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Fundamental Laws Governing the Development of the Hydrographic Net and the Mechanism of Peneplain Formation

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FUNDAMENTAL LAWS GOVERNING THE DEVELOPMENT OF THE HYDROGRAPHIC NET AND THE MECHANISM OF PENEPLAIN FORMATION

(Printed on the basis of the revised and supplemented report first read at a meeting of the Geomorphological Commission of the All-Union Geographical Society in March 1947)

The problem posed in the title of this article involves a number of central questions concerning geomorphology. Hence one must not close one's eyes to the extraordinary complexity and vastness of the task posed, the ultimate solution to which does not lie within the powers of one man. This is especially true in view of the fact that the author has set for himself the task of analyzing the fundamental laws which govern the development of river networks under conditions of complex geological structure rather than under conditions in which a structural plain has simply risen above sea level, as was preferred by Davis and his many followers up to Horton.

At the same time it is impossible not to acknowledge that only such a statement of the problem makes its over-all solution possible (a simple geological formation frequently proves to be complex rather than simple); moreover, practice compels us to develop [new] starting points for the theory of alluvial deposits.

In Osnovnykh problemakh geomorfologii (Basic Problems of Geomorphology) K. K. Markov (12) presented a developed criticism of the W. Davis and W. Penck conceptions, and showed conclusively

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that they no longer correspond to the standards of contemporary geomorphology and related geological and geographical disciplines.

This is absolutely true as regards the problems examined in this article. Hence it is not necessary for us to begin with a criticism of the views of W. Davis and W. Penck; it is even less necessary (especially in view of the limitations of space) to dwell any further on the "history of the problem," since there is in the literature on the subject no original explanation of the nature of the processes of peneplain formation which differs in principle from the generally known "orthodox" theory of W. Davis and W. Penck.

Meantime, the need for a theoretical generalization derived from the enormous amount of material accumulated in recent years, on the one hand, and the demands of practice, on the other, do not permit us to discuss at any greater length conceptions which were partly developed as far back as the last century, which from the present day point of view were based on patently inadequate factual material, and which were not developed according to the Marxist dialectical method.

In the present article the author takes the liberty of expressing a number of ideas about the problem formulated in the title of this article in the hope that this will give impetus to a broad consideration of related problems.

The space limitations of a journal article compel brevity, regardless of the great number of problems under consideration. In particular it was far from everywhere possible to adduce the full factual material in the author's possession for the support of this

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or that position. The author hopes to remedy this shortcoming in the near future by the publication of several articles devoted to a more detailed review and documentation of the various statements made below.

I. INITIAL STAGES OF THE WATER EROSION PROCESSES. THE INTERACTION OF WATERCOURSES

On a part of the earth's surface which as a result of fold formation and anteclinal upheaval has been isolated as a morphologically expressed elevated region, destructive forces take an increasingly large part in the process of contour formation as the tectonic movements abate. (Land erosion begins long before the abatement of the tectonic forces, but as long as the processes of tectogenesis are vigorous enough to nullify the effect of the erosional processes, the latter can be ignored and their consideration begun at a later time).

Among these processes erosional activity plays the leading part in a majority of cases. The hydrographic net which begins to develop under primary contour-formation conditions conforms at first to the already-present negative structural formations. Further development of the hydrographic net proceeds through transformation of the pre-erosion contour into an erosion contour. In this process a special, if not decisive role is played by the repeated reorganizations of the hydrographic net which take place as a result of the constant interaction between separate watercourses and between whole river systems.

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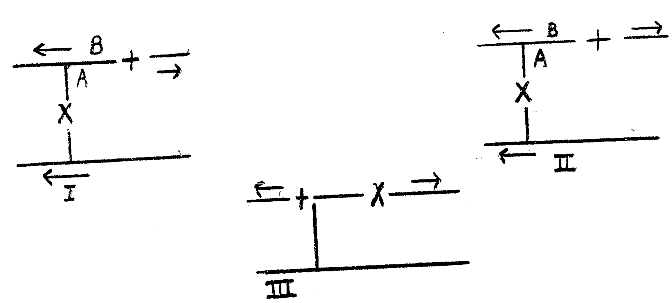
A few words on the nature of this "interaction." In the first place, let us designate two watercourses having a common water divide and flowing in opposite directions as "conjugated" watercourses. Conjugated watercourses always "interact," which interaction finds expression in the generally-known phenomenon of "aggression" on the part of the watercourse having the greater erosional activity against the watercourse which is less active.

It is also generally known that the watercourse which has the greater average slope in the region between the source and the nearest base-level of erosion will have the greater regressive erosion activity of the two streams.

It should be especially noted that the interaction of conjugated watercourses takes place in the form of a capture of the surface (still) and subsurface waters of that water divide zone from which both rivers are fed.

This is why the interaction over the course of relatively long time intervals does not lead to contact of the upper parts of the watercourses, the water divide between which continues to exist but gradually is displaced toward the side of the less active watercourse (Drawing 1).



Drawing 1. The Interaction of Conjugated Streams

X -- Receding water divide

+ -- Relatively stable water divide

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Such "peaceful" interaction between conjugated streams will develop at an accelerating tempo so long as the water divide does not shift to a point of junction of receding watercourse A with another watercourse B of the same river system. The moment this junction does take place, Watercourse B is joined to the system of the aggressor watercourse, and the action of regressive erosion is by degrees transferred to the vicinity of the sources of stream B (see Drawing 1).

The phenomenon described above is usually called river interception, representing a "jump" [of one square] on the ground where [the game of] interaction between conjugated streams is beginning.

In nature cases are observed where interception is not preceded by a "peaceful" interaction stage, but in which the upper part aggressor river makes a right angle raid on the valley of the adjacent river and "wins over" that part of the course of the river lying above the point of interception ("lateral" interception). Similar phenomena were recently described by K. I. Gerenchuk for the confluence of Prut and Seret rivers (10).

The process of interaction between conjugated streams is a self-inducing process, the "aggressor" watercourse (always getting stronger at the expense of the "receding"), which, in turn, intensifies the further advance of the aggressor, and so on.

On the other hand it must be noted that the diversity of the spatial distribution of the local base-levels of erosion in some instances brings about a pulsation of the water divide where repeated changes take place not only in the rate but the direction of the interaction of conjugated streams, such changes depending on

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the extent of the effect of the constantly descending base-levels of erosion. In short, the phenomenon on river interception can, in some cases, precede not a simple displacement of the water divide but a pulsation of it. (Drawing 2)

Drawing 2. Figures 1--6 show the successive displacements of a water divide resulting from the effect of constantly descending base-levels of erosion.

II. THE FORMATION OF PRIMARY RIVER SYSTEMS

The above applies with equal force to entire river systems; however, before we turn these considerations to the interaction between river systems we must touch upon a few problems concerning the formation of a river system such as might take place under the complex geological structural conditions of a mountainous area.

The primary erosional streams conform to the morphologically expressed negative tectonic structures and are localized in their bottoms; the orientation of the tectonic elements of the last orogenic phase here determine the orientation of the incipient watercourses.

In this stage the water-erosion activity on different parts of the mountain region develop independently from the base-levels of erosion dispersed around the boundaries of the mountain region. These base-levels of erosion will appear only on the periphery of the mountain region as long as the water-erosion streams do not become too deep to have as local base-levels of erosion only non-draining lake basins of tectonic origin.

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Examples of the formation of this type of tectonic lake are cited by I. V. Mushketov (see Bibliography, 14, page 473) who writes, "Both anticlinal and synclinal lines display an irregular slope as a result of which there appear along the latter articulated settlings which bring about the formation of tectonic lakes in these primary depressions; such lakes, as for instance Remorey and St. Poynt in the Dub River valley (in the Dub depression in Yura west of Lake Neuchatel), as well as the small lakes in the Orb River valley in the Neuchatel Lake system represent distinct extensions in the synclinal direction.

Another example of tectonic lakes conforming not to the folded but to the disjunctive negative structures is to be found in Academician V. A. Obruchev (18), who, while characterizing the contour of the southern part of neighboring Dzhungaria as "block mountains, fault blocks or wedgings of the crust.....limited by fractures and elevated to a different height" goes on to say that here "rivers or streams terminate in lakes or little by little dry up while within the mountain region..." The interaction of conjugated streams leads by degrees to the formation of rivers which are more extended (than the primary rivers), and also brings about the joining of river systems which are forming on the elevated locality under study to the water arteries of adjacent (lower) territories.

Simultaneously with the process of union between the primary streams there is beginning and developing a network of subsequent tributaries ~~when~~ which enter the main river at right angles. The life of all other (non-perpendicular) feeders is limited by the fact that

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the subsequent tributaries will take the maximum slopes and will hence display the greatest erosion activity.

At the same time it must be pointed out from the innumerable multitude of perpendicular directions the tributaries select for themselves the structurally favorable sections. They (the tributaries) adapt themselves either to the remaining unused primary stream beds of secondary tectonic form, or to elements of deeper structures opened as a result of erosion by primary rivers. In the latter case the role of the deeper and, as a rule, older structure comes down to the effect of the lithological features, since the deep structure cannot be shown to be of direct morphological action.

The presence in the main river of a tributary entering at an acute or even at an obtuse angle bears witness to the fact that this tributary was formed comparatively early, while subsequent tributaries developed later and still have not succeeded in intercepting the course of the oblique tributary (Drawing 3).

Drawing 3. Breakdown of an oblique tributary as a result of capture of its various sections by subsequent tributaries.

The development of subsequent tributaries leads in turn to interaction between tributaries of adjacent arteries so that in the last analysis the most active arteries pick up the pieces of the less active arteries parallel to them.

In this manner the formation of related river systems takes place out of different primary streams, in the process of which the

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primary (we suggest calling it the "fragmentary") hydrographic net changes into a dendritic, and still later into a lattice-type network.

III. THE INTERACTION OF RIVER SYSTEMS AND THE PERIODIC REORGANIZATION OF THE HYDROGRAPHIC NET

In the course of the described processes the moment approaches, of course, when the tributaries of one river system enter into interaction with the tributaries of another river system, in the process of which the more actively developing river system will join to itself parts of the adjacent weaker systems. Examples of this "conquering" of the rivers of one basin by rivers of another basin are fairly common and well known. One of the appropriate examples is shown in Drawing 4.

Drawing 4. Capture of the basin of the Sema River by the Katun' River. The newest section of the Sema River is crisscrossed with transverse lines; it is evident that the Sema previously flowed independently to the north. At present preparation for the interception of the upper section of the Sema is being made through the rivers Apshiyakhta and Sedlushka.

Interaction between river systems is accompanied by a breakdown of the valley of the less active systems and the formation of a section of dead, or, as they are commonly called, old valleys. (Old valleys, i.e., valleys which have been left over from a system of an active hydrographic network, have been noted by many researchers.

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A. R. Burachek, for example, writes of the old valleys of the Patomskiy uplands: "Many of these old valleys are well preserved. The largest of them are oriented along the course of the geological structures, that is, from northwest to southeast, and they intersect the watersheds of the present-day river basins. In many places the sedimentation of the old rivers was well preserved, at times reaching a thickness of probably 20-30 meters" [3].)

However, the further course of development of the processes described may lead to a breakdown of the attacking system itself. This takes place when different elements of a lattice-type system of rivers are intercepted on the periphery of the mountain area under study by a river system having a lower base-level of erosion for the entire region than that base level relative to which the development of the hydrographic net has taken place so far.

Rivers in this stage of their development display articulated configurations, governed by the configuration of the preceding (lattice) stage due to natural variance in the times of interception of all the rivers, forming one straight line.

The process of formation of articulated rivers augments the number of dead valleys ~~where~~ which appear at points of breakdown of a main valley in the lattice stage.

Further on the articulated rivers straighten their course through the destruction of their bends by regressive erosion between corresponding tributaries (Drawing 5).

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Drawing 5. The straightening of bends in the valley of the Lobva River (on the eastern slope of North Ural). The Kushva and Rybnaya rivers are "trying" to rectify bends in the Lobva River. The Royka River is trying to rectify a bend formed by the Kushva and Lobva rivers (in the Vakhrushevka-Talitsa section). The Krasnoyarka River is trying to join the Lobva River (in the vicinity of the mouth of the Rybnaya River) to the Sos'va River. Upon completion of all these processes the Lobva River will acquire a single latitudinal direction of flow.

These interceptions also are accompanied by the formation of new sections of dead valleys and a change in direction of flow in some sections. Thus a new cycle in the development of the hydrographic net begins, marked with the formation of rivers which we designate as "secondary" rivers. These rivers have a direction of flow which is perpendicular to the flow of "primary" rivers.

Due to the augmented erosional activity on the newly formed straight sections of the valley, tributaries appear. These tributaries, just as in the original stage of land formation, adapt themselves to the favorable structures opened by erosion along the sections of the straight valley.

Thus the normal course of the process of erosional breakdown of the primary tectonic contours inevitably leads to its reversal (inversion). For example on the eastern slope of the Urals several tributaries of contemporary latitudinal (or articulated) rivers

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~~having~~ have meridional valleys, the water divides between which are complex, with a surface of Oligocene-Miocene alluvial sedimentation (20).

Subsequent development of the hydrographic net is proceeding, through the formation of secondary "lattice" and "articulated" systems and under definite conditions, toward the formation of rivers of a third generation, which may have an orientation close to orientation of the primary rivers, though not spatially congruant with them. The formation of rivers of the third generation is accompanied, under the proper geological conditions, by the phenomena known as "contour inversion".

For a better picture of the causes which bring about periodic reorganization of the hydrographic net, see Drawing 6.

Drawing 6. Readaption of the hydrographic net from base-level of erosion No 1 (B. E. 1) to the lower base-level of erosion No 2 (B. E. 2).

The drawing is a schematic representation of an elevated mountain locality surrounded on four sides by depressed areas which serve as its base-levels of erosion. These base-levels of erosion have varying absolute heights above sea level. Since the first to develop was a lattice-type system built relative to B. E. 1, the system will later be reorganized under the effect of the lower base-level of erosion -- B. E. 2 -- in the manner described above.

If the remaining base levels turn out to be still lower, then sooner or later they will compel the hydrographic net to reorganize again and again.

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We must also take into account the fact that at the time of formation of the hydrographic net the relative importance of the various base-levels of erosion may periodically change due to oscillatory movements, each such change bringing about a reorganization of the hydrographic net.

IV. FORMATION OF A DENDRITIC HYDROGRAPHIC NET. AUGMENTATION OF THE ROLE OF SURFACE WASHOUTS

The periodic reversals of the river systems in a plane, accompanied by the spatial incongruities of such systems, lead to a riddling of the contour, in the process of which each new cycle of breakdown of the water divides progressively increases the number of slopes.

Simultaneously with the increase in the number of slopes, a leveling of the high points of the positive forms of the contour is taking place. This is explained by the fact that the highest sections of the "primary-tectonic" contour of erosion, and hence also the interaction between the different rivers, are developed the most rapidly.

This explanation may perhaps include the cause for the formation of mountain peak faces -- a problem which K. K. Markov treats extensively, but at the same time fails to resolve.

Thus, as the erosion processes develop, the "primary" contour not only lowers (this is known) but is substantially broken down (diminished in size) and flattened (in the sense of leveling of the maximum crests).

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In the final stages of development of this process, the water-erosion activity, because of the progressive breaking down of the contour, widens the field of activity for the processes of physical weathering and surface washouts. Total destruction of the land and "tightening" of the slopes and peaks by products of subaerial denudation result in the elements of the geological structure affecting the development of the hydrographic net less and less. The moment approaches when the development of the hydrographic net will forever be regulated solely by the action of the force of gravity.

At this time the main artery and its tributaries take on the characteristic dendritic form.

All the watercourses now flow in conformance with the general angle which the locality adopted at the time of the last reconstruction of the hydrographic net. In this stage the processes of water erosion, having completely reorganized the locality, act entirely independent of the geological structural features.

In its overall direction, the process tries to create uniform drainage for the area in place of chaotic distribution of drainage adapting itself to the different tectonic directions of the valleys.

Going ahead a bit, let us assume that such "ideal" drainage of an area is exhibited on the eve of the disintegration of the hydrographic net (see below).

Let us bring out a few of the preliminary results deriving from the preceding exposition.

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(1) The development of the hydrographic net from the fragmentary stage to the dendritic stage is a self-inducing process. At the end of each cycle of reorganization of the hydrographic net river systems are formed, the main arteries of which have an orientation perpendicular to the rivers of the preceding cycle.

These changes in the orientation of the main streams come about because the most active tributaries of the main rivers in each stage are the perpendicular (subsequent) tributaries (see above), the activity of which predetermines the formation of new main rivers.

(2) However, spatial congruance of the erosional forms of the repeatedly rearranging hydrographic net does not come about, because in their development the water courses "exhume" deeper and deeper geological structures and once again the tributaries which evolve are located in the favorable sections for erosion of the latter; i.e., as has been repeatedly stated above, out of the innumerable possible perpendicular directions the erosion selects the structurally favorable sections, and in this sense the development of the hydrographic net is guided by the geological structure.

V. THE DISINTEGRATION OF THE HYDROGRAPHIC NET AND THE FORMATION OF THE MELKOSOPOCHNIK [SMALL CRATER]

The formation of a dendritic hydrographic net leads to the augmentation of a whole series of processes which together bring about the disruption (disintegration) of the hydrographic net. These processes are as follows:

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1. Progressive increase in the number of slopes leads to excessive intensification of the processes of surface washout and eroding of the products of weathering in the valley of the watercourse.

2. Progressive increase in the number of streams without a change in climate (that is, a constant quantity of precipitation) results in a weakening of the erosional energy in each of the streams.

3. The accumulation on the slopes of loose weathering products leads to an increase in the filtration of precipitation, which in turn leads to diminished supply to the watercourses from runoff waters, and consequently the erosion force is still further lessened.

4. The accumulation of alluvial sedimentation in the negative forms of the contour leads to an increase in the filtration of bed waters in the ground, which also serves to weaken the force of erosion.

It should be noted that factors 3 and 4 naturally bring about a shortening of the upper parts of the watercourses.

The above processes, together leading to a weakening of the water-erosion action and to a broadening of the field of activity for slope-terracing agencies, in the last analysis result in a damming up of the different sections of the river course. This initiates the degradation of the river net and the formation of non-draining craters so characteristic of the low hills [melkosopochnik] of the Kazakh landscape.

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The same conclusion was reached more than fifteen years ago by G. Ye. Bykov on the basis of field investigations in which he noticed the following genetic series in the development of the crater forms of contour of the Kazakh melkosopochnik: "River bed, stretch of water, stretch of lake, lake valley, round lake, dry lake crater" (5).

In the light of investigations of recent years (4, 5, 6, 7, 8) there remains still less doubt as to the erosional-denudational derivation of the Kazakh watershed melkosopochnik. (From the number of opponents of the erosional-denudational derivation of the Kazakh watershed melkosopochnik we may cite I. S. Shchukin who believes that this type of contour "is formed for the most part by arid weathering and wind erosion" (23, page 53). It is interesting to note that where these forms have not been affected by a modern revival of erosional action and have not been half buried under the marine sedimentation of a tertiary sea, we have evidence that on the eve of the melkosopochnik stage the hydrographic net possessed dendritic character. Such a semi-degradation in which traces of the dendritic configuration of the hydrographic net are none the less retained is shown in Drawing 7, referring to the region built almost entirely of paleozoic complex rock (north of Lake Balkhash).

Further breakdown of the positive forms of the contour take place through a washing out of the slopes until they acquire critical angles of equilibrium. (The slopes of the valleys which the watercourses are developing will have a steepness considerably exceeding the critical angles of equilibrium. Hence it is quite evident that these angles begin to form only after the process of washing of the river net has come into its own right).

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Thus in the development of the erosional-denudational contour the melkosopochnik stage corresponds to the interval of time from the formation of short critical slopes to the formation of slopes having critical inclination angles, which takes place through filling in of the negative forms of the contour with the products of the breakdown taking place on the slopes.

At the end of this process there has been formed, instead of a mountain area, an undulating semi-plain (peneplain) having as its base complex geological structures covered by no less complex products of breakdown.

To the number of "post-peneplain formation" processes must be added the formation of the old weathering crust "fixing", as K. K. Markov put it, the old denuded contour.

VI. THE EFFECT OF THE MOVEMENT OF THE CRUST ON THE COURSE OF THE PENEPLAIN FORMATION PROCESSES

Analyzing the development of the erosional processes, we have purposely kept away from the role of endogenous forces acting on a given territory during the period of peneplain formation, believing that otherwise we might detract from rather than add to a correct understanding of the importance of erosion in contour formation. On the other hand the extent of effective action of the tectonics on the contour can be properly understood only after exhausting all possibilities of recreating different stages of contour development with the aid of internal laws of development of the hydrographic net.

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Now let us examine the influence of the ceaseless motion of the earth's crust on the development of the erosional processes.

With this point of view it is advantageous for us to give the following classification of the motion of the earth's crust:

A. Movements noticeably disturbing the geological structure of the area. Let us agree to call these deformational movements. Here we are referring to both plicative and disjunctive dislocations which appear equally in different sections of the area.

Deformational movements in turn must be distinguished according to the relative speed of their manifestation:

1. Vigorously developing movements as a result of which the entire plane of the area is altered and the whole hydrographic net, so far in effect, is disrupted.

2. Slower movements in the course of which the hydrographic net is able to adapt itself to the new contours. This category, in turn, must be divided into two limiting cases:

a. The newly arising structures grow transversely to the course of a given section of the river.

In this case antecedent valleys are formed at the points of development (growth) of positive structures and anomalously thick strata of alluvia at points of development of negative structures.

b. The newly arising structures grow parallel to the course of a given section of the river.

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In this case "drift" occurs, i.e., a displacement of the course of the river according to the newly emerging slopes toward the side of the axis of the nearest negative structure (displacement of the course of the latitudinal tributaries of the Yenisey according to the slopes of the extended growths, and in recent times the structure of the Taymyr Depression [21]).

B. Movements not disrupting or only imperceptibly disturbing the geological structure of the area. Here we refer to (1) regional anticlinal upheavals, or (2) general subsidence affecting the entire area under observation.

It has been generally agreed in recent times to call this type of movement "oscillatory" movement.

In distinction to the deformational movements, which at least to some degree inhibit or even reverse the process of peneplain formation, oscillatory movements, generally speaking, favor this process. This statement may at first glance seem strange. However, one must take into consideration that the entire positive regional movement of the earth's crust, which leads to intensification of the erosion processes (this is always noted), simultaneously facilitates the progress of hydrographic net reorganization processes relative to the base-levels of erosion which surround the given locality. Thus after each regional upheaval the contour of the locality acquires a more and more complex appearance (i.e., it diminishes in size) since the erosional activity is guided by the geological structures into continually new directions (see above). During the period of subsidence this

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process is somewhat retarded so that it can revive again during the period of upheaval.

The full completion of peneplain formation (degradation of the hydrographic net) can, however, only take place under conditions of relative rest (relative to neighboring territories) or subsidence.

In brief, the positive regional movements tend to facilitate reduction of the contour, this comprising, as we have said above, the first (and evidently the most prolonged) stage of peneplain formation. Subsidence also assists in completing the secondary and final stages, but only under the condition that the preceding periods of contour upheaval have achieved a critical degree reduction.

Below is a tabular representation of what we have said above:

(See over)

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INFLUENCE OF THE MOVEMENTS OF THE EARTH'S CRUST ON THE DEVELOPMENT OF THE HYDROGRAPHIC NET AND THE PROGRESS OF THE PENEPLAIN FORMATION PROCESSES

Type of Movement			
Deformational Movements		Oscillatory Movements	
		Positive Movements	Negative Movements
Speed of movement exceeds speed of erosional processes.	Breakdown of previous hydrographic net and new formation of the tectonic contour.	Promote the process of contour reduction.	Promote the process of wearing down the contour where the latter has achieved a critical degree of reduction.
Speed of movement slower than or equal to speed of erosion.	Adaption of the hydrographic net to the incipient structures.		

For the completeness of this section it is proper to introduce a statement by N. I. Nikolayev (16) who says (after V. V. Beolusov [1] and others) that "at the present time there is to be noted an adequately clear connection between the structure and character of the manifestation of the most recent movements of the earth's crust, reflected most of all in the sculpture,

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i.e., the geomorphological features of the area." In other words, the "primary" structure may show not only the direct effect on the development of the hydrographic net (see section I, II and III of this article) but can also affect it in an indirect way through young movements.

To illustrate the various statements made in this section we have found it most instructive to treat various moments in the meso-cenozoic history of the Urals.

Characteristic of the mesozoic alluvial deposits in the Urals is, as is well known, their conformance to the old meridional depressions. These deposits, in turn, inherited the negative tectonic structure formed at the time of the varisic orogenesis. Throughout the mesozoic era the basic water arteries of the Urals repeatedly reconformed their courses according to the meridional depressions. These facts testify to the disruption of the normal erosional processes, and we are compelled to come to the conclusion that in the mesozoic era the meridional structures of the Urals underwent repeated "rejuvenation", which was expressed as a false "conservativeness" of the hydrographic net of that time. It is still necessary to add that the presence of mesozoic lake deposits within the depressions affirm the fact that "normal" development of the hydrographic net in the different epochs of the mesozoic age was retarded by slow, almost ceaseless subsidences beginning and repeating at different times on different sections of the depression. In other words, due to the prolonged development of the varisic structures in the mesozoic age the hydrographic net of the Urals not only was "trampled into place", but was even at

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times regenerated to the fragmentary stage (formation of non-draining basins). At the same time the occurrence in the Urals of variously aged (mesozoic) formations of crust weathering bears out the fact that in different epochs of the mesozoic age the contour of the Urals acquired a considerable degree of wear. For these same epochs there is data on the time of the existence of the latitudinal arteries which is indicated by the material composition and slime-mineralogical composition of several varieties of loose mesozoic deposits.

Thus for the mesozoic Urals there are to be noted alternating epochs of revived deformational tectonic movements with epochs of comparative rest characterized by the predominance of anticlinal upheavals of wide radius. Such a relatively "tranquil" epoch was the time just preceding the upper cretaceous-paleogenic transgression when the reduction of the contour took place.

The final leveling off of the contour, manifested in the formation of the Ural melkosopochnik, demands that we identify this event with the epoch of the paleogenic transgression. At this time, due to the high position of the base-level of erosion the wearing away of the diluvial material from the slopes finally "drowned" the activity of the water arteries which up to this time, we must assume, had had their own dense net of diminishing streams. The absence of any data whatsoever on the presence of alluvial deposits belonging to the epoch of maximum transgression of the paleogenic sea (paleocene and eocene) can serve as evidence of this.

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Judging from available bibliographic data the same things took place in the paleogenic era in central Kazakhstan.

In the oligocene, miocene, and on the eastern slope of the Urals in the pliocene as well, there was a new "rejuvenation" of the mesozoic meridional structures (echoes of Alpine folding). In the Quaternary period, and on the western slopes of the Urals in the pliocene also, favorable conditions for the reorganization of the hydrographic net were brought about through the diminishing of the differentiational movements of the Ural structures. There appeared articulated, and in places latitudinal rivers, which developed in conformance with the geographic location of the general base-levels of erosion, which were, at that time, the Russian Plain and the West-Siberian Lowland. Thus because the orographic contrasts within the Urals (i.e., the meridional valleys and meridional water divides) in the Quaternary period little by little moved into the background in comparison with the more stable contrasts between the entire Ural mountain area as a whole and the surrounding plains, the internal laws of erosion came more and more into their own.

The activity of the Quaternary latitudinal valleys is accompanied by the antecedent cutting-through of the meridional zones of upheaval and the simultaneous accumulation of anomalously thick strata of alluvia in the meridional zones of sagging (depressions).

VII. THE ROLE OF CLIMATE

With regard to the influence of climate on the progress of

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the development of erosional and denudational processes, it is believed that this factor affects only the rate of these processes. It is pertinent for our purposes to point out that in the contour "riddling" period the process of peneplain formation accelerates as the climate becomes damper; conversely, in the last stage of peneplain formation (washing out of the hydrographic net and eroding of the slopes) the process accelerates as the climate grows drier. In this connection it may also be noted that an arid climate has the special role of "canning" the different stages of contour development. For example, on a great part of the territory of central Kazakhstan there have been preserved up to our time sections of the development of the melkosopochnik untouched by recent erosion, and even an indication of the peneplain formation contour overlapped by lower-Tertiary period crust weathering (I. P. Gerasimov, [7]). (In the post-paleogenic period the territory of central Kazakhstan unquestionably underwent not only oscillatory but in places also deformational (13) movements whichshould have under other climatic conditions promoted marked erosional disintegration of the surface of the paleogenic peneplain).

In estimating the preservative qualities of an arid climate we are in complete agreement with the opinion of S. Yu. Geller (6), who believes that the contour of a desert is inherited from the old erosional-denundational cycles and is carefully preserved under contemporary conditions of the desert in which, in comparison with all other landscape zones, the processes of contour formation have been specifically diminished.

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CONCLUSIONS

1. The history of the destruction of a mountain area is the history of the development of its hydrographic net. Its repeated reorganizations accompanied by the formation of new valleys and washing out of the old, and, of course, the degradation of the hydrographic net all determine the course of the destruction of a mountain area from the stage of high "primary tectonic mountains" to the melkosopochnik and peneplain stage.

2. The struggle of the various watercourses and whole river systems in the field of underground and slope feed is the fundamental internal law of the development of the hydrographic net, governing its repeated reorganization even under conditions of comparative tectonic rest.

In this connection the gradual distribution of the effect of the constantly descending base-levels of erosion may bring about repeated changes not only in the rate but also in the direction of the process in different sections of the area.

3. The role (passive) of the geological structures, which determine the concrete forms of the hydrographic net development, results in each new water artery "conforming" to the increasingly deeper structural features uncovered by the preceding stage in the erosional development.

In the last stages of the development of the hydrographic net breaking down of the contour leads to intensification of the processes of subaerial denudation. The role of the internal

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structure dwindles down to nothing and the hydrographic net acquires the characteristic dendritic configuration of flat countries, and then disintegrates entirely.

4. Peneplain formation is a two-stage process: stage I -- breaking down of the "primary" contour by erosion, accomplished through repeated reorganization of the hydrographic net; stage II -- washing out of the slopes by diluvial processes, acquiring decisive value for the maximum development of stage one.

5. Movements of the earth's crust which may develop during the period of peneplain formation are to be divided into: (1) oscillatory movements which do not change the structure of the locality, and (2) deformational movements which change the structure of the locality (active role of the geological structure).

While deformational movements retard or even reverse the processes of peneplain formation, oscillatory movements, on the contrary, encourage this process. This is explained by the fact that regional upheavals facilitate the breaking down of the contour while subsidences contribute to its washing out, with the stipulation that the degree of breakdown must have already reached its limit.

Hence it is our belief that in explaining the process of peneplain formation there is no necessity to assume the existence of whole geological periods of complete tectonic rest, which assumption, it is recognized, is the weakest point in the W. Davis and W. Penck arguments.

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6. On the territory of a region selected for study there may be simultaneously represented many of the types of hydrographic net described above, genetically related to each other. Each stage of the development of the hydrographic net produces its own complex of alluvial accumulations, the study of which has great practical importance in the search for alluvial mineral products. Only when we are able to reestablish in detail the history of the development of the hydrographic net of whole regions will the problem of finding alluvial placers acquire a stable theoretical foundation.

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APPENDIX

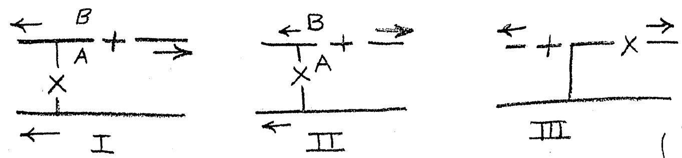


Figure 1. Interaction of conjugate streams.

X - receding water divide
+ - relative constant water divide

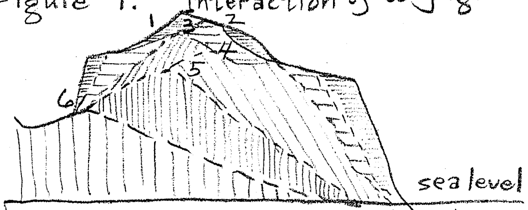


Figure 2. Numbers 1 to 6 indicate successive displacements of water-divide as a result of influence of constantly lower and lower placed erosion-basins.

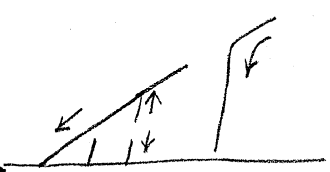
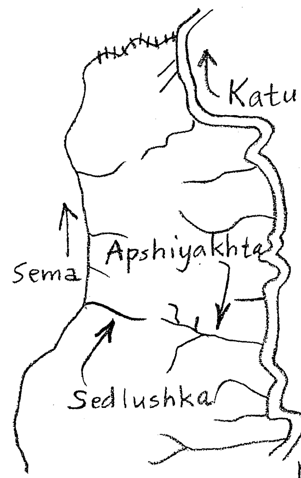


Figure 3. Collapse of "oblique" tributary in consequence of the capture of its individual sections by subsequent tributaries.



Capture of the basin of the Sema River by the Katun' River. The newest section of the Sema is criss-crossed with transverse lines; evidently the Sema previously flowed independently to the North. At present preparations for intercepting Sema's upper section are being made thru the Apshiyakhta & Sedlushka.

Figure 4.

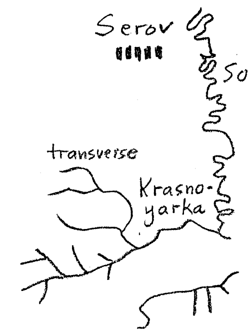


Figure 5. The straightening of bends in the Lobva River valley (on east slope of N. Urals).

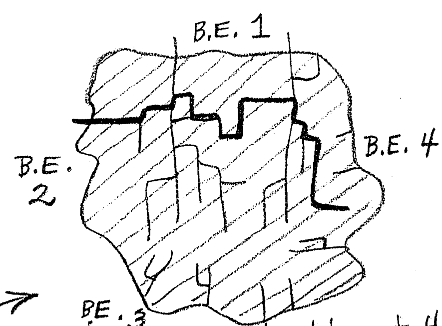


Figure 6. Readaption of the hydrographic net from baselevel of erosion No 1 (B.E. 1) to the lower base-level of erosion No. 2 (B.E. 2)

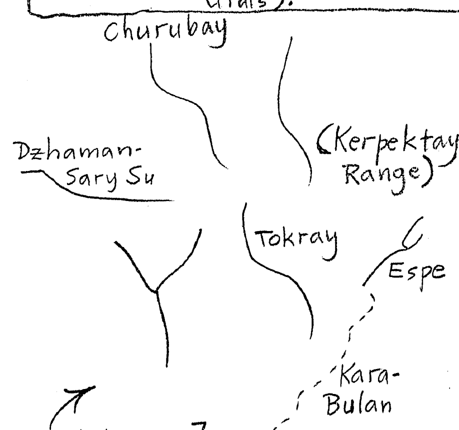


Figure 7. Semi-degraded hydrographic net in region of Central Caucasus low hills [melko-sopochnik].

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