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SOME OBSERVATIONS ON THE DENUDATIONAL SURFACES OF THE UPPER GODAVARI AND KRISHNA BASINS (MAHARASHTRA)

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ABSTRACT : The problem of the probable mode of the evolution of the denudational surfaces of the Upper Godavari and Upper Krishna has been examined on the basis of recent geophysical, palaeoclimatological and palaeogeomorphological data. The present exercise attempts to evaluate the possible factors and sources of adjustment in the geomorphic regimes. The investigations demonstrate that the available techniques and evidences are inadequate to accurately establish the denudation chronology of the area under review, and therefore, it will be premature to arrive at any definite conclusion.

GENERAL

Evidences of modern geomorphic processes of erosion, transportation and deposition are abundant in the Upland Maharashtra and there is a need to consider these evidences for any interpretation of the historical evolution of the landscape. Transportational and depositional processes are readily visualized because landorm units representative of these classes are seen being formed or modified in the present environment. Other basin forms like denudational surfaces, valley and hillslopes, pediments, etc., are seen only indirectly as fragmentary remnants of the record of sübaerially sculptured and formed landscapes of past ages.

Different researchers pursuing a variety of interests have found a common ground in establishment of a sequence of the Trappean landscape evolution (Dikshit, 1970, Subramanyam, 1981, Umarjikar, 1984, Jog, 1985, Kale and Rajaguru, 1986). However, due to patchy and discontinuous evidences it has not been possible to precisely establish the chronology and mode of landscape evolution. The situation is further impaired because the majority of the Trappean landforms are erosional and there are no fossiliferous sediments of Tertiary and early Quaternary period. Even the most powerful available tools, that of palaeomagnatic and radiometric dating have remained unsuccessful. Thus, the inter-basin correlation of landforms and their genesis, beset by many problems, is ambigious and doubtful.

In view of the fragmentary evidences, the present communication attempts to propose and evaluate the different possibilities of landscape evolution, by employing morphometric, geophysical and palaeogeographical data.

MORPHOSTRATIGRAPHY OF THE LANDSCAPE

The area under investigation includes the Upper Godavari and Upper Krishna (including Bhima) basins of Western Maharashtra. The area has an average relief of about 700± 100 m ASL, and the highest peaks seldom exceed 1460 m ASL. Measurements of K/Ar whole age of the Deccan Traps occuring at 1400 m ASL has indicated an age of + 60 m Yrs (Molnar and Francheteau, 1975). The drainage network and the landscape is thus, not older than sixty million years and is of post-Cretaceous period.

Field and map analyses, supported by LANDSAT studies, demonstrate the presence of succession of gently sloping denudational surfaces, normally occupying the divides and sometimes occupied by Tertiary laterites (+ 850 m ASL). Below this occur the vallyside slopes, linking the high-level surfaces with the lower surfaces or present valley floors and pediments. Resting on the pediments and valley-floors are colluvial deposits interfingured with vertisols. Along the rivers, the stratigraphy exhibits the presence of yellow brown on reddish brown silt capping indurated on unconsolidated pebbly-cobbly gravel.

The Denudational Surfaces

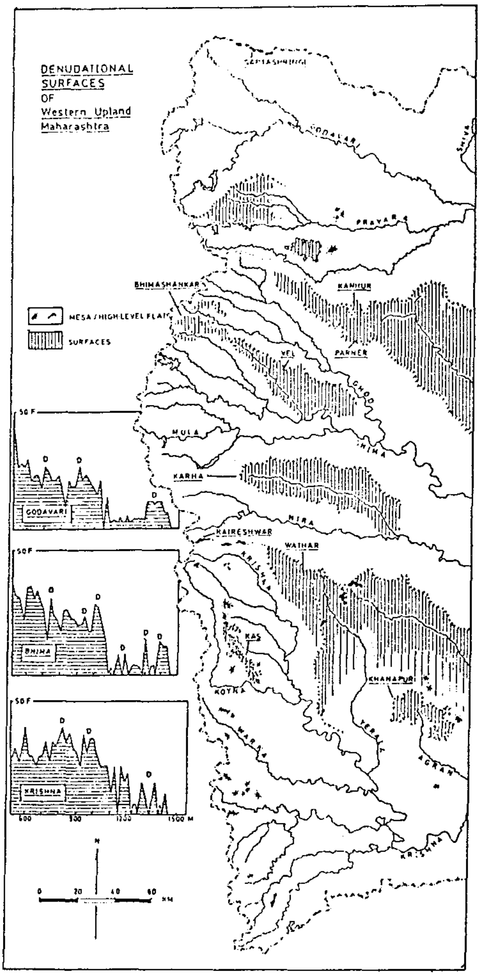
A lack of clearly defined term for surfaces has led to many complications in the Indian literature. Since late sixties the tendency is to use the term planation surfaces for a surface formed under conditions of prolonged tectonic or climatic stability, by exogenetic processes. It is, however, desirable to have a non-committal term for describing the geographical surfaces, whether it be erosional surface, peneplain (Davis), pediplain (King), panplain (Crickmay) or exhumed plain (Wayland). Therefore, in the present account a non-committal term "denudational surfaces" has been used to indicate geographical surfaces developed under subaerial conditions (Melhovnand Edgar, 1981).

One branch of geomorphometry has developed with the objective of identifying denudational surfaces, to provide a quantitative basis for the denudation chronology of an area. This requires measurement and analysis of height of surfaces. Of all the traditional methods, the altimetric analysis provides a sound quantitative summary of an area (Goudie, 1983). Accordingly, elevation data from topographical maps have been employed to define the denudational surfaces in the review area. Application of the method to the Upper Godavari and Krishna basins has facilitated the identification of prominent levels (Fig. 1). Dikshit (1970) described multiple surfaces in the Bhima basin (and adjoining areas) recognizing four surfaces occurring at 625 m, 700 m, 800 m and 900 m ASL. Subramanyan (1981), Umarjikar (1984) and Jog (1985) have identified two more levels, one at 1035 m and another at 1400 m ASL. The present analysis of the entire Western Upland region provides additional information about the Krishna and Godavari basins, and supports the deductions of the earlier workers (Table 1).

Table 1

Denudational Surfaces		Elevation in Metres ASL
A) Godavari Basin		
1)	Saptashringi	C. 1350 ± 100
2)	Krishna	C. 1000 ± 100
3)	Kanhur	C. 910 ± 80
4)	Balaghat	C. 710 ± 20
B) Bhima Basin		
1)	Raireshwar - Raigad	C. 1290 ± 1400
2)	Bhima Shankar	C. 1010 ± 50
3)	Kanhur	C. 910 ± 80
4)	Parner - Karha - Vel	C. 750 ± 50
5)	Nagar	C. 670 ± 50
C) Krishna Basin		
1)	Panchagani-Mahabaleshwar	C. 1200 to 1430
2)	Kas	C. 950 ± 70
3)	Khanapur	C. 830 ± 30

All the identified surfaces are associated with primary or secondary water-divides occurring between various west-east flowing rivers (Fig. 1). In brief most of these denudational surfaces are irregular as a result of dissection. Some of the surfaces are occupied by semi-arid and highly seasonal rivers like Vel, Sina, Karha, Agran, Yerala etc. These rivers originate in the semi-arid region and therefore, it is likely, that they have been very ineffective and inefficient in the recent geological past. Owing to their location in the high energy environment of the Western Ghats, most of the + 1200 m ASL surface are fairly dissected and discontinuous.



THE DENUDATION CHRONOLOGY

That the denudational surfaces are not due to lithological variation only is quite clear, because the rocks exposed in the valleys and on the surfaces are not very different in type and characteristics. Further, because the surfaces are progressively sloping towards the east or south-east (downstream) and because these surfaces are marked by isolated inselberg – like hills, the possibility of their being completely structural is remote. Other evidences supporting this hypothesis of their subaerial development are as follows:

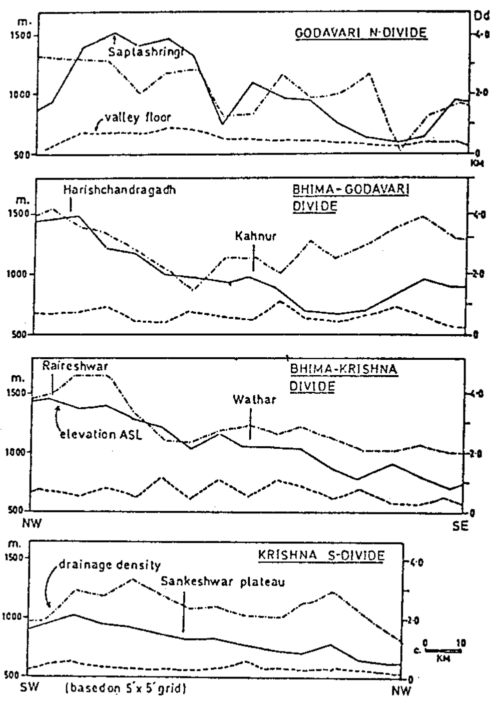
a) Comparison of the decrease in altitude over the surfaces with that of the valley floors, shows a good agreement between the two.

b) The orientation of these surfaces also exhibits a good correspondence with the regional orientation of the drainage network.

c) The semi-arid streams like Vel, Sina and Karha occupying the eastern surfaces do not cross a noteworthy inflection point, before descending down to the main valley floors.

d) Detailed study of the spatial distribution of slopes, drainage density and drainage frequency shows that relief, slope and dissection values on the major divides decrease, and drainage density and stream frequency values increase towards the east (Fig. 2). Whereas the high values of drainage density are associated with the high energy environment of the west, the high density values on the eastern parts are suggestive of an advanced stage of drainage network development (late elaboration to elongation). This observation combined with the gradual decrease in the divide elevation implies a normal allometric growth of the drainage and landforms.

Thus, it is quite evident that the subaerial processes have played an important role in the development of these surfaces. In fact, the whole landscape of the basins has the appearance of being polycyclic (Spate and Loarmonth, 1967). West and Coubey (1964) and Dikshit (1970) are of the opinion that these flat surfaces have evolved as a result of pediplanation. This appears to be plausible. The secret of landscape evolution lies in the mode of development of hillslopes (King, 1953). There is little argument about the retreat of valley slopes in the semi-arid and sub-humid regions for mesas, inselberg-like hills and the box-shaped valleys permit no other explanation. Development of V-shaped cross-section might have started in the initial period, but the valley widening, after the streams had attained normal gradients, appears to have occurred due to the recession of valley walls, without reference to the lateral cutting of the rivers. Gravity slopes (scarps) and wash slopes or pediments (Meyerhoff, 1981) characterize the present landscape. Most of the present surfaces reveal gravity slopes along their margins (Fig. 1). These accompanied by stumps of inselberg, extensive pediments and box-shaped valleys amply support the hypothesis of pedimentation in this area. Moreover, in view of the present under-fit nature of the rivers, it is unlikely that these surfaces have been formed due to lateral planation by the rivers. One may therefore, infer that most of the denudational surfaces have developed as a result of scarp retreat (Dikshit, 1970) and are in fact "denudational pediplain surfaces." The geomorphic processes responsible for + 1000 m ASL, surfaces however, appear to be different. In the absence of any other evidence these surfaces can be attributed to the erosional cycles, as suggested by Dikshit (1970).



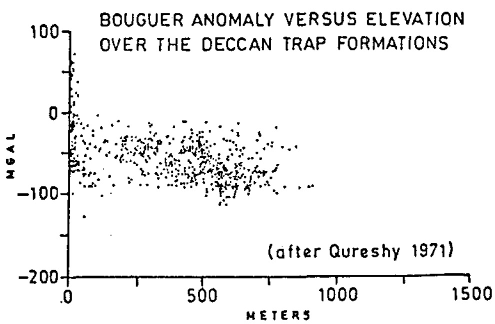
If one accepts that these surfaces are denudational pediplains, there are many problems with respect to dating. Ollier (1981) is of the opinion that pediplains can be created at two or more levels at the same time and thus are undoubtedly diachronic, and it is likely that these surfaces are even extending today. In such circumstances it is hazardous to establish a chronological sequence of the landscape evolution. Schmidth et al. (1983) have palaeo-magnatically dated the Panchagani laterites to the early Tertiary. One can therefore, only infer that the highest surfaces (+ 1200 m ASL) represent some cycle of early Palaeogene, while the lower surfaces were initiated during some still stand of the post-Palaeogene period.

PALAEOGEOGRAPHY

The foregoing discussion supports the proposition that denudation surfaces can be identified in the study area. It is generally believed that surface development takes place in response to an adjustment in geomorphic regimes resulting from three sources viz. tectonic, eustatic and climatic changes. Although, hypothesis of base-level change provides an easy source, in case of Upland basins it is difficult to establish. As the sea (ultimate base-level) is more than a thousand km away, the correlation between the eustatic changes and the eposides of denudation cannot be established without errors. Nevertheless, the magnitude of its impact is likely to be reduced remarkably, and it is possible that other factor may attain greater significance in the landscape development.

i) **Palaeotectonics**

The role of tectonics continues to be a subject of debate, because it is difficult to accurately date the episodes of orogeny and quescence. Athavale et al. (1972) have established uplift by about 325' m in the middle Godavari, during the post-Trap extrusion period. Similarly, epeiorogenic or cymatogenic movements have been infered by Kailasam (1979), Powar (1980) and Qureshy (1982) on the basis of geological, geophysical and photogeological studies. However, these studies have failed to arrive at the exact periods of orogency. An analysis of Bouguer anomaly vis-a-vis elevation over the Deccan Traps (Fig. 3), carried out by Qureshy (1971), shows that Bouguer anomaly values decrease with an increasing elevation. The correlation between the two parameters has been interpreted in terms of epeirogenic or cymatogenic movements during the Cenozoic and not in the recent times. Powar (1980) is of the view that the structural fabric of the Deccan Volcanic Province is largely the result of vertical movements of cymatogenic type, which are probably still continuing. The observation therefore, suggests that some of the Neogene cycles could have been initiated by the epeirogenic or cymatogenic movements. Ollier and Powar (1985) have attributed the broad valley in the Indrayani head-waters to warping, subsequent to the formation of the valley by an ancestral Indrayani.



The basins of Upland thus, might have been affected by cymatogenic movements and it is possible that tectonic processes could have operated during the post-Trap formation period.

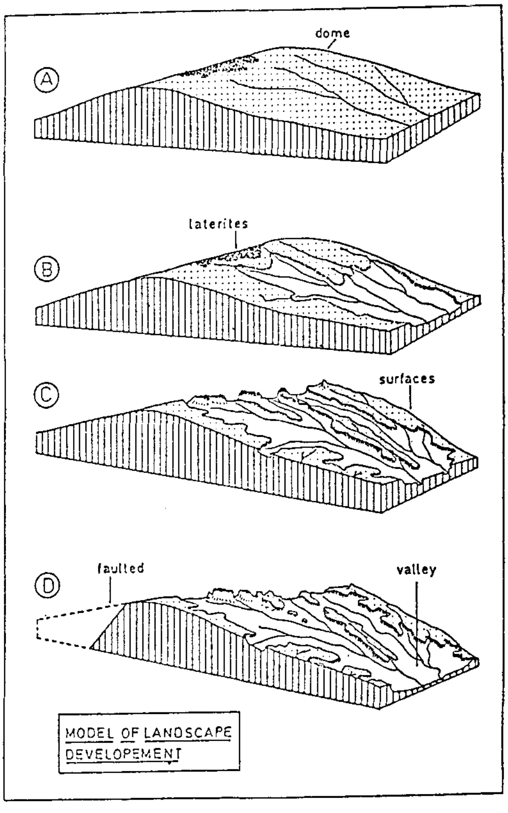
ii) **Palaeoclimatology**

Climatic changes increase or decrease the rates of weathering and erosion and can have a significant influence on the landscape. In the Upland basins, although there are many evidences of climatic changes during late-Quaternary, the Neogene climatic history is almost obscure. Nevertheless, fossil evidences from central India point to wetter and humid climate in the late Cretaceous and Early to Mid-Tertiary (Meher Homji, 1977). Palaeocene formations of the Peninsular India suggest the prevalence of warm and humid climate. Furthermore, Mio-Pliocene sediments are characterized by a prolific tropical and subtropical flora (Anil Kumar, 1986). It is clear from these observations that the study area had favourable climate for deep weathering and erosion and for the development of surfaces from the Palaeocene.

A latitudinal drift curve constructed on the basis of palaeomagnetic data from Cambrian through Quaternary shows that durings its sojourn the Gondwanic India entered Koppen's 'A' zone between 65 and 53 m yrs, (Anil Kumar, 1986, Kale, 1983). The accelerated northward drift into the tropical zone propelled Gondwanic India quite rapidly into zone favourable for laterite formation, deep weathering and erosion. Examination of the palaeomagnetic dates of laterites and their correlation with palaeo-latitudinal locations reveals on excellent fit (Kale, 1983, Anil Kumar, 1986). This suggests that valley development and planation processes must have extended over the entire study area. The subsequent northward drift, lead to location in zone of drier conditions and perhaps initiated pediplanation processes, giving rise to box-shaped valleys and stepped landscape.

iii) **Palaeo-Geomorphology**

Detailed morphometric analysis of the laterites and photogeological interpretation by Sahasrabudhe and Rajaguru (in press) suggest the possibility of a low domal structure in the study area during the post-Trap extrusion period or during Palaeogena period. A similar ridge has been infered by Jog and Karlekar (1983) for the Upland region. It, therefore, appears that the differences in the levels of the denudational surfaces is due to the development of basins in the intermediate zone (e.g., Vel, Karha) and in the eastern margins (e.g. Sina) of the domal structure. Subsequent dissection of the dome might have given a stepped appearance to the landscape (Fig. 4). This hypothesis, however, needs to be tested and supported by additional evidences before arriving at any conclusion.



Denudational surfaces, like other landforms are the expression of the interplay between external and internal forces. These forces vary in rate and intensity over space and time; and the interaction is dynamic. The rate of vertical and lateral erosion may be distinctive because of inequality of forces. River basins with large catchment area and higher inputs will have greater potential and total energy. The Upland basins appear to be a good example of such unequal forces at work, other things being the same. Rivers like Bhima, Godavari, Indrayani, Ghod, Kukadi, Krishna, Koyna, Warna etc. have their sources in the high rainfall zone of the Western Ghats and thus have greater total energy. As against this, rivers like Sina, Vel, Karha, Yerala and Agran have their sources in the semi-arid tract. Obviously, the available total energy would be less than the former rivers. The latter rivers, consequently, will have lower rates of vertical erosion and valley floor lowering, than the earlier ones. The semi-arid basins will, therefore, gradually rise above the general landscape, giving an appearance of high-level flats. The hypothesis assumes that this situation has prevailed since early Neogene times and there has not been a major catastrope that disturbed these unequal forces at work. The inequality hypothesis, however, fails to explain the occurrence of the Bhimashankar surface. It seems, therefore, that more than one factors have sculuptared and moulded the landscape since Palaeogene times.

OVERVIEW AND CONCLUSION

The extensive flats and surfaces occupied by middle order streams convey a subaerial origin. Climatic changes and tectonic movements during the drift and the palaeo-topography combined with the inequalities of river energy have contributed in the development and preservation of the denudational surfaces of the study area. Although, a passive structural control on the landscape cannot be ruled out completely, there is little possibility of a strong active control of structure on the genesis of these denudational surfaces. The valley flanks of many rivers reveal starth terraces at different levels. These are undoubtedly related to the flow characteristics of the Deccan Traps. But the geomorphic data of the major surfaces certainly implies a sub-aerial origin.

In the absence of sedimentological evidences, reconstruction of the mode and chronology of denudation will always remain ambigious and speculative. Nevertheless, there is little doubt that the existence of multiple denudational surfaces indicates a succession of geomorphic events. However, whether these surfaces represent the erosional cycles or simply some geomorphic accident is impossible to decipher. Ollier (1981) is of the view that,to find Davision cycles one must look on a longer-scale to Mesozoic and Cenozoic times. Since the present landscape is of Post-Mesozoic period, one has to establish the cycles of the early-late Cenozic period. Cyclical landscape formation might have taken places in the study area during the Palaeogene period, but the situation is complicated by the drift, tectonic movements, and climatic changes.

The present exercise thus, fully demonstrates that it is not easy to reconstruct the denudation chronology of the study area, because the landforms have responded to numerous changes in the geo-environment during its evolution and there are no apparently detectable evidences of these disturbances. In view of the inadequacies and limitations in the available methodology, there is a need to evolve new techniques to deciphere the denudation chronology of western Upland region of the Deccan Province.

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