Correspondence re: "Evidence of dissected erosion surfaces in the driftless area". 1958-1959

Thwaites, F. T. (Fredrik Turville), 1883-1961
[s.l.]: [s.n.], 1958-1959

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Evidence of dissected erosion surfaces in the driftless area

F. T. Thwaites

It is my belief that this paper should not be published in its present form. For the most part is is a re-hash of older opinions without any new data. As a matter of fact, there is no new interpretation either as the author comes to the same conclusion [illegible] Martin did long ago. There are many references to earlier opinions without stating specifically <u>who</u> expressed them. Some of these are clear cut cases of beating dead horses. Others apparently are the result of a grudge against the Geological Survey and perhaps still other sources that are less apparent. If this paper is ever to be published it must be carefully rewritten. I have made no effort to correct the many grammatical and typographical errors. So far as I can tell, there is nothing publishable in this report. However, some additional work might make it worthy of a note in the Bulletin.

I am very much inclined to agree with the author's conclusion that there are no remnants of peneplains in the driftless area. However, I have little to go on and this paper adds nothing to the extant body of knowledge.

Some specific criticisms are listed below.

Page 13. The symbol for proportional generally is written .

Figure 2. The approximate amount of vertical exaggeration should be indicated.

Figure 3. The coordinates are not labeled. This is a peculiar upside down way of plotting. Are the lower ends of these profiles at streams or elsewhere? The author should read Strahler regarding slopes. Also, the places where slopes were measured should be mentioned.

Page 14. Why is it necessary to conclude that equalibrium conditions are attained? Certainly the explanation given is not convincing. Does Fig. 3 really show that remnants of earlier topography cannot persist on the divides?

Page 15. The discussion does not show that solution is important in lowering the divides or, at any rate, more important than elsewhere.

Figure 4. Are the symbols the same as for Figure 2?

Page 19. Why should the contact of two erosion surfaces be gradational rather than abrupt if they are the result of peneplanation?

Plate 2. The argument that this surface is the result of marine erosion during the Ordovician is not at all convincing.

Page 20. What is the chemical nature of the soil that does not suggest weathering of quartzite. Why do chert fragments rule out post-Paleozoic erosion surfaces?

Page 21. Why do potholes necessarily indicate a velocity sufficiently high to require fall from a formation now missing?

Page 22. Who says peneplains have to be formed by weathering and slopewash?

Page 24. Leopold and Wolman do show a relation between meander size and discharge, etc. The argument that meanders form only in firm materials and braiding in soft is a new one to me. Does the peneplanation hypothesis necessarily require climatic change?

Page 25. Do all intrenched meanders indicate uplift? Also, the statement that velocity required to transport particles of a size is easily determined ~~as~~ is an error.

THE GEOLOGICAL SOCIETY OF AMERICA
OFFICE OF THE SECRETARY
419 WEST 117TH STREET, NEW YORK 27, N. Y.

January 12, 1959

Mr. Fred T. Thwaites
41 North Roby Road
Madison 5, Wisconsin

Dear Mr. Thwaites:

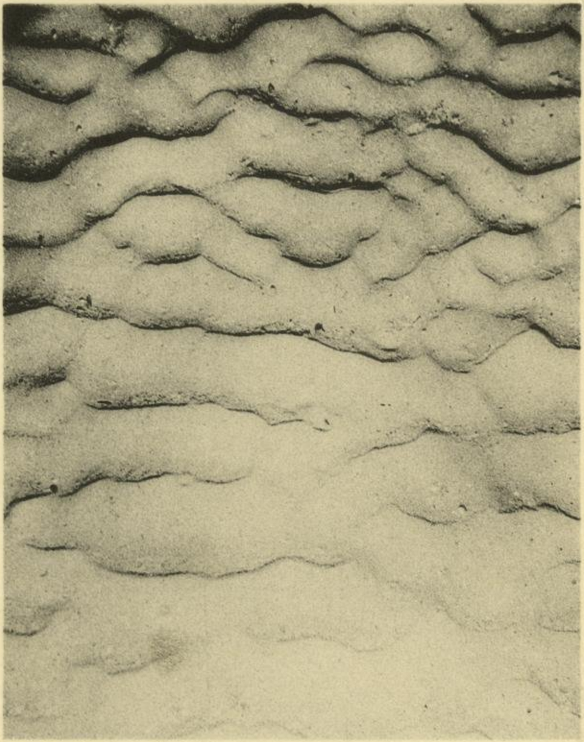
To keep you informed of the progress of your manuscript "Evidences of dissected erosion surfaces in the driftless area" I enclose for you a copy of the report of the first critic.

When other reports are in, they will be sent to you.

Sincerely,

Elizabeth Herod

Secretarial Assistant



OCEAN-BOTTOM PHOTOGRAPH

Current ripples in 410 fathoms (2460 feet.) on the side of Josephine Seamount in the Eastern Atlantic

Width of photo about 3 ft. Pos. 36°51′N 14°18′W

Sta. V4-27-14 Lamont Geological Observatory

Photograph by M. A. S. LAUGHTON

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Report concerning it will be sent to you as soon as it can be read critically.

H. R. Aldrich, *Secretary*

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THE GEOLOGICAL SOCIETY OF AMERICA
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September 15, 1958

Dear Sir:

At its meeting on August 22 the Program Committee for the Annual Meeting in St. Louis accepted your abstract for printing in the program. You are scheduled to present the paper at 4:15-4:25 on Saturday, November 8 in the Gold Room of the Hotel Jefferson.

If you find that you are unable to attend, kindly notify Secretary Aldrich immediately.

Sincerely yours,
Raymond E Peck
Raymond E. Peck
Chairman, Program Committee

28 Nov., 1958

Dr. H. R. Aldrich, Sectetary
The Geological Society of America
419 West 117th St.,
New York 27, New York

Dear Crombie:

Enclosed please find manuscript of my paper on "Evidences of dissected erosio surfaces in the Driftless Area" which I summarized briefly at St. Louis on the 8th.

This manuscript is accompanied by blueprints and other rough copies of the illustrations to avoid harm from handling by readers. The photographs are seconds which have been mutilated so that they could not be used by mistake. Originals and better prints will be furnished on request. The text was read carefully by Mrs. Thwaites. On account of my small staples is is sent in two parts which not stay together although now fastened. There are no extra copies of the descriptions of the illustrations sc these should not be lost.

We enjoyed our trip to St. Louis very much especially the Pleistocne field trip which we went on on our 30th anniversary. Messors Frye and Willman certainly did a good job in planning and conducting this trip.

We got home on schedule although it was very rough air north of Chicago.

Sincerely yours,

Evidence of dissected erosion surfaces in the Driftless Area.

F. T. Thwaites

There is certainly no doubt that what Mr. Thwaites has to say should be said. It is worthwhile. And the skein of circumstances makes Mr. Thwaites the man to say it. But even a casual perusal of the paper indicates that there is need of very extensive revision.

Specific appraisal is difficult in the present state of the manuscript. In general I think there is much of value and cite the material in the sections on Uplands, Upland Divides, Beveling of Bedrock Divides, Bridge between Upland Surfaces, Happy Hill, Relation of Stream Courses to Structure, Superposition, the stratigraphic background and historical summary.

I find in general that the chief weaknesses lie in the presentation. The argument is not closely knit. There is little attempt to separate out and emphasize the significant points or ideas (witness the long unparagraphed pages). I understand, but object to the diatribes directed toward the "men in Washington" and it seems unnecessary to ride the mistake of the Baraboo plain "peneplain" quite so hard. The discussion of "what is a peneplain?" and that which immediately follows does not seem germane as presented. I find the photos poor and not very enlightening. I would welcome a more concise statament of the stratigraphic column, perhaps in a diagrammatic form.

DEADLINE - JULY 15

ABSTRACT FORM

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PRESENTATION

	Indicate Preference By Number	Indicate Time Desired (Min.)
Oral Regular	1	15
"5-Minute Session"	2	5
Exhibit	No	No
Conference	No	No
By title	3	0

INDICATE CLASSIFICATION

- Sedimentation
- Structure
- Pleistocene
- ✓ Geomorphology
- Stratigraphy
- Paleontology
- Areal
- Petrology
- Mineralogy
- Economic
- Vulcanology
- Geophysics
- Engineering
- Geochemistry
- Submarine

For presentation at 1958 meeting

Type in quadruplicate, double-spaced, one side of sheet only. Not over 250 words, or abstract will be returned.

Do not include names for new taxonomic units or for new rock units, time-stratigraphic units, or time units.

Title Evidences of dissected erosion surfaces in the Driftless Area

By F. T. Thwaites

Underline name of speaker.

Address 41 N. Roby Road, Madison 5, Wis.

(Make it informative—or abstract will be returned)

~~ABSTRACT.~~ Evidence of dissected erosion levels in the Driftless Area of the Upper Mississippi Valley has been discussed for many years without agreement. The writer has studied the problem since 1907. Hypotheses include one (general) peneplain, two (distinct) peneplains levels, one peneplain just ?touching the crests of several cuestas, and no peneplains, simply cuestas. Major evidences offered were: the even skyline, the bevelled of rock formations, an upland connection between (bridge which connects) cuestas, the flat plain of central Wisconsin, the level top of quartzite bluffs (Happy Hill), a terrace on the flanks of these bluffs, entrenched meanders, and upland gravel (Windrow formation). Each of these (is considered with the conclusion that every one) has a more logical explanation than formerly considered. The skyline is a will-o-the-wisp, always in the distance. The Bevelling is explained by the relative length of time that the dolomites have been exposed from below younger strata. The "bridge" is explained by a thin weak formation. Happy Hill and the terrace are wave-erosion features ~~which~~ that date from Ordovician submergence. Entrenched meanders are inconclusive. The parabolic slopes of the uplands demonstrate recent mass movement. The Windrow gravels are very limited in distribution. The Central Wisconsin plain is lacustrine. No proof exists that any of the uplands are remnants of a pre-valley landscape. Martin's hypothesis of unaltered cuestas is best. The hypothesis of pediplanation lacks evidence.

preserved on crests of??? GAH

δ? GAH

=??

not evident. GAH

?

So?

G.S.A. JUN 26 1958

227

THE GEOLOGICAL SOCIETY OF AMERICA
OFFICE OF THE SECRETARY
419 WEST 117TH STREET, NEW YORK 27, N. Y.

June 17, 1958

Dr. F. T. Thwaites
41 North Roby Road
Madison 5, Wisconsin

Dear Fred,

The way I hear it there's no bounty on peneplains any more! But beyond doubt in any other language we will always be interested in the development of topographic anomalies. May I share with you a hunch that willy-nilly we are all influenced by or even do a certain amount of physiographic or geomorphologic thinking if we do any field work, whether we are conscious of it or not or whether we think it beneath our dignity or not. Because we can't get away from it. I have the further hunch that just as the paleontologists are turning to living flora and fauna to develop an understanding of paleoecology, so the geomorphologists are missing a bet that they don't increase emphasis on present landforms as a key to the understanding of paleogeomorphology and the restoration of fossil landscapes.

Anyway, herewith are the Forms and I for one will be interested to see your Abstract.

Best to you and Amy,

As ever,

H R. Aldrich, Secretary

Encls.

15 June, 1958

Dr. H. R. Aldrich, Secretary,
The Geological Society of America,
418 West 117th St.,
New York 27, New York

Dear Crombie:

Since retiring a year ago I have completed [illegible] er of number of papers which I never had time before to do. Am these is one on the ancient controversy about peneplains i the Driftless Area. Could I introduce and read or rather discuss at the coming meetings in November? If so could you kindly send me the requisite blanks. I realize that peneplain hunting is now a bit out of date but I have worked on the problem for many many years and before I must sign off for good would like to register this reworked part of the old Sparta-Tomah Folio which they refused to publish at Washington.

Sincerely yours,

STONE TRACK, RACETRACK PLAYA

INYO COUNTY, CALIFORNIA

Track extends 62 feet; rock measures 10 by 8 by 7 inches and weighs about 60 pounds

Photograph by courtesy of G. M. STANLEY

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H. R. Aldrich, *Secretary*

Revised abstract

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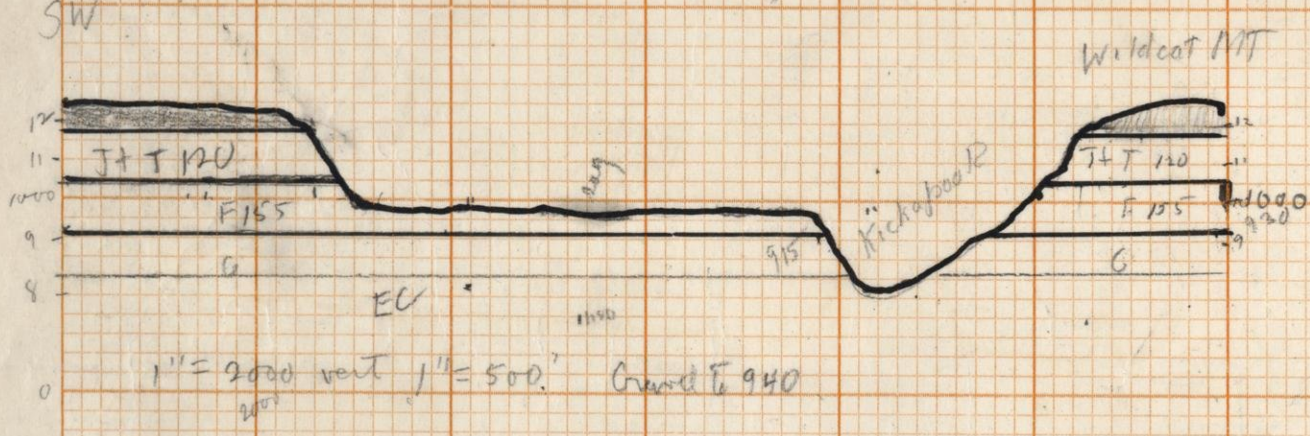
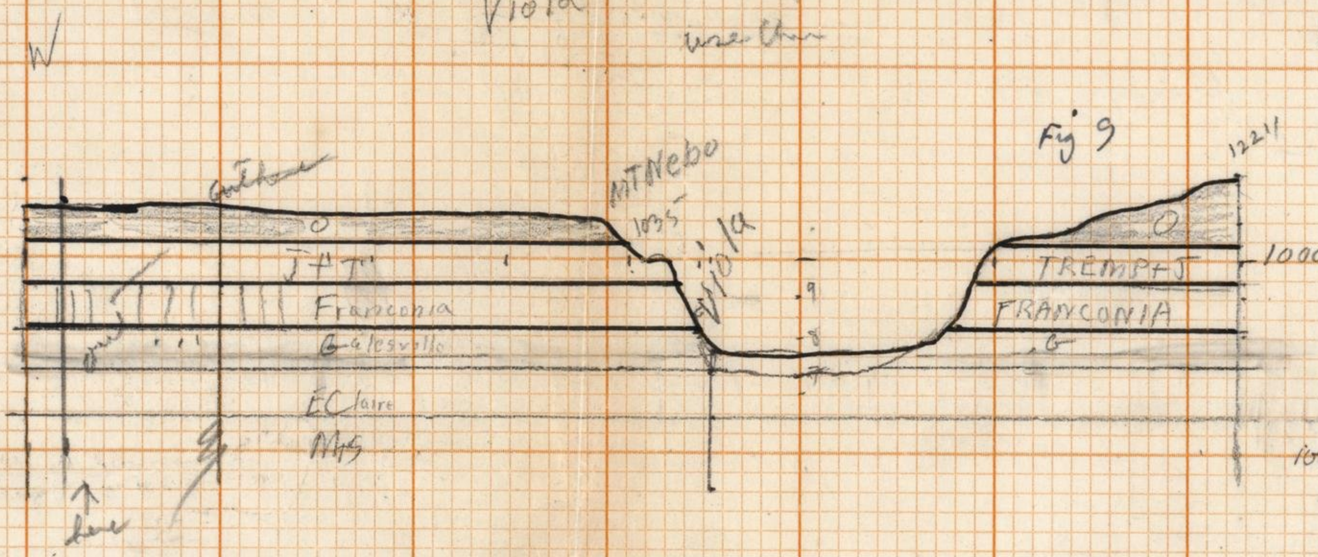
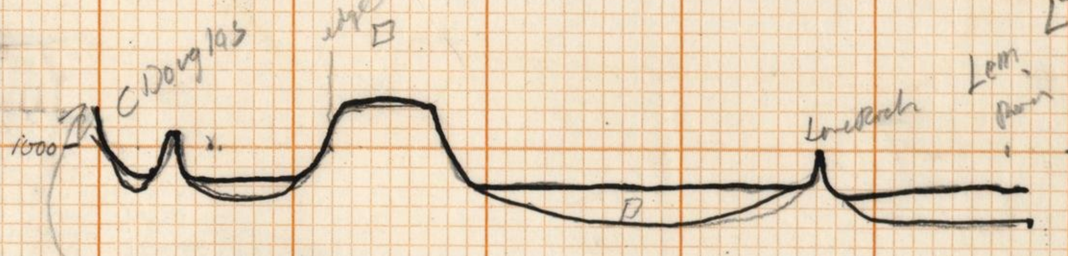
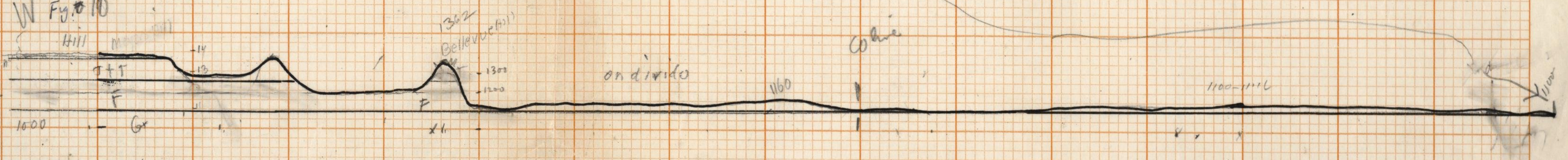
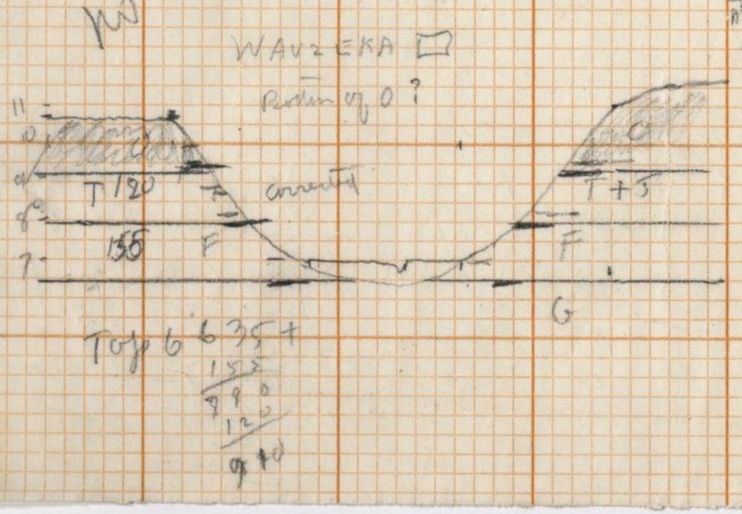
Fig #9 Cross section of Franconia benches in Kickapoo Valley

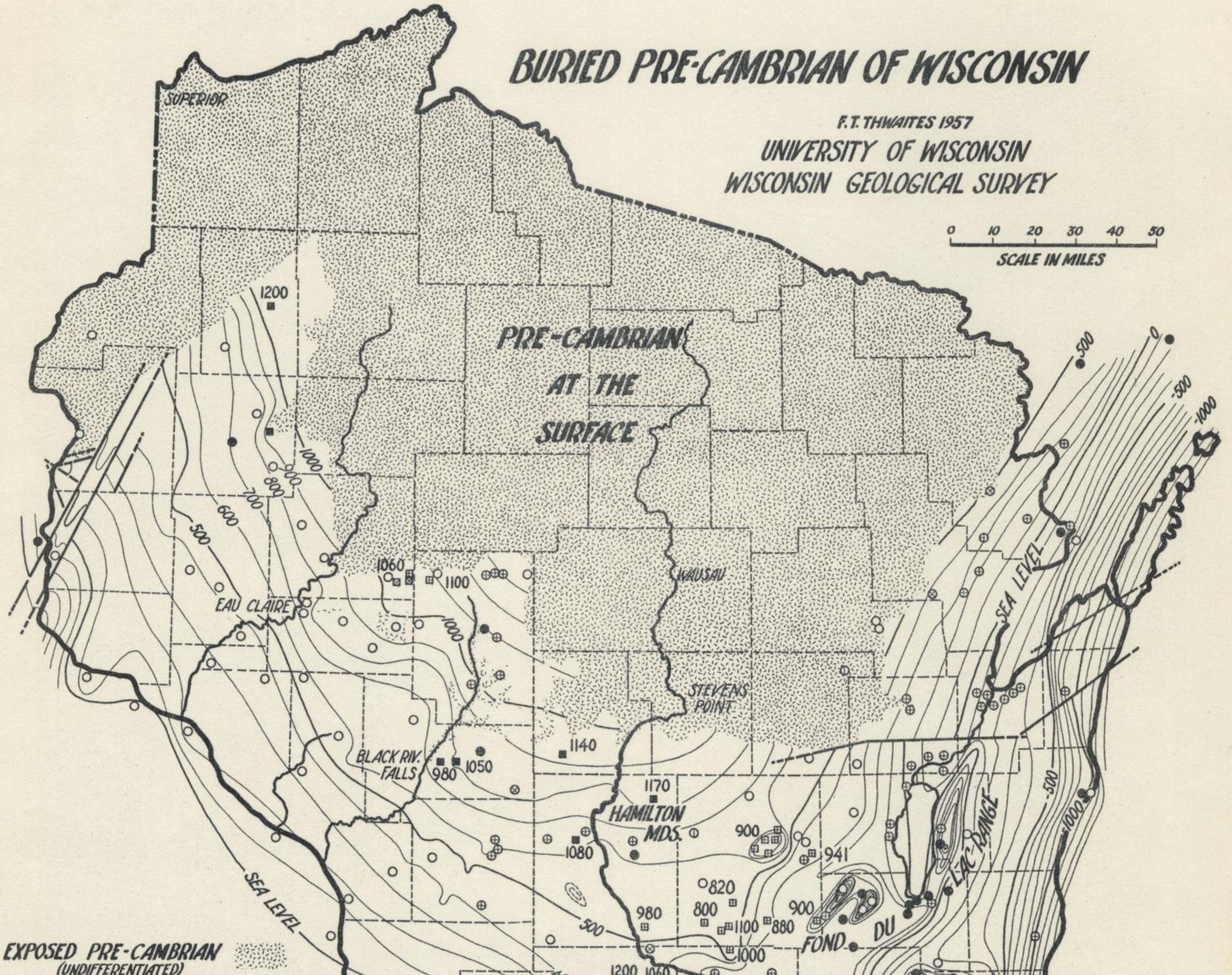












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THE GEOLOGICAL SOCIETY OF AMERICA
OFFICE OF THE SECRETARY
419 WEST 117TH STREET, NEW YORK 27, N. Y.

July 22, 1958

Professor F. T. Thwaites
41 North Roby Road
Madison 5, Wisconsin

Dear Professor Thwaites:

Before reaching final judgment on your GSA paper "Evidences of dissected erosion surfaces in the Driftless area" proposed for presentation at the 1958 St. Louis meeting, the Program Committee suggests a revision of your abstract would be helpful.

Specifically, we believe the abstract should provide the reader with some substitution for what is rejected. With fifty-one years of study on the problem, it seems to the committee that you should be able to provide a more informative and satisfying analysis. We sincerely hope you will find the time to do so. Enclosed is one copy of your abstract with some additional revisions made by one of the readers.

I am enclosing another set of abstract forms for your use. As the final committee meeting is scheduled for August 23, it is imperative that you return the revised abstract to the G. S. A. office before that date.

Sincerely yours,

Raymond E Peck

Raymond E. Peck
Chairman, Program Committee

enclosure:

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THE GEOLOGICAL SOCIETY OF AMERICA
OFFICE OF THE SECRETARY
419 WEST 117TH STREET, NEW YORK 27, N. Y.

September 11, 1959

Prof. F. T.Thwaites
41 North Roby Road
Madison 5, Wisconsin

Dear Fred:

We now have a second critical report on your manuscript on the Driftless Area, a copy of which is enclosed herewith.

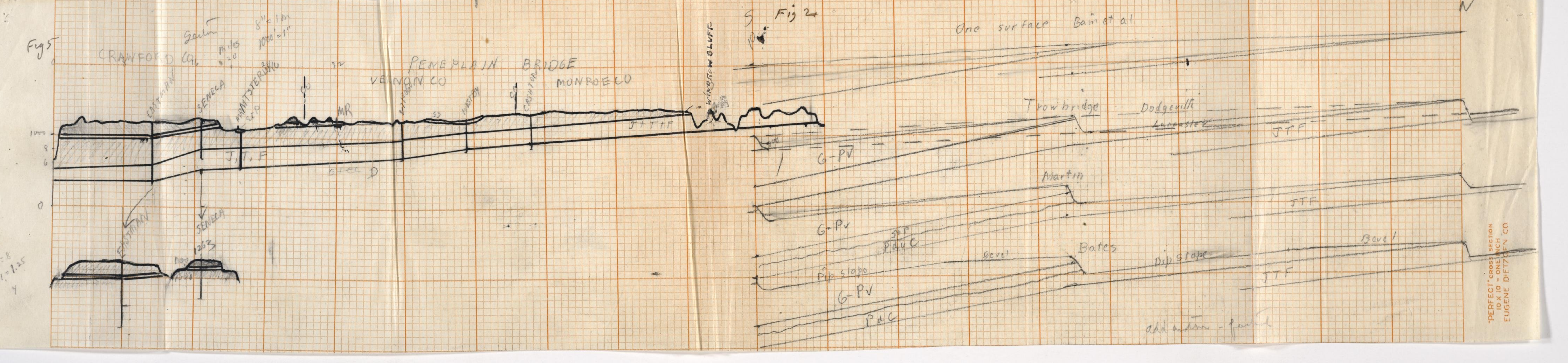
I do not like to reject manuscripts, especially those from old friends, but I have no alternative than to follow the advice of the two men who appraised the paper. So I return it to you under separate cover.

Yours as ever,

Secretary

Fig 5

Fig 2



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GEOLOGY 109
GEOMORPHOLOGY

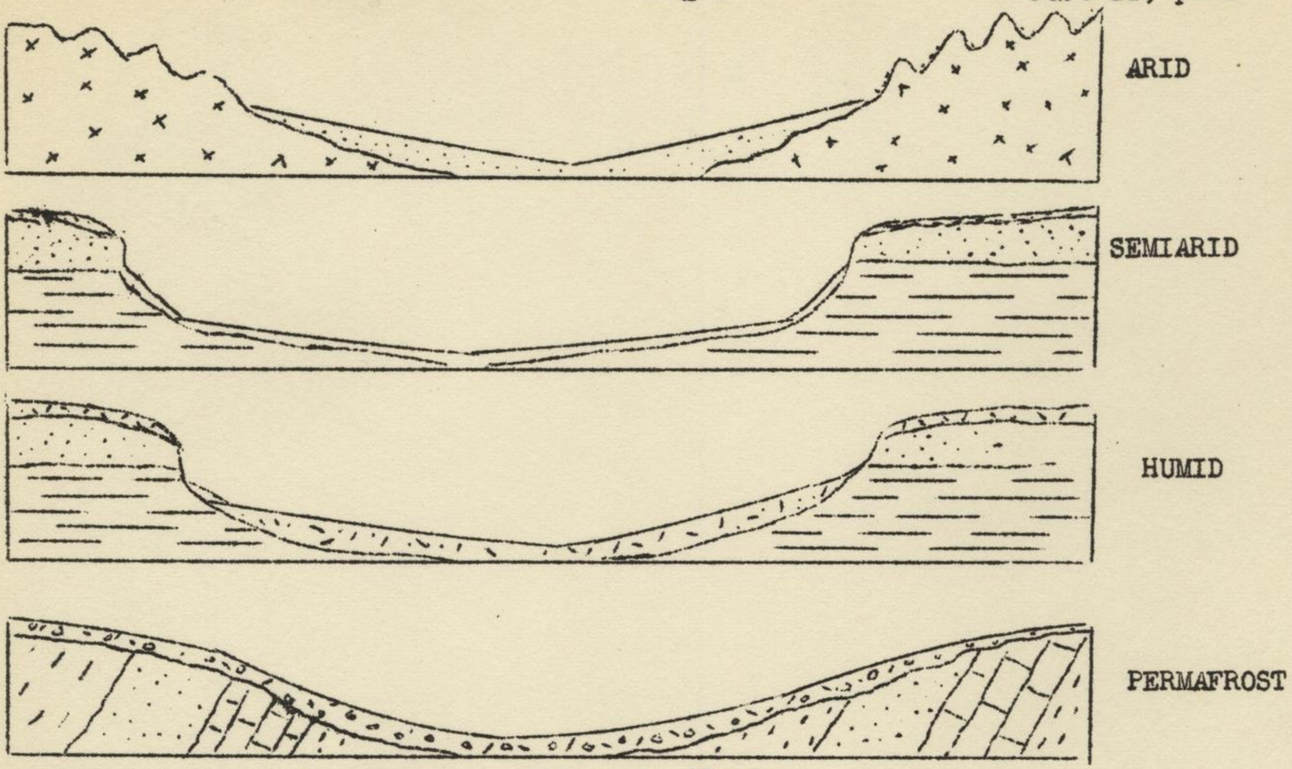
Supplements, 1953, part II

Pediplanation vs peneplanation.

Introduction. Although the subject of final stages in denudation by running water has been covered in previous supplements, data which has appeared in the past year offer further food for though on this extremely important problem. Before beginning a discussion, however, it is well to repeat that the definition of the word peneplain (peneplane of Johnson) is far from uniform among students of geomorphology. This makes it extremely difficult to argue about either processes or end results. Let us here return to the original ideas and neglect later attempts to change the definition to one which is so broad as to be almost meaningless.

"Normal climate" One of the often unwritten but necessary conditions for the origin of a peneplain (under the original meaning) is the so-called "normal climate", in other words a climate similar to that of northeastern North America and northwestern Europe where temperatures are moderate, rainfall well distributed seasonally, vegetation abundant, and chemical decomposition of the material of the earth's surface well developed. True, this climate is that in which a very large part of the civilized inhabitants of the world dwell, but from the areal standpoint it is certainly not that of the main portion of the present lands. We must look at a globe and not at a Mercator projection map to form an intelligent opinion on this point. Besides this fact, we must recognize the strong possibility that the present distribution of climates was not a permanent feature during the history of the earth. Evidence to prove this is not easy to obtain and rests largely upon inference. Soil profiles are not much help for many are not more than a few thousand years old. Marine deposits offer even less aid except insofar as they demonstrate wind and current directions. Hence we must turn to continental deposits and evaporites. With them the influence of now-eroded mountain chains must be evaluated. Besides this, many geologists offer the time-honored excuse of movement of either or both poles and continents. Whatever might be the correct conclusion on this debatable subject for the older geological periods, considerable evidence has been presented to demonstrate that the hypothesis of changes in latitude must be rejected for the Tertiary and Quaternary. Distribution of plants and of glaciation substantiate this. The occurence of glaciation alone proves that climatic changes of the first magnitude took place at that time. The later Tertiary is notable for the immense alluvial deposits of Western United States which must have been laid down under a decidely different climate than now prevails in the same place. It has often been suggested with considerable assurance than the present-day wind and climatic belts still show the effects of the Pleistocene glaciation because of surviving ice caps. Such being the case it is best to forget about such a thing as a "normal" climate and to realize that much more of the globe may have once been semi-arid. We should then reject the idea that either aridity or semiaridity is a "climatic accident".

Climatic control of debris removal. Fig. 1 shows cross sections of slopes in arid, semi-arid, humid, and sub-arctic climates. All but the last have in common the presence of enough rain to remove more or less completely the debris formed by weathering. In the truly arid environment weathering is almost wholly mechanical. When it does rain the water is not enough in amount or duration of flow to remove the debris of weathering from the area but instead it accumulates in alluvial fans and filling of enclosed basins. Both chemical changes and restraint by vegetation are at a minimum. Resistant crusts of chemical origin are formed. In a semi-arid region some chemical weathering is pre-



Cross sections of valleys in different climates

FIG. 1

sent but vegetation is not important. Enough rainfall occurs to keep the debris shed from steep slopes moving toward the sea or other base level. Much debris is water-born, the only proviso being that the particle size distribution be within the competence of running water. In a humid land, however, chemical alteration of the bed rock is very important. Although the average particle size is thus reduced, the presence of vegetation slows down removal. Mass movement is, however, very important. Slow erosion is especially conspicuous where grass is present for all experiments demonstrate that it is by all means the most effective of all vegetation in restraining erosion. In a region of perpetually frozen ground the net result is to make all bed rocks and mantle rock alike into a solid, massive material. The seasonally thawed or "active" layer of the hills is moved in large part by mass movement to the streams.

Changes in climate. Due to the indubitable fact that climates change at any given locality it is expectable that we should find the characteristic climatic landscapes superimposed one upon another. Many believe that adjacent to the Pleistocene ice sheets vast areas were once frozen. Consideration of the heat requirements for melting of ice show that such could have been possible only during the advancing stages of the glaciers, if indeed it ever affected areas of marine climate. However, changes in amount of rainfall and vegetation can be and have been detected. Pluvial periods with more rain than at present have been postulated by many geologists in areas which are now semi-arid. Students of soils have also noted past climatic changes, particularly near to major lines of division due to climatic control. In this discussion, however, we will mainly concern ourselves with the later stages of erosion, the production of surfaces of low relief late in the progress of erosion.

Davis' idea of the peneplain. Fig. 2 shows two contrasted theories of the retreat of slopes. W. M. Davis held that the slopes on the sides of a stream constantly diminish in angle throughout the "cycle of erosion". Little attention was paid to details of just how material was removed from low slopes and less to the conclusion that a balance must ultimately be attained between the force available to remove material and the resistance of that material to erosion. Fig. 3 shows the original concept of the peneplain where it was concluded that the streams would no longer be able to remove the debris of weathering as fast as it formed and would hence form extensive floodplains. A deep mantle of disintegrated rock was assumed to be present all over the area and residual elevations or monadnocks were left only where the bed rock was particularly obdurate to weathering and erosion. Elsewhere rounded convex divides should merge into the falts of the floodplains. The pre-Cambrian surface of Canada and north-central United States appears to fit fairly well with this concept, although we must recognize that it has been buried by marine sediments and later exhumed. There monadnocks are confined to extremely resistant materials, quartzite, hard iron formation, and fine-grained igneous rocks. Between these, slopes are in many places very low and divides are inconspicious. Bed rock is disintegrated to considerable depths not only in exposed areas but also where the cover of later rocks still persists.

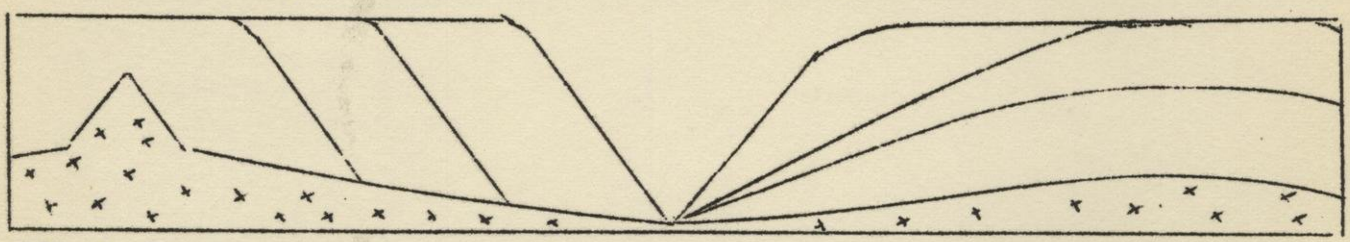


FIG. 2 Two ideas on slope retreat

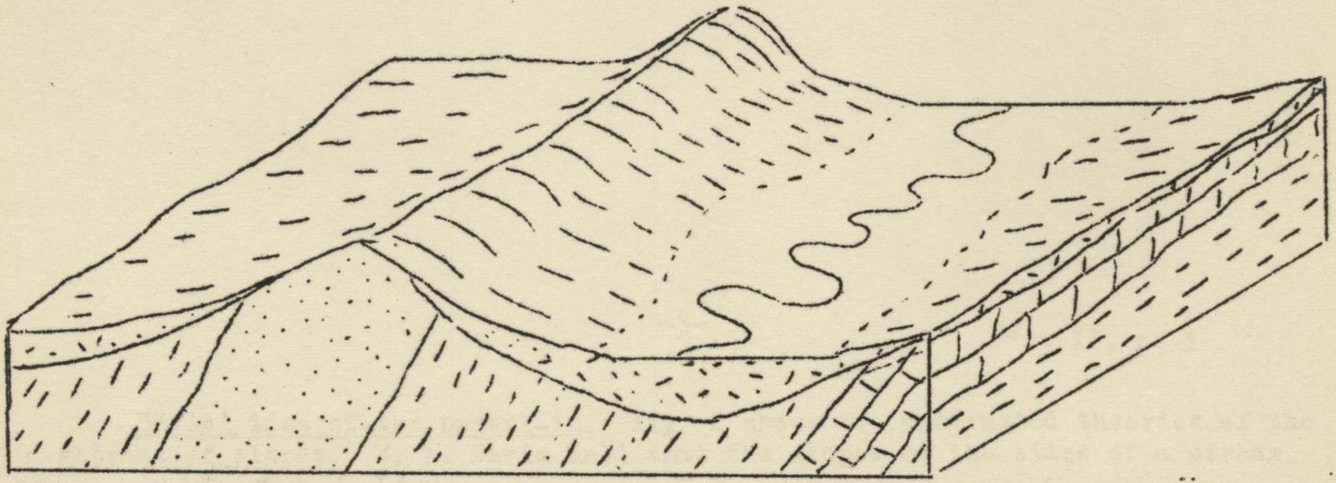


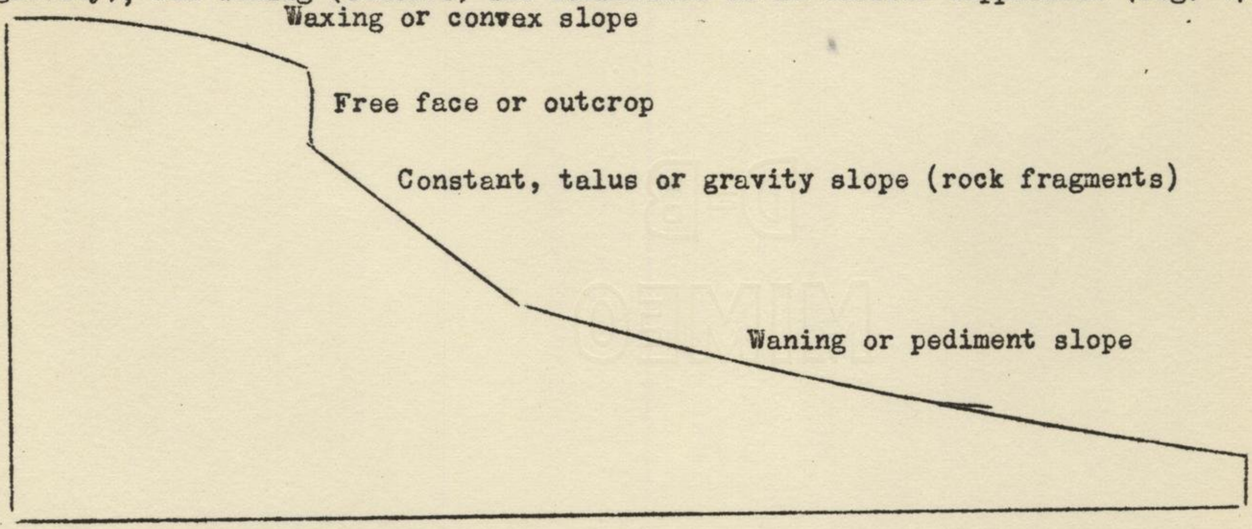
FIG. 3 The peneplain concept of W. M. Davis. Note survival of the ridge on hard sandstone, the thick layer of mantle rock and the wide floodplain. The last is what apparently led some of the later students to include depositional areas with peneplains. Note convex divides with any possible concave slopes buried under floodplain deposits.

Objections to the peneplain hypothesis. Other than buried and resurrected surfaces such as mentioned above, very subdued erosion topography is observable only on soft shales and on limestones where it is greatly aided by solution. The whole idea that a thick mantle of weathered material would form on surfaces of low relief ignores the head necessary to force water far below the surface. Absence of a deep residual mantle on the pre-Cambrian is generally ascribed to glaciation and it is true that in the lightly glaciated or unglaciated pre-Cambrian of central Wisconsin the mantle rock locally exceeds 140 feet in thickness in schist. The problem remains, however, to what extent was this due to chemical reaction by ground water while still buried. For that matter, how much erosion was caused by the waves and currents of the sea which transgressed this surface long ago! Other objections are of a more theoretical nature. Just how could debris be removed on very low slopes? Monadnocks should be rounded and grade into the adjacent landscape save perhaps where difference in bed rock geology is abrupt. A very serious objection lies in the apparent presence of old subdued surfaces near together and separated by a steep escarpments. Are these all explicable by differences in bed rock geology? Or is there something radically wrong in the hypothesis of origin of subdued erosion surfaces? Why did not the process that made the younger surface obliterate all those of older levels? Horton held that under his hydrophysical approach there must be "a definite end point for both stream and valley development." This point would be reached when the area between the streams is all within the belt of no erosion. Indeed Horton held that "most of the observed gradation of divides takes place before the streams which are separated by the given divide are developed--in other words, the terrain where the divide is located is graded in advance at a time when sheet erosion is taking place along or across the line which subsequently becomes the divide." He rejected entirely the idea that divides are graded down indefinitely. Horton also stated "The ultimate surface of erosion within a main basin boundary is neither 'almost a plane, as the prefix 'pene' implies, nor is it usually as close to being a plane as was the original surface area from which it has been derived. It seems better to call it a 'base surface' generally concave upward except along divides". Horton appears to have assumed soft material to considerable depths.

Parallel retreat of slopes. The theory that slopes do not lessen with time but retreat parallel to themselves after the initial formation was first presented by Penck and is shown on the left side of Fig. 2. This view requires the formation of a gently sloping surface between the foot of the steep slope and the channel of the adjacent stream. Material derived from the wearing back of the steeper slopes must be transported across this area by running water. This was the concept of the pediment, an idea also put forward by Gilbert from his observations in the semi-arid western part of this country. Davis did at one time write a paper on rock floors in which something of this theory was recognized although he rejected the idea of parallel retreat of slopes.

Strahler's equilibrium theory. Strahler used a statistical analysis of certain measurements in California and concluded that slopes lessen to a point where the adjacent streams can just remove the debris shed by weathering and fed into them by slopewash and mass movement. He found that these slopes have the same angle from top to bottom. It is apparent, however, that the area in the Coast Range probably represents a very early stage in the cycle of erosion, possibly prior to stabilization of slopes in relation to kinds of rock debris, each of which probably has a distinctive particle size distribution.

Wood's classification of slopes. Allan Wood's discrimination of types of hillside slopes into the waxing (convex), free face (outcrop), constant (talus or gravity), and waning (concave) was summarized in an earlier supplement (Fig. 4).



FIG° 4 Classification of hillside slopes after Wood.

Examples of each are found in almost all climates, although some may be absent at any given locality. We will first consider the methods by which each is formed and altered.

Convex or waxing slope. Formation of a rounded edge or convex surface on hill tops is not due to one process alone. It implies a removal of material toward lower ground at a rate which increases downshope. As pointed out by Davis long ago a sharp angle between original surface and hillside, such as is formed early in the cycle of erosion, is vulnerable since it is attacked by the agents of weathering from two sides. Once weathered, removal may occur either by slopewash or mass movement. Variation in intensity of rainfall causes the boundary of Horton's "belt of no erosion" to fluctuate in position. This should result in rounding off the corner. King has a similar idea for he states: "as the volume of water increases with distance from the crest of the slope and its speed downhill increases with the steepening declivity, there comes a stage where modification of the surface under the action of running water exceeds the modification due to soil creep. This is the end of the waxing slope." Soil creep is favored by this rounding off of the corner, by rock which weathers into a mantle which has low viscosity when wet, and by the presence of a restraining cover of sod or other vegetation which minimizes sheet wash. In the White River Badlands of South Dakota it has long been noted that convex divides occur only on the weaker layers.

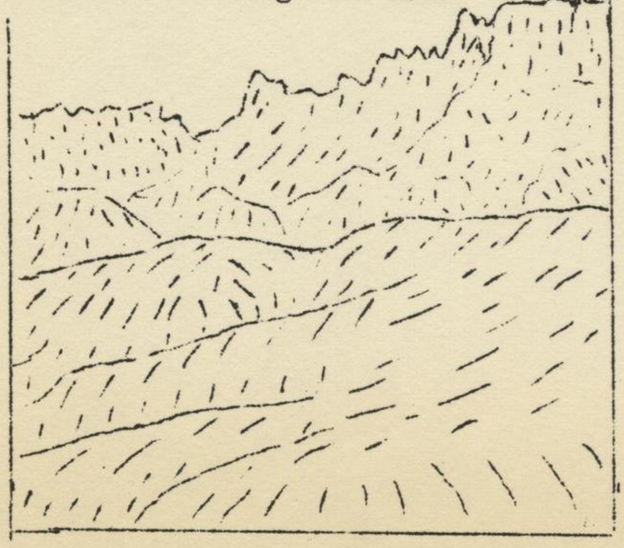


FIG. 5 Convex divides in White River Badlands of South Dakota from photograph by F. T. Thwaites. Note that these are confined to a certain soft stratum whereas the harder beds above make the craggy divides in the background. Note also the very steep sides below the convex crests which slope down to beds of ravines and in other places to true pediments. Small residual masses of the soft clay resemble haystacks.

Wherever firm material is present the divides are jagged and narrow. Convex divides are, then, best developed in humid lands with weak bed rock and abundant protecting vegetation. Rock exposures, other than large boulders moved from their original position, are rare in true convex slopes. However, convex slopes are not of universal occurrence.

Free face or outcrop. In the zone of the free face or rock outcrop it is evident that the debris of weathering derived from above must be moving with much greater speed than it does near the hill summit. Acutal outcrops can occur only where the bed rock is fairly resistant to weathering and are best developed in regions of horizontal strata, particularly where the resistance of different layers varies considerably. In the latter case there may be more than one such line of exposure. The actual type of rock forming outcrops varies with climate. In semi-arid regions we even find that gypsum, which is water soluble, is exposed because of its mechanical resistance. In very humid regions sandstone, quartzite, or fine-grained igneous rocks are common ledge-makers. Where slope development is reaching its endpoint, due either to a long time or to the weakness of the underlying material to both weathering and erosion the free face may be absent. Obviously this is most common where relief is low.

Talus, debris slope, or constant slope. Since the free face or outcrop is exposed to the elements it sheds fragments of rock. The size distribution of these depends upon bedding and jointing which is in turn an inherent feature of the type of rock. These fragments roll, slide, or fall into the slope below which is varyingly described as talus, scree, debris slope, or constant slope. The mechanics of this zone, which in many localities has a constant declivity, have been previously discussed. However, the fact that with most rocks and in most climates talus fragments disintegrate through weathering. The resulting finer material may be retained between the larger rocks for a time because of their protection and the restraint of vegetation. If there is enough moisture, and clay has been formed, mass movement of the talus is possible. Landslides may then reveal the sloping surface of only slightly weathered bed rock which is the underlying basement of these slopes. This may reduce the slope of the lower part of the talus. If removal of material both thus and by rill erosion is not fast enough the free face above will be buried and talus formation will cease. Rill erosion is more probable than unconfined slope wash because the steep slope promotes high turbulence with associated channel erosion. It is the view of King that in South Africa such erosion is enough to cause retreat of the face of a hill so that the burial of the outcrop is postponed and the entire slope retreats at a constant angle, that determined by the size of rock fragments. Some talus slopes are interrupted by ledges where resistant formations have not been buried and by projecting butresses of bed rock which is more resistant than adjacent material. Rock outcrops may, therefore, be found in some places within this zone. Material which is removed from the talus only when its particle size is within that which can be transported by water on the available gradient, but it is evident that running water will be unable to decrease the angle of the entire slope because of the protection afforded by the larger rock fragments. To wear back a talus slope to a significant distance must involve weathering and erosion of its bed rock floor.

Waning or pediment slope. In many localities valley filling has obscured and buried everything below the talus slope. This is the case throughout the Driftless Area of the Upper Mississippi Valley and the cause is valley filling consequent upon nearby glaciation. In the Coastal Plain a recent rise of sea level has had the same effect and in much of the western part of the United

States climatic change has interferred with the normal development of hill slopes. In many places slopes are undercut by streams of considerable size which also prevents the formation of a concave lower slope. It is in semi-arid regions of sparse vegetation that these slopes are best observed and many of them were at first confused with the somewhat similar form of coalescing alluvial fans. Where typically developed these slopes are underlain by rocks which readily disintegrate to particles within the range of water movement. They have a thin veneer, locally absent at the top, of water-transported detritus which rests upon relatively fresh bed rock, The surface is scarred with rill marks which grade into less abundant ravines (dongas of South Africa). It is the problem of just how these smooth surfaces developed which is not yet solved to the satisfaction of everyone. Suggestions include (a) lateral erosion by streams which are at local baselevel fixed by a balance between erosion and deposition, for many grade into depositional slopes downhill; (b) erosion by many rills similar to those described from the talus slopes; and (c) erosion by sheet or slope wash including the sheet floods of McGee. King has gone out onto such slopes during rains to observe what actually happens. Higgins has dug trenches across little pediments and filled them with a different sand to check on rills vs. sheet wash. In rains of moderate intensity King found only clear water in the sheet flood close to the upper limit of the slopes. This disclosed laminar flow by having a depressed surface above obstacles. Just how such flow, which was not eroding or transporting material, could shape the pediment was a problem. Material eroded in the talus above must in this case have been deposited temporarily at or near its lower border. However, later studies showed that farther downslope and in heavier rains turbulent sediment-transporting flow is present, although deep floods like those described by McGee were not observed. It is obvious that to have sheet flow there must first be a smooth surface on which the water can spread out. King explains this by the multitude of small rivulets which descend the talus. He rejects the idea of lateral stream erosion largely because the great escarpments of South Africa are parallel to the coast, do not extend far up rivers. He thinks of them as originally as great monoclines which erosion has worn back parallel to themselves through several geologic periods at a rate of one foot in 150 to 300 years. He also rejects the stream erosion hypothesis because of the comparatively straight and level bases of the escarpments. However, this view does not seem to meet all observed conditions. The lateral extension of pedimented surfaces joining into a pediplain with only small residual, steep-sided hills rising above it implies recession of valley sides. In other areas it is evident that pediments have formed along fault scarps. Moveover, some form of channel erosion would seem a prerequisite for preparing the ground for widespread sheet floods. Possibly Horton's theory of rill grading

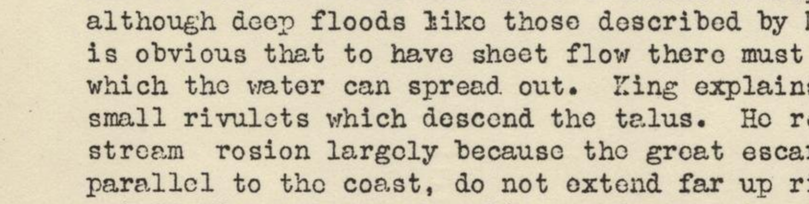


FIG. 6 After King Steep-sided residuals of granite rising from smooth pediment which has a thin grass cover. Slopes of hills are talus blocks. Similar residuals are common in The Great Plains. From photograph. East of Pietersburg, Transvaal

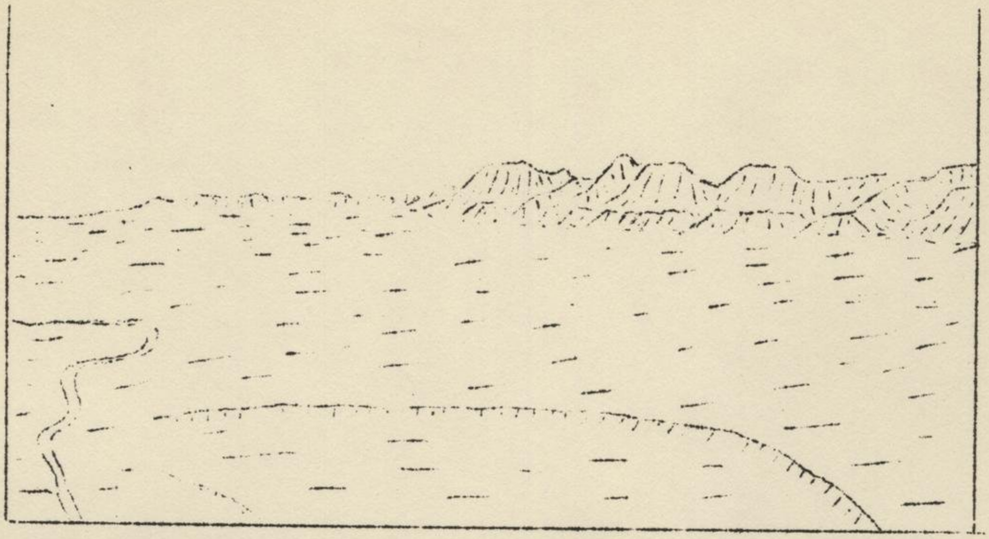


FIG. 7 After .photograph by Fair published by King. The river has no real flood plain but pediments rise gently to the steep-sided residuals of andstone and dolerite (basalt). No convex hilltops can be distinguished but the concavity of the pediment is plainly shown. Vegetation appears to be scanty brush, possibly some thin grass. The Karroo, South Aftrica.

is the key. But when all is said and done the reality of these rock-cut slopes must be admitted. They do not fit in with the old concept of peneplains. They could explain preservation of remnants of more than one erosion cycle in adjacent hills for on top of the remnants erosion is very slow. They do not require for formation a very arid climate and might occur in somewhat modified form in humid regions unless deeply buried by crept mantle rock. They explain the apparent youthfulness of the mountains of the Basin and Range province despite the width of valleys, a fact which puzzled early students of that area.

Form of pediment cross section. Pediments have a characteristic concave cross section leading down from the more or less level, abrupt upper limit either to streams or to an alluvial fill in the center of the adjacent valley. Wide stream spacing may be a factor in pediment formation. The sharpness of the upper contact is best developed in hard rocks. In weak rocks this contact is a gradational curve. The various causes of the concavity due to running water have been explained in a previous supplement. The matter is not simple and is unlike conditions on alluvial fans for rain falls all across the pediment slope.giving increased depth down slope with consequent decrease in shearing force. Indeed, it has been declared that pediment slopes are formed in order to facilitate disposition of sudden heavy downpours which are common in semi-arid regions. As pediments join at divides the divide is commonly abrupt and angular rather than rounded, although both forms may occur apparently depending upon the resistance of the bed rock. The best-developed pediment profiles occur where the bed rock is granite rather than soft sediments such as shale or limestone. Residual elevations within a pediment or pediplain (area of coalescing pediments) characteristically have concave sides. Mount Monadnock, New Hampshire, rises in this fashion from adjacent uplands of the same kind of rock. However, this area was glaciated and a basal mantle of decomposed rock might have been eroded by the ice or the base might have been eroded by waves. A feature of pediment slopes is that gullies (dongas of South Africa) occur entirely on them rather than on higher slopes locally extending to the upper border. Some change to low alluvial fans below. It is thought that these ravines are due to local concentrations of the sheet flow which set up more turbulent flow which causes erosion. Some are certainly due to disturbance of the ground by farming. Rock outcrops occur in the walls of such gullies, at the head of the slope of pediments, and in small isolated "islands" or residuals. The only cause of convex profiles in pedimented areas is erosion at an accelerating rate due to later uplift, or to climatic change toward greater humidity. In this connection we may ask if erosion surfaces which bevel the bed rock and yet show deep weathering are (a) pediments developed in humid climates or (b) pediments which have been altered by a change of climate. Since the theory of pedimentation can explain the occurence of several different levels in the same region it opens up many new possibilities in interpretation, Could it be that the Piedmont Plateau of southeastern United States is a pediment whose surface was later eroded by a more humid climate possibly associated with uplift? Such a view would explain the anomaly of stream capture along the youthful divide of the Blue Ridge to the northwest, features which seem impossible under the peneplain hypothesis. The convex divides of the Piedmont together with deep disintegration of the bed rock would be more recent than the original bevel. Widespread gravels of late Tertiary age in the Coastal Plain seemingly support this view. The Harrisburg terrace, which is so conspicious throughout the entire Appalachian region, would then be correlated with the Piedmont and possibly also the Highland Rim surface west of the high plateaus. Many will object to this suggestion because it seems to imply a marked climatic change, but just how much of a change is debatable. Perhaps only enough to affect the vegetation cover to a moderate extent. Turning to the Rockies, it is obvious that the upland surfaces are true pediments correlated with alluvial filling of adjacent lowlands. Climatic change, possibly associated with, or due to, uplift, has removed much of the fill but a remnant persists in the Gang Plank west of Cheyenne, Wyoming. Surely, it is inappropriate to call the upland surface a peneplain if we stick to the original meaning of that word. Some in the Uinta Mountains have in part been described as pediments. Throughout the Great Plains many of the residual hills have steep concave sides which appear to demonstrate pedimentation.

Summary. The following table, adapted from King shows the differences between what may be inferred as characteristics of peneplains (under the original Davis view) and those of pediplains. We must note that peneplains are inferences, whereas pediplains may be actually observed in the field. Moreover, it seems doubtful that there can be any sharp line of division on the basis of either climate or kind of rock. King declares that the peneplain, as originally defined, is an "imaginary landform", so that it may be that debate is futile. The exact method of formation of the theoretical peneplain is only vaguely described in the literature and is not backed by actual observation. A factor in comparison, which King suggests, is that the mantle of grass which so effectively restrains erosion and makes for convex divides was not present prior to the middle Tertiary. Indeed, others have suggested that vegetation on the lands was absent in the earlier geologic periods, and that erosion was then everywhere like that of semi-arid regions of today.

Peneplain (Davis, theoretical)	Pediplain (observational)
Broad flood plains.	Narrow flood plains.
Convex or subdued divides with much creep of a deep mantle.	Divides sharp with concave slopes on both sides, locally convex over a narrow width.
Residuals gentle and convex.	Residuals sharp with concave sides except where top is very weak rock.
Lower slopes only, concave.	Dominantly concave slopes, except on very weak rock.
Origin by slope flattening.	Origin by scarp retreat and pedimentation by running water.
Origin destroyed all older surfaces.	Several levels may be present in one locality.
Mantle rock due only to weathering and creep.	Mantle rock thin, and water-transported.
Bed rock deeply weathered(?)	Bed rock fresh.

REFERENCES

Bryan, Kirk, The retreat of slopes: Am. Assoc. Geogr. Annals 30: 254-268, 1940

Bryan, Kirk, Gulley gravure, a method of slope retreat: Jour. Geom. 3: 80-109, 1940

Davis, W. M., Rock floors in arid and humid climates: Jour. Geol. 38: 1-27, 1930

Davis, W. M., Sheet floods and stream floods: Geol. Soc. Am. Bull. 49: 1337-1416, 1938

Gilbert, G. K., The convexity of hilltops: Jour. Geol. 17: 344-350, 1909

Higgins, C. G., Miniature "pediments" near Calistoga, California: Jour. Geol. 61: 461-465, 1953

Horton, R. E., Erosional development of streams and their drainage basins: Geol. Soc. Am. Bull. 56: 275-370, 1945

King, L. C., Canons of landscape evolution: Geol. Soc. Am. Bull. 64: 721-752, 1953

Lawson, A. C., Epigene profiles of the desert: Univ. Calif. Pub. Dept. Geol. Bull. 9: 29-43, 1915

McGee, W. J., Sheetflood erosion: Geol. Soc. Am. Bull. 8: 87-112, 1897

Penck, Walther, Die morphologische analyse, 1924 (English translation now available)

Wood, Allan, The development of hillside slopes: Geol. Assoc. Proc. 53: 128-146, 1942

Definitions of words peneplain and peneplane.

Wooster, p. 193
The peneplain, originally defined by Davis as almost a plain, — designates the ultimate stage reached in a normal cycle of erosion. It represents a large land area that has been reduced nearly to baselevel by streams. In reality peneplains may not be "almost plains" but actual plains in the true topographic sense of the word. Some may approach the quality of a geometric plane, therefore, may be properly designated peneplanes (almost planes). The final process by which a land mass composed of rocks of varying structure and composition is reduced to a peneplain is planation brought about by the lateral erosion of streams—. As a rule the surfaces of peneplains are not flat but gently rolling.

VonEngeln, p. 83
For if an indefinitely long period is at the disposal of the normal degradational processes and agencies, namely weathering processes and streams flowing down to the sea, it is obvious that such activity will eventually bring about the reduction of the highest and broadest of uplifted regions to an ultimately lowest level.
As unchanged peneplains in situ are not available for observational study many of the characteristics of peneplains must be deductively inferred.

Lobeck, p. 634
It is admitted by most investigators that peneplanes may be formed subaerially by streams, or by marine planation, or by wind action under arid conditions. Some authorities restrict the term peneplane to surfaces developed only by stream action, but in this text it refers to an almost flat surface produced by destructive forces.

Cotton, p. 20
—the surface of very faint relief which the cycle theory requires shall eventually result from the prolonged action of normal erosion on a land surface without interruption by further uplift or other earth movements is a peneplain.

Salisbury, p. 153
It is doubtful whether any extensive land area was ever worn down to a perfect base-level; but great areas have been worn down almost to that level— a region in this condition is called a peneplain (almost plain) (gives an illustration from Camp Douglas, Wis.)

Davis, Physical Geography, p. 152
It may be imagined that, at a very late stage of development, even the mesas and buttes of an old plateau may be worn away, the whole region being then reduced to a gently rolling lowland, a worn-down plain, or "plain of denudation" —a lowland of this kind may be called a "peneplain", because it is an "almost plain" surface.

Webster dictionary
Plain (noun) = level land or broad stretch of land having few irregularities of surface.
Plane (noun) = a surface, real or imaginary, in which if any two points

are taken, the straight line which joins them lies wholly in that surface; or a surface any section of which by a like surface is a straight line; a surface defined completely by any three points not colinear; or a surface more or less approximating a geometrical plane. (illustration, inclined plane).

Wooldridge and Morgan, p. 183
In the orthodox presentation of the cycle of erosion, the later stages are represented as largely concerned with the gradual lowering of the interfluves by atmospheric wasting. This process is regarded as continuing long after active valley deepening has ceased, so that it tends to the obliteration of the strong relief of maturity, producing in the limit, a rolling upland, on which rivers flowing with gentle gradients are separated by low swells of the surface. For such a surface W. M. Davis proposed the term "peneplain".

Johnson, D. W., Plains, planes, and peneplanes, Geogr. Rev. 1: 443-447, 1916
We must recognize (1) the perfectly plane surface of ultimate erosion and (2) the imperfect "almost plane" surface which characterizes the penultimate stages of the several erosion cycles.
(1) The level erosion surface produced in the ultimate stage of any cycle may be called a <u>plane</u>.
(2) The undulating erosion surface of moderate relief produced in the penultimate stage of any cycle may be called a <u>peneplane</u>. A low-relief region of horizontal rocks would be called a <u>plain</u>.

<u>References not included in general list</u>

(1) Cook, H. L., Outline of the energetics of stream transportation of debris: Am. Geophy. Union Trans. 16: 456-463, 1935.

(2) Laws, J. O., Measurements of the fall-velocity of water drops and raindrops: Am. Geophy. Union Trans. 22: 709-721, 1941.

(3) Horton, R. E., Sheet erosion-present and past: Am. Geophy. Union Trans. 22: 299-305, 1941.

(4) Knapp, R. T., A concept of the mechanics of the erosion-cycle: Am. Geophy Union Trans. 22: 255-256, 1941.

(5) Straub, L. G., Discussion: Am. Geophy. Union Trans. 22: 311-315, 1941.

(6) Shulits, Samuel, Rational equation of river-bed profile: Am. Geophy. Union Trans. 22: 622-631, 1941.

(7) Matthes, G. H., Basic aspects of river-meanders: Am. Geophy. Union Trans. 22: 632-636, 1941.

(8) Claxton, Philip, Meandering of alluvial rivers governed by a fixed law: Engr. News-Record 99: 268, 1927

(9) Fairchild, H. L., Earth rotation and river erosion: Science 76: 423-427, 193

(10) Jagger, T. A. Jr., Experiments illustrating erosion and sedimentation: Harvard Univ. Mus. Comp. Zool. Bull. 49: 285-305, 1908

(11) Towl, R. N., Behavior of rivers in alluvial flood plains: Engr. News-Record 102: 433-435, 1929

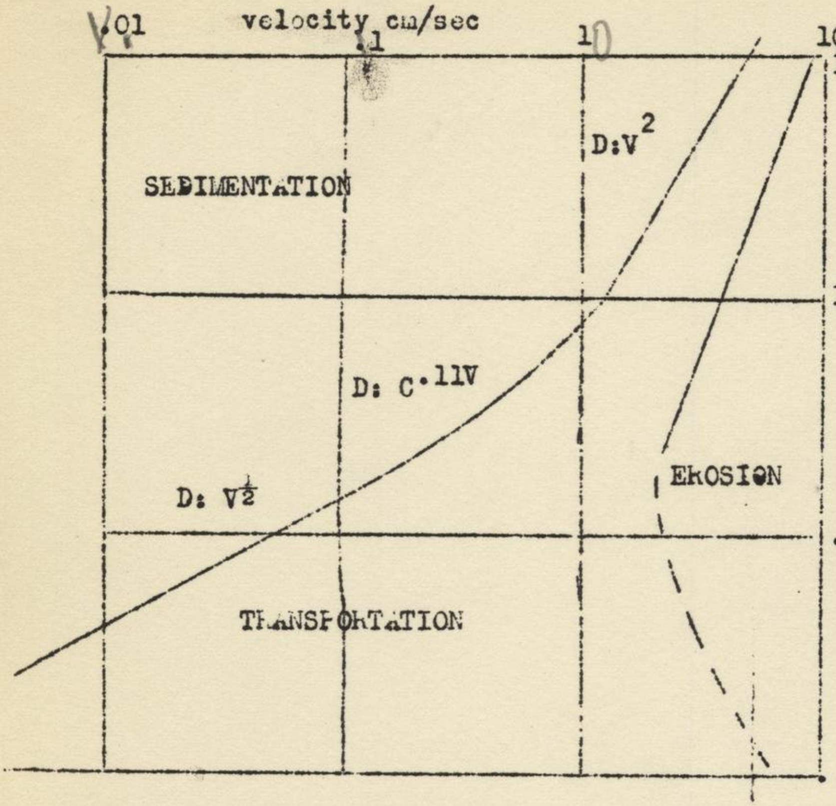


Fig. 51, p. 34
Relation of velocity of water to erosion, transportation and sedimentation of particles with different diameters, D. After Nevin, G. S. A. B. 57: 674 Note that for D 1 mm up the kinetic energy of the water is the major factor. For D less than about .2mm viscosity is dominant. There is a gradual change in the transition region. The curve for start of erosion is difficult to draw for so much depends upon the degree of packing of the small sizes of material.

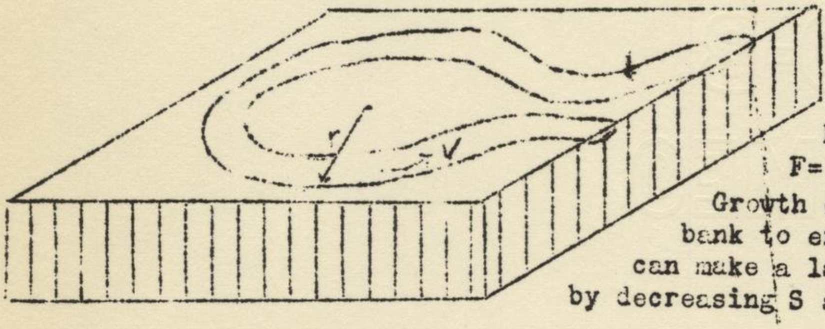


Fig. 55, p. 37
Rotational component of force in a curveed or meandering stream. Radius of curve = r Slope = S $F = mV^2/r$ As $V: S^{\frac{1}{2}}$ then $F: m.S/r$ Growth ceases when F = resistance of bank to erosion. Only a large stream can make a large meander. Increase of length by decreasing S also serves to set a limit.

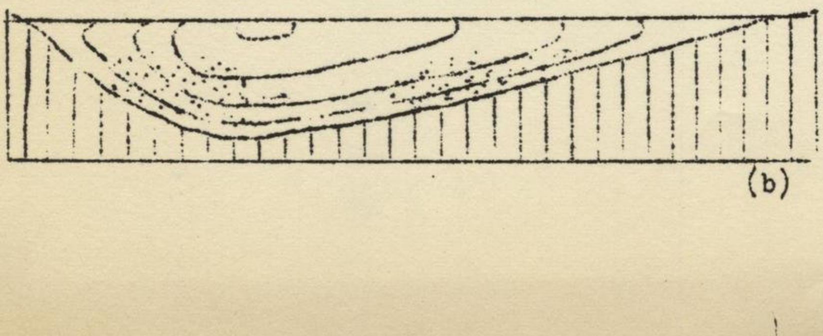


Fig. 56, p. 37
Distribution of velocity and inferred intensity of turbulence in (a) straight and (b) curved streams.
Intensity of turbulence is rate of transfer of energy. Hence sediment should move away from the dotted areas . This explains erosion of cut banks and transfer to insides of bends and may also explain start of sand bars in middle of a stream, prehaps the beginning of braiding where accumulation of deposits is rapid.

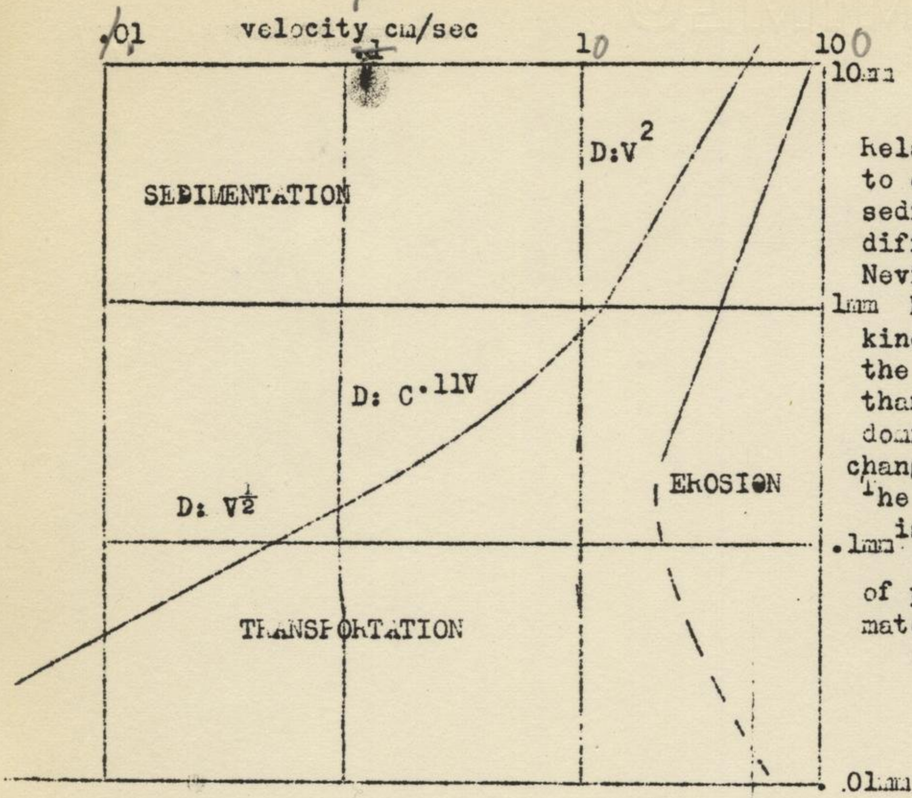


Fig. 51, p. 34
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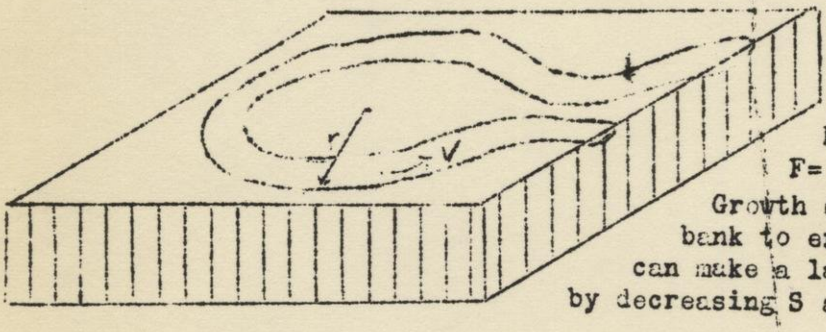

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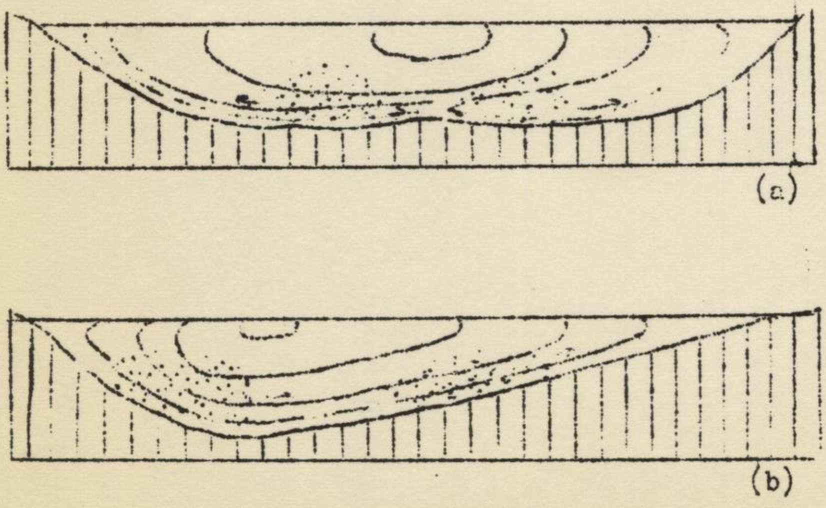

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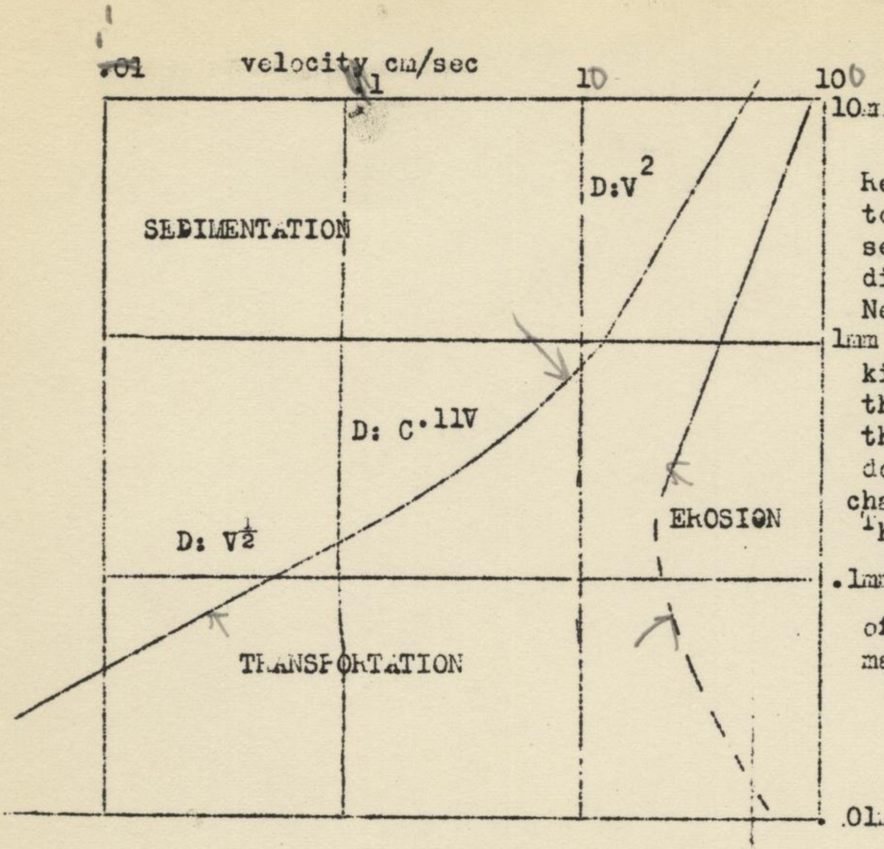

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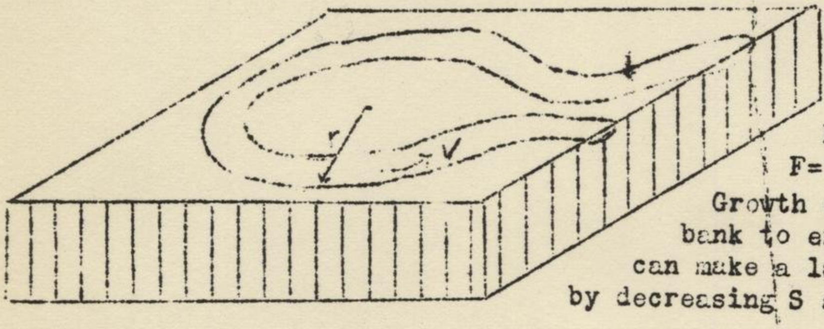


Fig. 55, p. 37
Rotational component of force in a curveed or meandering stream. Radius of curve = r Slope = S $F = mV^2/r$ As $V: S^{\frac{1}{2}}$ then $F: m.S/r$ Growth ceases when F = resistance of bank to erosion. Only a large stream can make a large meander. Increase of length by decreasing S also serves to set a limit.

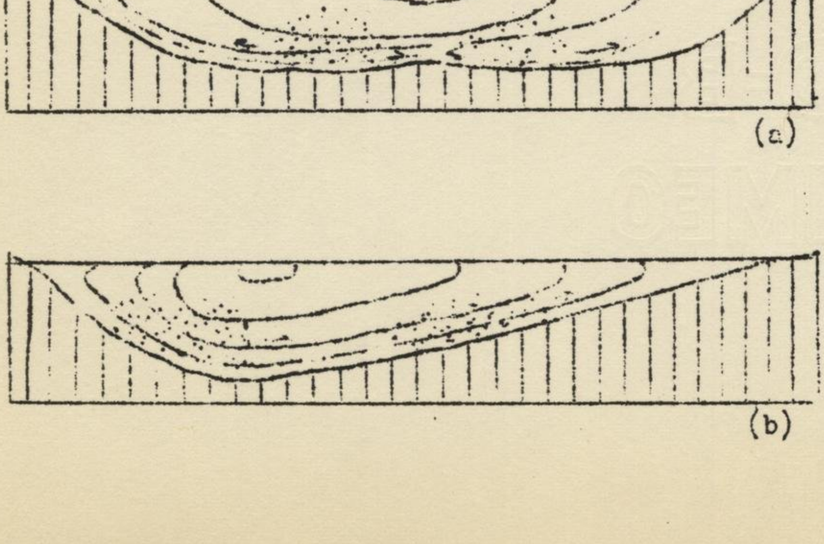


Fig. 56, p. 37
Distribution of velocity and inferred intensity of turbulence in (a) straight and (b) curved streams.
Intensity of turbulence is rate of transfer of energy. Hence sediment should move away from the dotted areas . This explains erosion of cut banks and transfer to insides of bends and may also explain start of sand bars in middle of a stream, prehaps the beginning of braiding where accumulation of deposits is rapid.

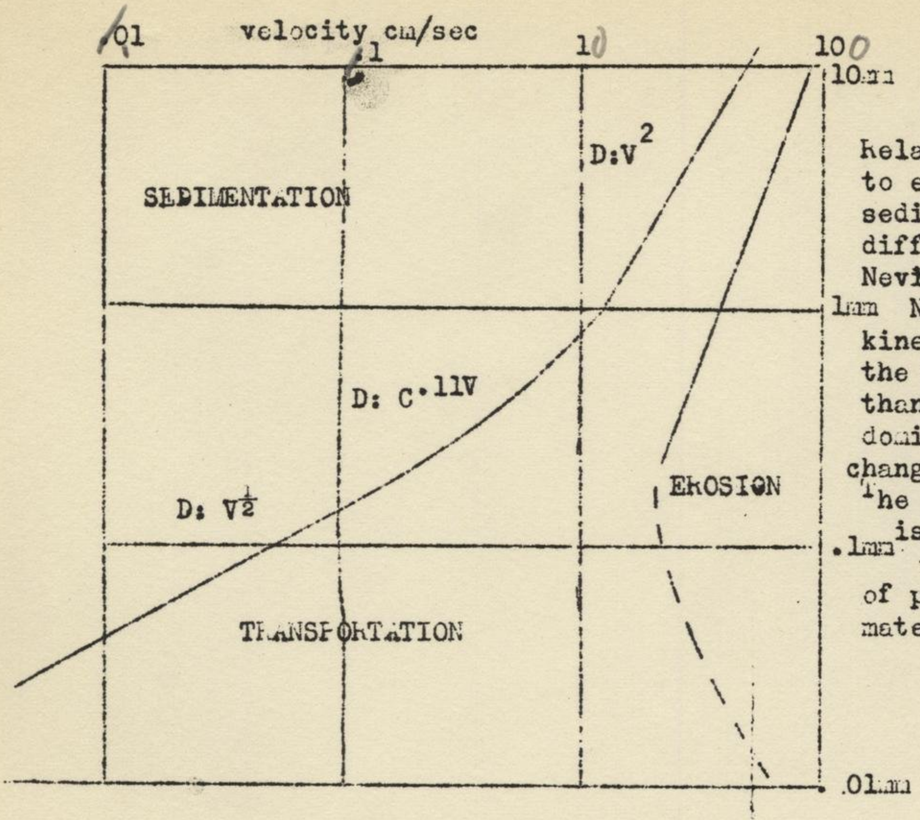
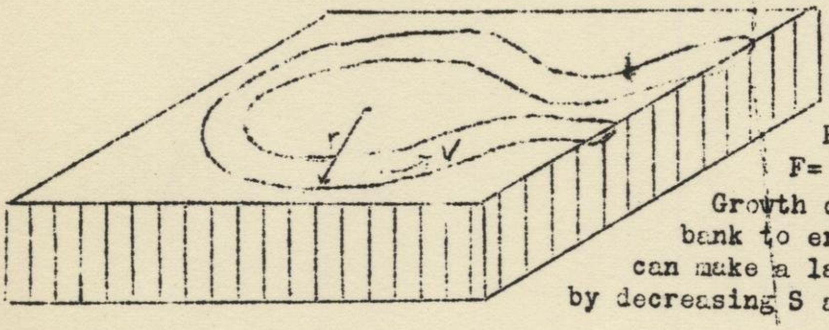


Fig. 51, p. 34

Relation of velocity of water to erosion, transportation and sedimentation of particles with different diameters, D. After Nevin, G. S. A. B. 57: 674 Note that for D 1 mm up the kinetic energy of the water is the major factor. For D less than about .2mm viscosity is dominant. There is a gradual change in the transition region. The curve for start of erosion is difficult to draw for so much depends upon the degree of packing of the small sizes of material.



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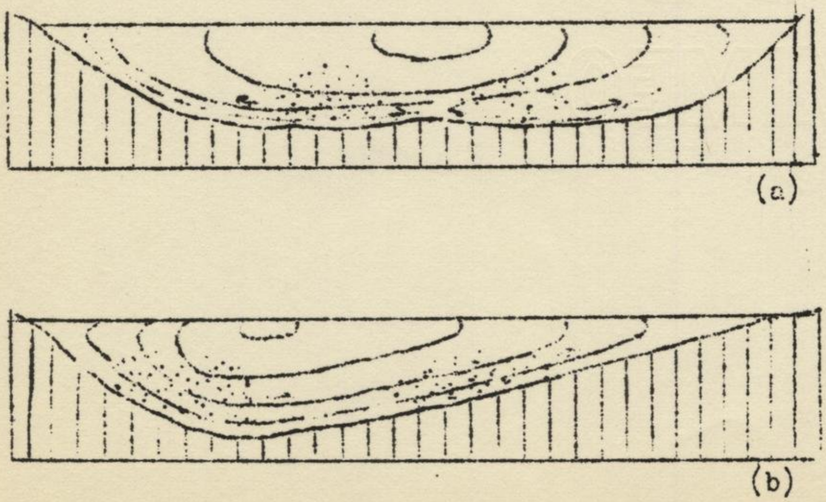

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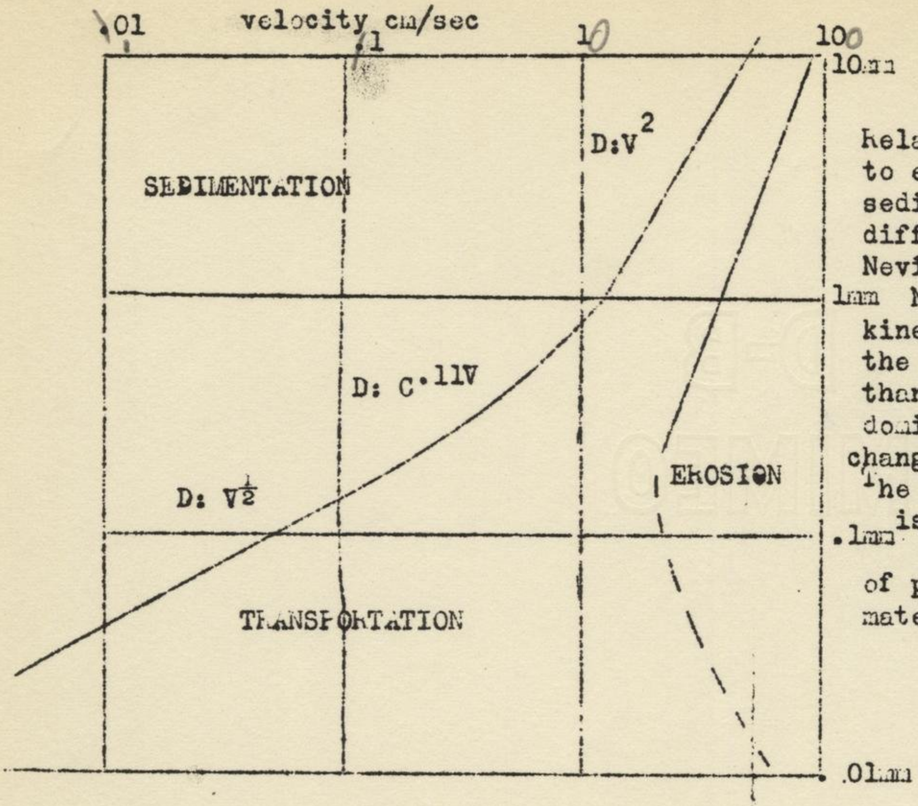

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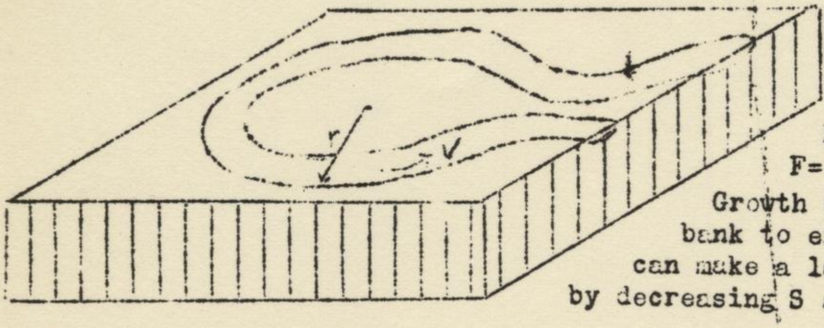

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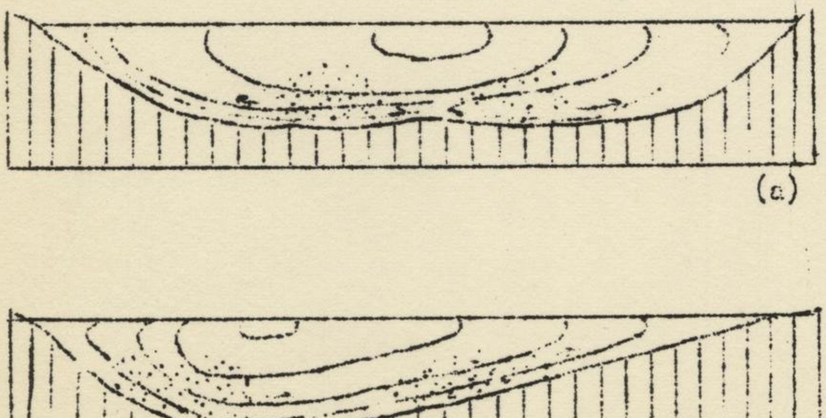
Rotational component of force in a curveed or meandering stream.
Radius of curve = r Slope = S
$F = mV^2/r$ As $V{:}\ S^{\frac{1}{2}}$ then $F{:}\ m.S/r$
Growth ceases when F = resistance of bank to erosion. Only a large stream can make a large meander. Increase of length by decreasing S also serves to set a limit.



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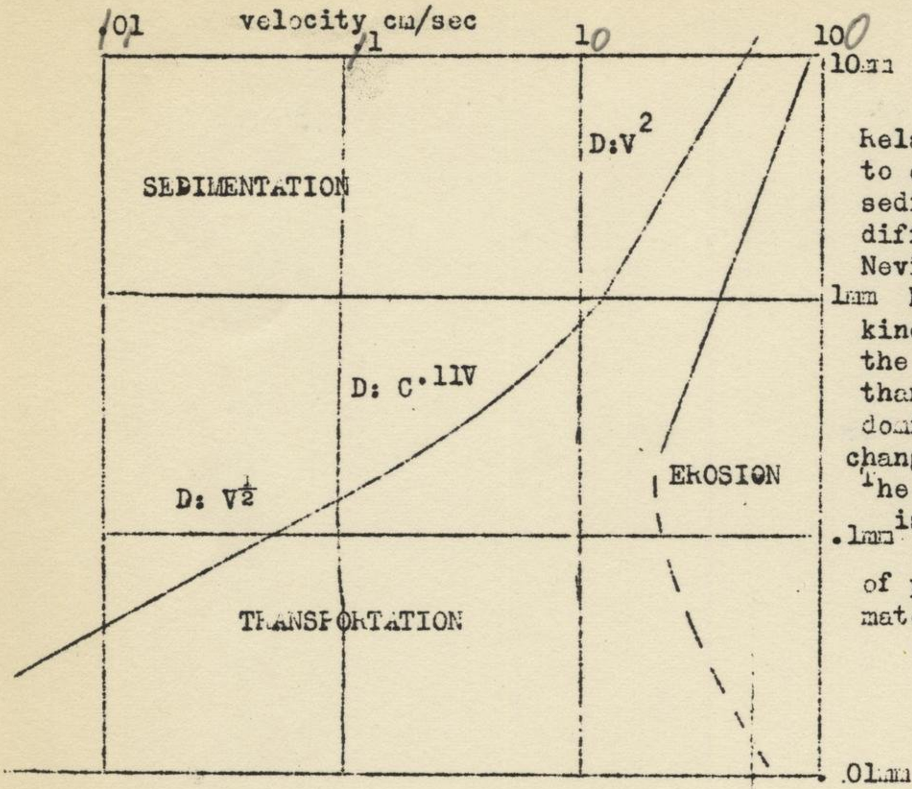

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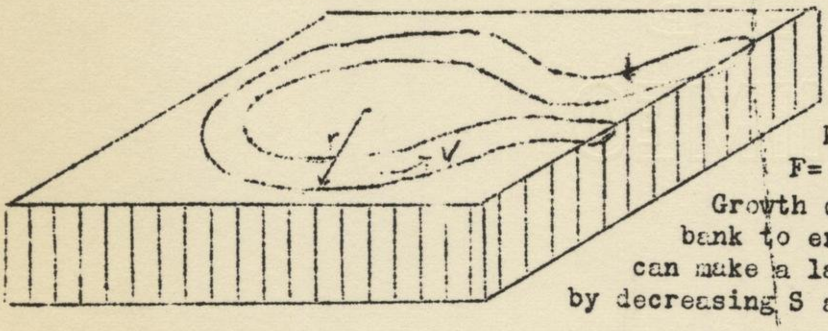
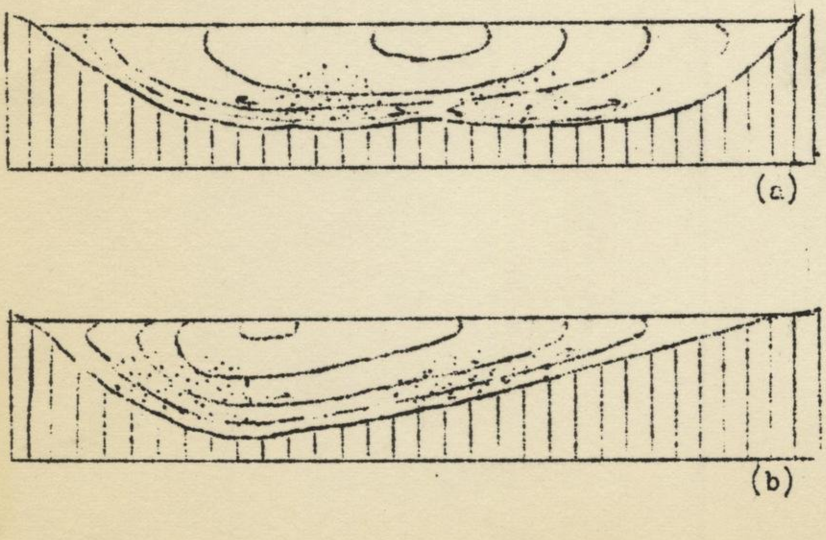


Fig. 55, p. 37
Rotational component of force in a curved or meandering stream.
Radius of curve = r Slope = S
$F = mV^2/r$ As $V: S^{\frac{1}{2}}$ then $F: m.S/r$
Growth ceases when F = resistance of bank to erosion. Only a large stream can make a large meander. Increase of length by decreasing S also serves to set a limit.



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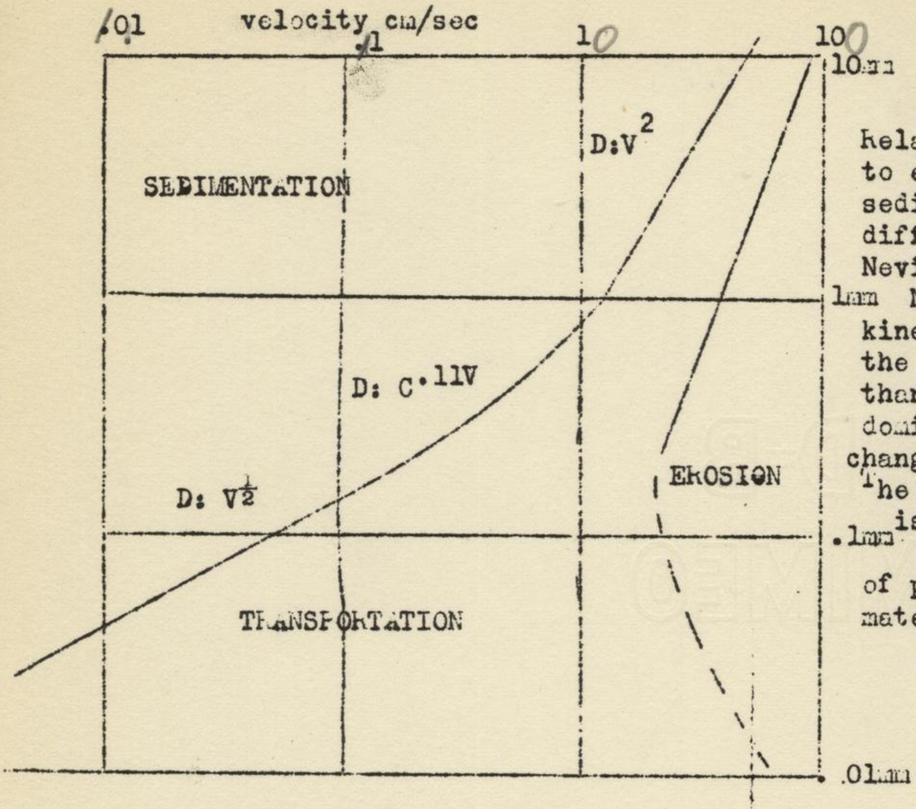

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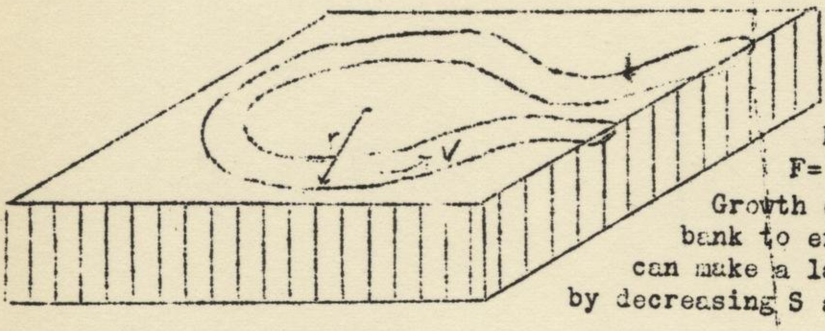

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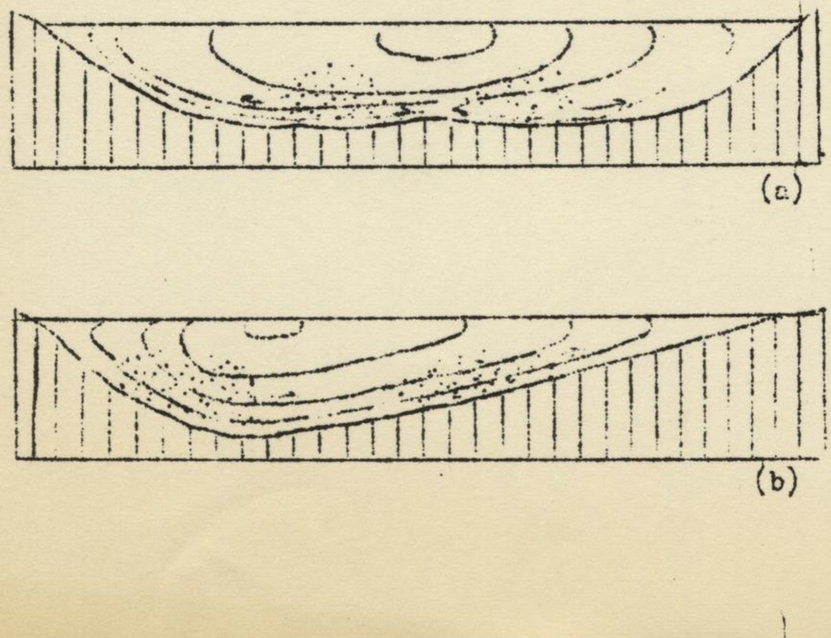

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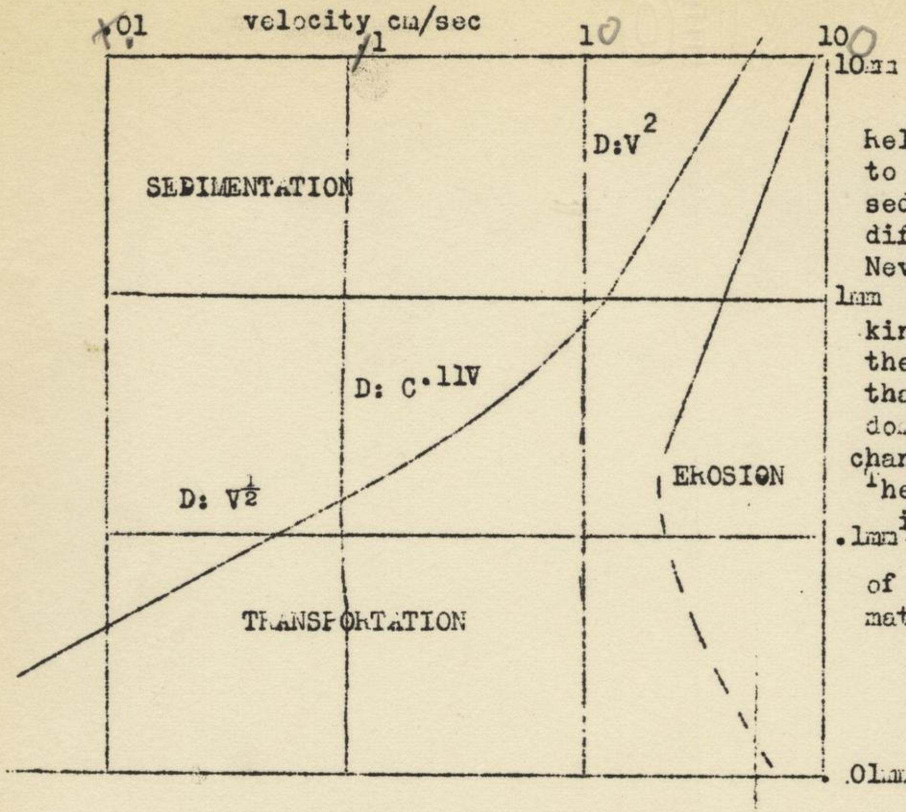

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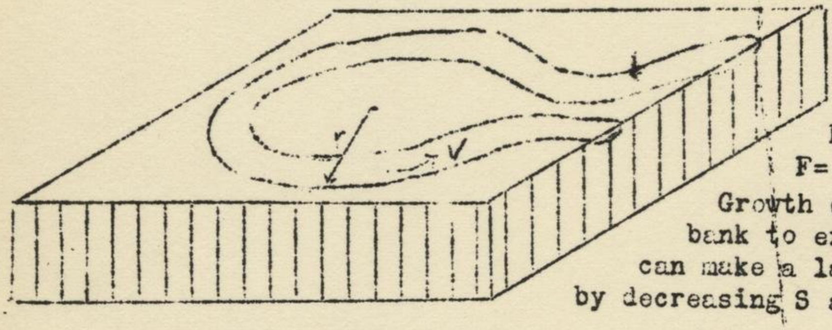

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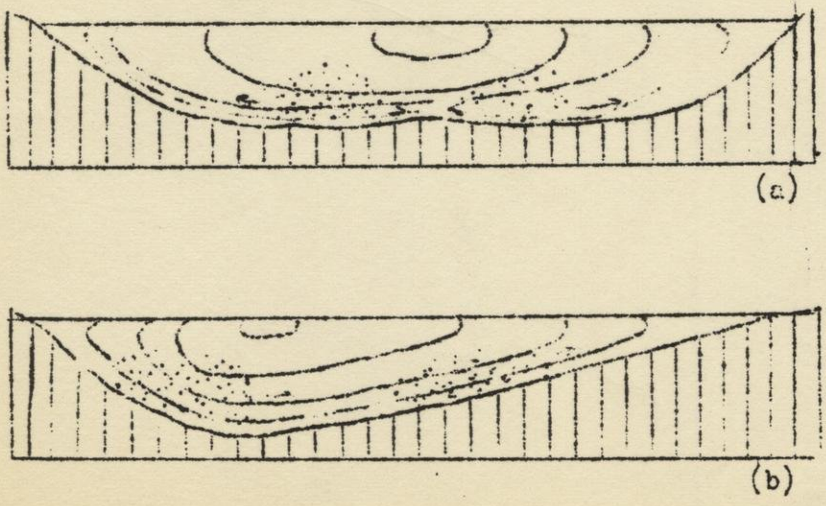

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