater has not yet been devitrified, so that it has, as its name indicates, a dead black color.

The Sunset and some other peaks on the other hand the tuffs of the upper part of the Mt. have been weathered so as to take on a deep red color. It is this red color which characterizes the upper part of the peak making it always appear as if the sun was setting which gives the name to the larger of

the peaks of this place. At Sunset Peak in one place an earlier consolidated tuff was found, which had been most profoundly modified by solfataric action.