Trans. Inst. Indian Geographers.
Vol. 2, No. 1, January 1980

THE LANDSCAPE EVOLUTION OF THE BARAKAR BASIN IN THE LIGHT OF THE GEOMORPHIC MODELS

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ABSTRACT : The main object of this paper is to critically analyse the sequential stages in the history of the landscape of the Barakar Basin in the light of the models of landscape evolution. The analysis leads to the conclusion that the Barakar Basin shows neither slope-reduction of Davis nor slope-retreat of Penck – King, in all aspects, though both these phenomena are partially observed. They heavily lean to the state of dynamic equilibrium envisaged by John T. Hack, as the Barakarian landscape carries the composite slope forms, shifting divides with varying degree of slopes on their sides, high density of hydrographic network and drainage texture in the areas of moderate gradient, and increasing and decreasing eroding capacity at the same stage in the cycle. That is why the authors are inclined to conclude that the geomorphic features observed in the Barakarian landscape are mostly in a state of dynamic equilibrium and they accept the Hack Model with the modification as the basis for explaining the geomorphic featares in the basin.

The Barakar Basin – The Study Area

The Barakar Basin (23° 41' 30" N. and 24° 31' 30" N. Lat. and 85° 10' 00" E. and 86° 54' 00" E. Long.) is a well defined geomorphic unit comprising the entire catchment area (7026.1 Km.²) of the Barakar River, a tributary of the Damodar, in Bihar (India). It is a part of the Chotanagpur Highlands (Fig–1).

The Barakar Basin is a region of physical diversities. It presents a rich panorama of topographical features, characterized by scarp-zones, erosional surfaces and residual hills. Its general slope is in the southeast direction. Extensive areas lie between the 152 metre and 457 m. contours, which present a variety of morphological features. River – Valleys, most of them long, deep and terraced and a few of them with gentle slopes alternate with low elongated ridges, someitmes hilly spurse, projecting from higher tableland or elongated into chains of hills and ridges.

The area under study has been a part of Archaean Basement complex, which has been subjected to many cycles of erosion. It is, therefore, a polycyclic region. A large part of the region is covered with rich forest and scrub-jungle. These protect the area at places from severe soil-erosion. But great elevations and steep slopes facilitate quick run-off which renders the streams ephemeral. At present the Basin is under sub-tropical humid climate. Other features of morphological interest in the region are waterfalls and springs. Waterfalls and rapids have greatly influenced the topography of the area, causing the long profile to be interrupted by abrupt breaks of slope.

The 300 metre surface : the core of the basin

The 305 m. surface constitutes the core of

the Barakar Basin. On the southeastern side, it gradually slopes down to about 100 m. at the confluence of the Barakar with the Damodar River. In the southwestern corner, it ascends up to 609 m which is a part of the Upper Hazaribagh plateau. The transition from 305 m. to 381 m. surface is gradual on three sides of the plateau. Thus the general topography is undulating (except in the south and southwestern parts which comprise the scarps and hills. But if the lofty Parasnath Hills are included the relief increases, to about 1265 m, the Parasnath being 1365 metres high and the lowland near Chirkunda Barakar being only 100 metres above the sea level.

In landscape evolution, the critical element is the behaviour of slopes. Landscapes are made of slopes, and even a surface that looks absolutely flat to the naked eye usually proves to be at least gently inclined. So the study begins with the question of slopes which assume varying forms.

Discussion on Models in the Light of the Geomorphic Features of the Basin

1) The authors observed and measured the slopes of a number of hills in the Basin and found that there was one type of slope on one side and a different one on the other. The measured profiles are not equally uniform in their slope variation from foot to crest. Convex and concave segments both include those units which are rectilinear sections or maximum segments of profile (Fig. – 1). The presence of maximum units, their length and amount of angularity, influences the degree of curvature of convex and concave slope units. Its presence or absence determines the complexity of profiles and nature of development. So it is difficult to decide whether flattening or steepening tendencies of these profiles are prevailing.

According to Strahler's 'equilibrium–slope hypothesis' (which is more or less similar to the slope system in dynamic equilibrium of Hack), the slope angle represents a condition of balance involving not only rock type and structure, but also climate, soil, vegetation, and other circumstances. If one of these conditions were to change (say an increase in annual rainfall) then we could expect the angle of slope to change as well. Forces act on the materials of the slope. Gravity pulls down, and the underlying bedrock pushes up. Matter passes through the system from the top to the bottom. Energy also passes through the system. The upper rocks gain potential energy from previous tectonic uplift. Potential energy changes to kinetic energy, when gravity pulls the rock materials downslope As in any system, there are movements and changes of material and energy on a slope. Strahler suggests that the angle of the slope adjusts itself so that the system operates efficiently.

2) The eroding capacity of the Barakarian drainage has been increasing gradually for the last 250 years with the removal of the vegetal cover. The fact finds support in a personal discussion with Mr. R. K. Mukherjee, Deputy Director, Soil Conservation Department, Damodar Valley Corporation. He corroborates that no sign of flood by the Damodar was traced in West Bengal before 1730 because its basin had a dense vegetal cover and was thinly populated. As the pressure of population increased the demand for agricultural land increased. Consequently deforestation started which resulted in increasing erosion on the slopes and silting of the river channels. Consequently, the floods started occurring year after year until they were moderated by the construction of a number of dams in the upper reaches of the streams.

The most plausible inference is that the phenomenon of geomorphic shift is directly related to the dynamic equilibrium of landscapes and is not stage – dependent as postulated in the models of Davis and Penk – King.

3) The study of divides depicts the landscape evolution. The outskirting divides of the Basin have migrated towards the main stream from North and South resulting

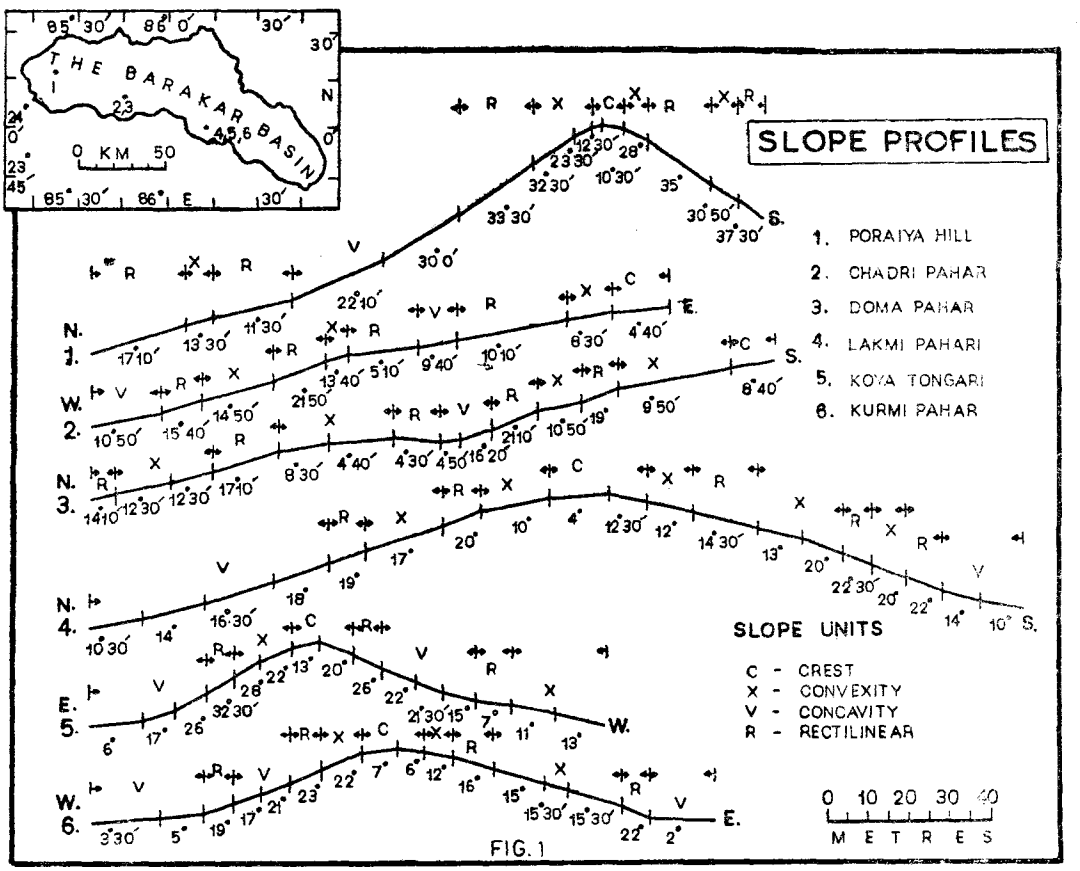


FIG. 1

in the contraction of the area of the Basin. This is mainly due to disproportional erosional activity of the adjacent rivers. There is steeper slope beyond the Basin where erosion is more severe than on the gentler slope towards the Basin. The divides in the Barakar Basin are spaced ununiformly and the gradients differ very much on opposite sides of divides suggesting unequal erosive capacity of adjacent streams though the stage is the same on both of the divide. This shows the triviality of the stage concept of Davis.

4) The analysis of the 'Hydrographic Network' reveals that the areas of high density of source heads and confluences are physiographically a combination of peneplain and outer erosion fringe lying between 285 metres and 380 metres. Geologically, this area is the linear Gondwana trough on the Archaean base. So, here is a peculiar situation. The high density Zone should have occurred along the scarps, ridges and hills of high gradient, but these areas fall mostly under low density zone ($\angle 5$) and medium density zone (5 – 20) to some extent (Fig. 4 & 5). This is because the initiation and the development of streams has been more rapid on the relatively less resistant rocks.

5) A striking geomorphic feature of the Basin, which has recently been studied by Ahmad (1969) is the higher marginal

scarp. As we approach the edge of the scarp zone towards North (Fig-6), "we not only come across the sudden drop of surface represented by the steep slope of the scarp, but we also observe ridges and monadnocks rising remarkably above the general level of the planation level giving a saucer-like appearance to the area" (Ahmad : 1969). Ahmad suggested that these are " the eminences (stems of older mountains) of older erosion surfaces out of which the present surfaces and scarps have been carved. " (Ahmad : 1969).

For the existence of this feature, there may be two alternatives at least. Firstly, the force of reduction or retreat did not act upon, and secondly they have acted upon the surface, but the force of dynamic equilibrium has given the maintenance of this feature; although there may be a case that the older stems of mountains do not exist in the original form, rather represent the forms under the new *environmental conditions.* The second alternative is more logical than the former, and can be more plausibly explained by a state of dynamic equilibrium which changses with the change invironment.

6) The gullies observed in the Barakar Basin are neither related to the stages of landscape development nor the concept of slope retreat nor that of the slope reduction. It is related to the uplift of the area and the local condition.

7) The Barakar Basin is characterized by entrenched meanders, and represents a rejuvenated landscape. One may argue that a new environmental condition (tectonic or

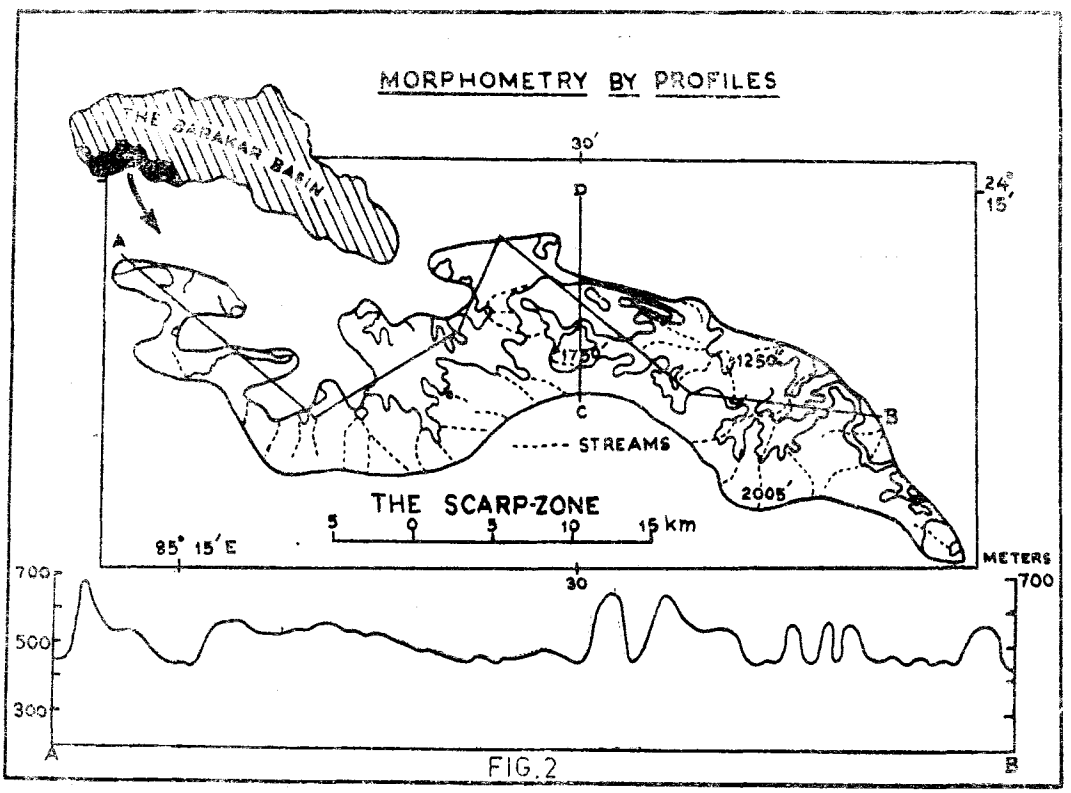


FIG. 2

climatic change and so on) may produce such a surface where meandering of rivers may be achieved and the subseqent uplift may lead it to entrenching possessing potential energy.

8) The analysis of the drainage texture of the Barakar Basin, suggests that its development is not related to the stages of landform development. The drainage texture of the Barakar Basin is probably the result of rock structure, relief, vegetation with an overriding control of lithology.

9) The study of streamline surfaces of the Barakar Basin reveals that the scarp – zone in the West and the Parasnath Tundi area in the mid – southeast seem to be stepping down northwards while the lower denuded areas seem to be receding westward rapidly specially after the uplift of the area during the Himalayan Orogeny.

Erosion and Sedimentation in Barakar basin

The study of silting in the reservoirs (Tilaiya and Maithon) of the Barakar Basin may throw some light on the development of landforms. Silting of reservoirs is a universal phenomenon, because no runoff is completely free from siltload.

Murthy and Ayengar (1956) estimated the probable life of the DVC reservoirs on the basis of the quantity of silt likely to be deposited in the reservoirs. They based their computations on observations of silt during the period 1949 to 1953 at Barhi (near Tilaiya) and Chivkunda (near Maithon). Working on certain assumptions they calculated the quantity of silt that would settle down annually in each reservoir as follows :

Table I

Tilaiya	404	Acre/feet
Maithon	684	,,
Total	1088	,,

Annual inflow of silt in Maithon was estimated as follows :-

Maithon

Suspended Silt	–	1486	Ac/ft.
Bed load 15 % of 1486	–	223	,,
Total		1709	,,

Again, in 1959, the Committee for Augmentation of Water Resources of Damodar Valley Corporation (A. W. R. C.) made an indepth study of the problem. The committee, taking into consideration the experiments carried out in the U. S. A. and Hirakud about vertical distribution of suspended sediment, were of the view that the actual annual silt deposit may be 30% or higher, Their estimates are given as hereunder :-

Table II

Reservoir	Estimated Annual Silt deposit (Ac/ft)		Annual Inflow of Silt (Ac/ft)	
	Murthy and Ayengar	A. W. R. C. (30% increase)	Murthy and Ayengar	A. W. R. C. (30% increase)
Tilaiya	404	525	—	—
Maithon	684	889	1709	2221

This estimate excludes the inflow of silt in the Khudia Catchment. If it is included, the annual inflow of silt in the Barakar Basin is estimated to about 2400 acre/ft.

On the basis of this estimate, we may draw some conclusions. The total area of the Barakar Basin is 7026.1 Km^2 (1736108 acres), and the average height of the Basin is 334 metres (1095'). So the total volume of the Basin is approximately estimated to be 1901038260 acre/ft. (1736108 acre × 1095 feet).

Now, we assume that the annual reduction of the Basin area is 2400 ac/ft. in all cases, neglecting the fact that gradual reduction in height will lead to the decreasing rate of erosion and thereby decreasing rate of siltingr It is so, because the reservoirs are, more or less, acting as local base-levels at the present time which have minimised the rate of erosion reducing the force of the absolute base-level (sea). Again, the rate of erosion must have been higher in the past due to comparatively high altitude and non-existene of the reservoirs.

Consequently if we assume it to be a normal estimate, the total reduction of the Basin up to the absolute base level will be reached in some 8 lakh years, provided that all things remain unchanged.

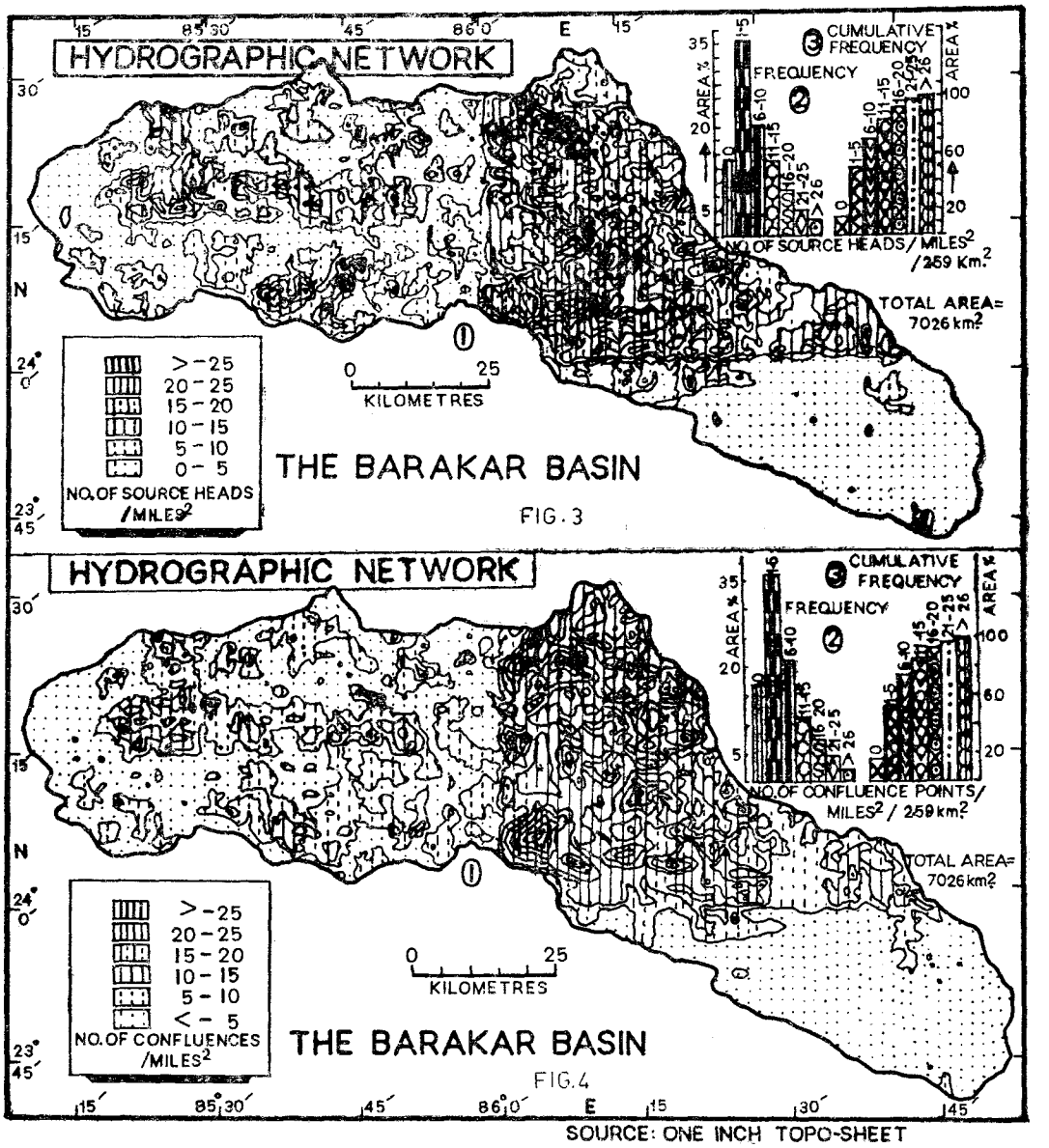
If we take the geomorphic interpretation of the Basin considering the surface as 'Stand-still' since the Pleistocene, the whole Basin should have reached the base level some one million years earlier. An alternative explanation would be that the Basin had attained almost double the height of the present surface during the last uplift. The alternative is against the assumptions of Dunn (1942), Ahmad (1958) and Singh (1969) who have worked in the region, and have delineated the major portions of the Basin as the part of the Lower Hazaribagh Plateau (305 metres), formed during the last upheaval of the Chotanagpur plateau. This average height of the Basin, estimated at 600-700 metres in the Pleistocene period, seems to be improbable.

Instead of assuming a height of 600-700m, before the initiation the cycle, one may think of a dynamic equilibrium which is time-independent. It may suggest that the annual inflow of silt cannot change the volume of the Barakarian landscape due to the preservation of the balance of energy. Hack claims that the rates of removal must be the same to preseve the overall balance of energy. Geologic history demonstrates that 'the degradational forces acting on the earth's surface are opposed by constructional forces." At present these deductions are subject to considerable doubt (Leopold, Wolman & Miller: 1969).

11) The Barakar and most of its tributaries have their sources in resistant granites and pass through the Gondwanas composed mainly and comparatively of less resistant rocks. In the resistant rock area, relief is high because there is high potential energy and consequently high kinetic energy. Although the surface of the soft rocks in the Gondwanas in the southeastern parts of the Basin is being lowered at the same rate as the resistant rock of the west or scarp-zone, the graded slopes are much gentler and the relief is low erin the soft-rock area.

Almost all the streams of the Barakar Basin pass through both hard and soft rocks. When they enter the area of less resistant rocks in the southeastern part they immediately adjust themselves. They develop comparatively broad plains specially on the extreme southeast, composed of the river alluvium and the residual soils derived from the weathering of bedrock.

The streams like Khudia and Pusai that pass through mainly soft rock, have a flatter gradient than those flowing on the resistant rocks. This is because the streams have adjusted to only the soft rocks and not to the resistant rocks. This goes in favour of an equilibrium Model that claims that large areas are mutually adjusted and the variation of form is mainly the result of rocks that yield to weathering in different ways. So, this characteristic of streams is an example



of equilibrium in the landscape.

12) The models of Davis and Penck-King are time-dependent, *i.e.*, everything depends on the stage in the cycle at which the landscape is observed and studied. Hack and others have argued that the only time when forms change is when there is a change of energy applied to the landscape-system.

The incised meanders and a number of genetic features like waterfalls, springs, gullies, tors, erosion surfaces are the different landforms of the Basin and suggest the tec-

tonic uplift of the Basin. This uplift has increased the energy applied to the landscape system. Again the energy has become less in the southeastern parts of the Basin where the land has gradually been reduced in height. So, the preservation of the balance of energy may account for different relief features.

Conclusion

This analysis leads to the conclusion that the Barakar Basin shows neither slope reduction of Davis nor slope retreat of Penck – King in all aspects. Both these phenomena are partially observed. But the explanation of these phenomena does not follow their interpretation. They are most probably related to the state of dynamic equilibrium envisaged by John T. Hack. Examples of dynamic equilibrium in the Barakarian landscape include the composite slope forms shifting divides with varying degree of slopes on their sides, high density of hydrographic network and drainage texture in the areas of moderate gradient, and increasing and decreasing eroding capacity at the same stage in the cycle. An analysis of silting in the reservoirs, gullies, and many other features discussed above, suggest that the features observed in the Barakarian landscape are mostly in a state of dynamic equilibrium. The major changes occurred during the Tertiary uplift, and will occur after an initiation of a new set sf enviromental conditions (tectonic, climatic or any other else). It lends support to the Hack Model in a modified form because it does accept the changes in landforms keeping the pace with balance in energy. Hack asserts that after a period of adjustment to new environmental conditions, a condition of dynamic equilibrinm is arrived at.

Now a question arises as to how it is noncyclic. The period between an environmental condition that has occurred, and a new environmental condition expected to take place is a time which must have development phases, may be of minor changes. Naturally it carries the implication of a cyclic order, though it may differ in technical jargon that of Davis (youth, mature and old) or Penck (*aufsteigende*, *gleichformige* and *absteigende*). But the term *new environmental* condition, is suggestive of an initial surface (Davis) or *primarrumpf* (Penck). Similarly, before the commencement of a new environmental condition in the Hack model, the stage is *endrumpf* (Penck) or the Davisian erosion surface at the end of the cycle. It may be peneplain – like or like *fastebene* (Penck). Hack did not relate peneplain to the erosional cycle, but he asserts that they are representatives of denuded surfaces formed in a certain environmental condition, *e. g.*, the surface of homogeneous structure, drainage and slope. So it is a difference in terminology rather than in concept. Thus in spite of the persistence and rejection of the cyclic concept, it is so simple, natural and so directly observable that it is probably impossible to give up the cyclic concept.

Thus, if the features are best explained by the dynamic equilibrium, they must be correlated with the stages of a cyclic order.

Bretz (1962) and Holmes (1964) have strongly contested the view of Hack, but our study area lends qualifying support to the view of Hack, though in a modified form.

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