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Denudational Processes and Landform Characteristics in the Laterites of Birbhum District, West Bengal, India

V. C. Jha

Abstract

Laterite occupies large areas in the western and south-western parts of Birbhum District, West Bengal, India. This tract lies immediately to the east of Rajmahal Trap country of Santhal Parganas in Jharkhand State, India, and it is very likely that thick masses of laterite, formerly developed in association with trap rocks in the latter area, were subsequently denuded and redeposited in parts of Birbhum District in Pliocene-Pleistocene times.

A study of various profiles in gullies and valley walls in streams reveals that the laterites of Birbhum District are secondary in origin. Reconstruction of the deposited lateritic material has resulted in the development of only partly mature profile. The various horizon of the profile, namely pisolitic, massive, concretionary and pallid zone with kaolinitic fines at the base, are still imperfectly developed and show a lot of disturbances.

The massive laterite with a thin pisolitic layer at the top occupies the highest parts of the lateritic plateaus. This original surface has subsequently broken by springs and gullies, weaving their way from two trunk streams, the Ajai and the Kopai, towards the interior of the lateritic plateaus. Occurrence of the two watertables in the laterite, one perched above the massive laterite and the other lying above the kaolinitic horizon, has not only helped in spring development but also in the break-up of lateritic plateaus into ridges and flat-bottom valleys. The break-up of the lateritic plateaus has also led to the disappearance of the water reservoir associated with the perched water-table. Consequently, forests which occupied the lateritic plateaus have disappeared. The present programme of afforestation is not to succeed, particularly on the top of laterite ridges, whose perched water table is now seasonal only.

This paper attempts to evaluate the intensities of denudantional processes and the resulting geomorphic features in Birbhum District on the basis of the satellite imageries. In fact the landform characteristics now show evidences of desertification in the area. An attempt has also been made to trace out the genesis of morphology of the characteristic features.

Introduction

The geomorphic processes encompasses all those physical and chemical changes which affect the modification of earth's surficial form (Thornbury, 1954, p. 34). Although, the existing morphology of the landscape is the result of endogenetic and exogenetic processes; the morphoclimatic mechanisms in particular have significantly changed the landscape in terms of spatial and temporal scales. Crucial in this regard are the denudational processes which are very effective particularly in the tropical and subtropical regions where the landforms characteristics are the best indicator in studying the rate of denudation. The thick development of laterites and deposition of alluvium over the fresh rock particularly in

northern and eastern India have given rise to a high rate of denudation. Though, the role of rivers and the processes of leaching, percolation and infiltration are also significant in changing the landscape in varied spatial and temporal scales.

Amount of runoff particularly the excessive runoff has resulted in pronounced changes in the landforms characteristics. The process of ecological/biogeographical and geomorphological change in response to human and natural forces across varied spatial and temporal scales are the main concerns of the landscape dynamics. Denudational processes are not only changing the landform characteristics but also degrading the quality of land resulting in the process of desertification. This phenomenon is affecting the world's landscape at large scale.

In fact, the denudational processes play a very important role in the morphogenetic system of the earth's surface which makes a modification in landform characteristics. The landform characteristic depends upon the nature and intensity of the denudation processes. The denudation process is controlled mainly by relief, drainage, slope geology, tectonics, climate, vegetation and soil.

The rate of denudation varies from local level to global level; the global rates have been estimated by Fournier, 1960. According to this estimate, the region of eastern India particularly the Birbhum District, is characterized by 1000-2000 tonnes/sq.km/ year. But this rate varies from landform to landform at the local level developed in due course of time. The loss of top soil layer and vegetation cover are the means of estimation of denudation rates.

A good period for monitoring the landscape change due to denudational processes is ten years. The best period means the time required for the landform to get the phase of adjustment and the phase of readjustment in the lateritic terrain where the lateritic landforms develop. There are, however, factors which disturb the denudational processes and accelerate the mechanisms such as man-induced forces in the lateritic terrain. The study of landforms characteristics is also useful in finding out the stability of the landforms.

Study Area

The District of Birbhum (23°32'30"N - 24°35'00"N; 87°05'25"E - 88°01'40"E) forms a part of the Lower Ganga Plain. It has an area of 4514.4km2 and is bounded on the west by the Santhal Parganas (Jarkhand State) and in the east and south by the districts of Murshidabad and Burdwan (West Bengal) respectively. The region is locally known as Rarh Land.

Physical Background of the Study Area

The average elevation of the district is about 80 m A.S.L. Its topography in the western part is undulating and rugged with a few isolated hillocks (extension of the Rajmahal Highlands) distinguishing it from the otherwise featureless plain in the east. With the general slope towards south east, the drainage of the area carried by Ajay, Kopai, Mor, Bakreshwar, Mayurakshi, Dwarka, Kandur, Brahmni, Tripta, Pagla, and Bansoli rivers all tributaries of the south flowing Bhagirathi river.

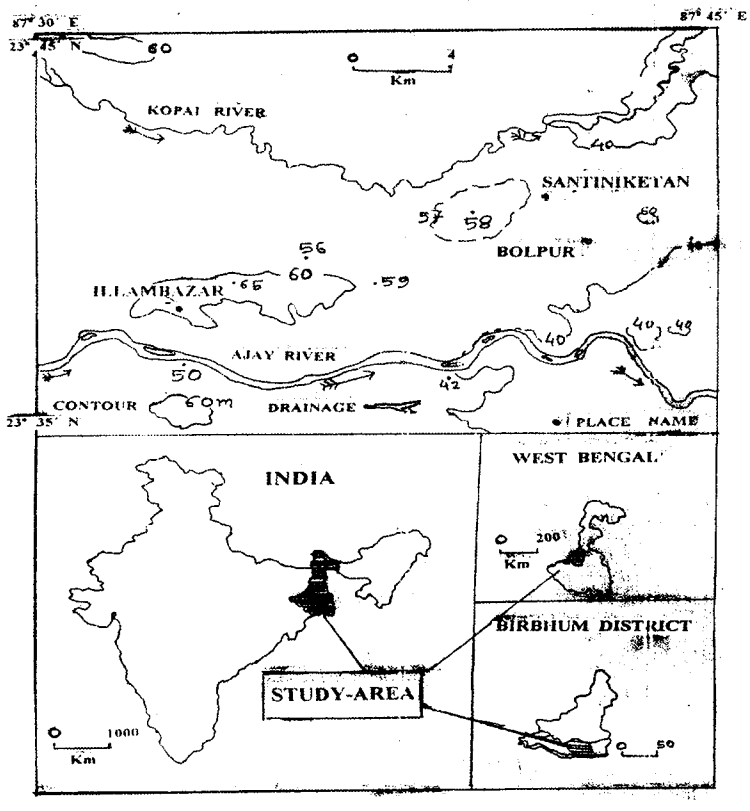


Fig.1

Geologically, the study area is composed of the following six geological formations

1. Recent Alluvium (Khadar),
2. Older Alluvium (Bangar),
3. Laterite,
4. Rajmahal Trap rocks,
5. Gondwana deposits, and
6. Archean Gneiss.

The archean gneiss is mainly found in Suri sub-division. Dubrajpur in particular, has big blocks of granite and gneiss. The Gondwana of Carboniferous to Permian age cover small area along the Ajai river in the western part comprising sandstone, snale, and coal seams. The basaltic lava of early Cretaceous age (Rajmahal Trap) occur in Rampurhat and Nalhati Police Stations in the extreme western part. Laterite occupies large areas in the western and south-western parts, particularly in Bolpur, Illambazar, Suri, Rajnagar and Mohammad Bazar Police Stations. The older alluvium (Bangar) of Pleistocene age, occurring in the northern and south-eastern parts of the study area, is now being dissected by stream incisions. Deposition of recent alluvium (khaddar) is noted along the major streams as well as in the gullies in the study area.

Laterites of Birbhum District

Laterite play an important role in the evolution of landforms particularly in the semi arid and sub-humid parts of the tropical zone. Large areas of Bolpur, Dubrajpur, Suri, Rampurhat, and Mahammadbazar Police station of Birbhum District are occupied by laterite. This tract lies immediately to the east of Rajmahal trap country of Santhal Parganas, Jharkhand State, India. It appears that primary laterites, originally formed in Santhal Parganas, were eroded and redeposited in the adjoining parts of the Birbhum District, probably in Pliocene and Pleistocene times. Subsequently, reconsolidation of the deposited lateritic material has resulted in the development of only a partly mature profile. The various horizons of this profile, namely pisolitic, massive, concretionary, columnar and pallid zone with kaolinitic material at the base are still imperfectly developed and show a lot of disturbances.

Several types of laterite, in various stages of their development or decay, occur in the north-western and south-western parts of Birbhum District These are as follows :

1. Pisolitic Laterite : The pisolitic laterite occurs above massive laterite zone. It forms the surface of the highest ridges near Ratanpalli, Shyambati, Baradhi, Taltore and Sriniketan. The pisolitic layer is 4.5m to 8 m thick in Bolpur Police Station. The removal of pisolitics from the highest part of the laterite plateau and ridges is still going on under the processes of sheet-flow and sheet wash along the spring and gully heads.

2. Massive Laterite : The massive laterite, with thin pisolitic layer at the top, occupies the highest part of the laterite plateaus. The massive laterite surface is found near Sriniketan and Ratanpalli in Bolpur Police Station. Breaks in slope in laterite plateaus have been noted 1.5 km north of Ratanpalli where the top surface belongs to massive laterite and pisolitic and nodular laterites.

3. Concretionary Laterite : The concretionary laterites develops below the massive laterite. It is exposed in the walls of gullies and springs at Ballapur and Taltore. Its occurrence has been also noted in places where the pisolitic and massive laterite horizons have been either removed by erosion or weathered to form nodules of various sizes.

4. Columnar laterite : Stalactite like columnar masses of laterite have been observed in vertical headwalls of springs and along the banks of the Ajai and the Kopai rivers. The columnar structure seems to have been formed due to rapid movement of water through the laterite profile on river banks due to fluctuations in the river level may also have caused this structure.

5. Reconsolidated Laterite : Occurrence of reconsolidated laterite of Pliocene-Pleistocene times is noted near Ballabhpur lateritic plateaus. Thick mass of primary laterites, removed from Rajmahal trap country have been redeposited in this area and have developed a peculiar gully characteristics with micro-morphological variations in the materials of the gully beds and gully valley walls.

6. Recent and Pleistocene Laterites:

Ground water laterite in the juvenile stage of development is observed in laterite sheet wash redeposited in the Taltore wide flats and in moderately well drained parts of the wide flat bottom valleys in Amar Kutir and Surul areas of the Bolpur Police Station.

Denudational Processes and Resultant Landforms

The denudational processes have influenced the evolution of laterite landforms in the study-area in several ways. For example- the original surface of the Birbhum Lateritic Plateau forms the erosion surface at 60 m - 68 m elevation above mean sea level. The topographical sheet published by Survey of India in 1928 depicts that throughout the study area this laterite plateau exists at this height, while base level of rivers in this region was between 40m-42m. the latest topographical sheet published in 1972 shows the plateau height at 58m-65m and the river beds between 39.5m-41m. on the basis of field observation in 2003 it is also noted that the upland level is between 57.5m-64m and the river beds between 39m-40.5m particularly in the south-western part of the Birbhum District where the two trunk streams, the Ajai and the Kopai rivers play a vital role in denuding the region. The denudational processes in this area have been operating by weathering, mass

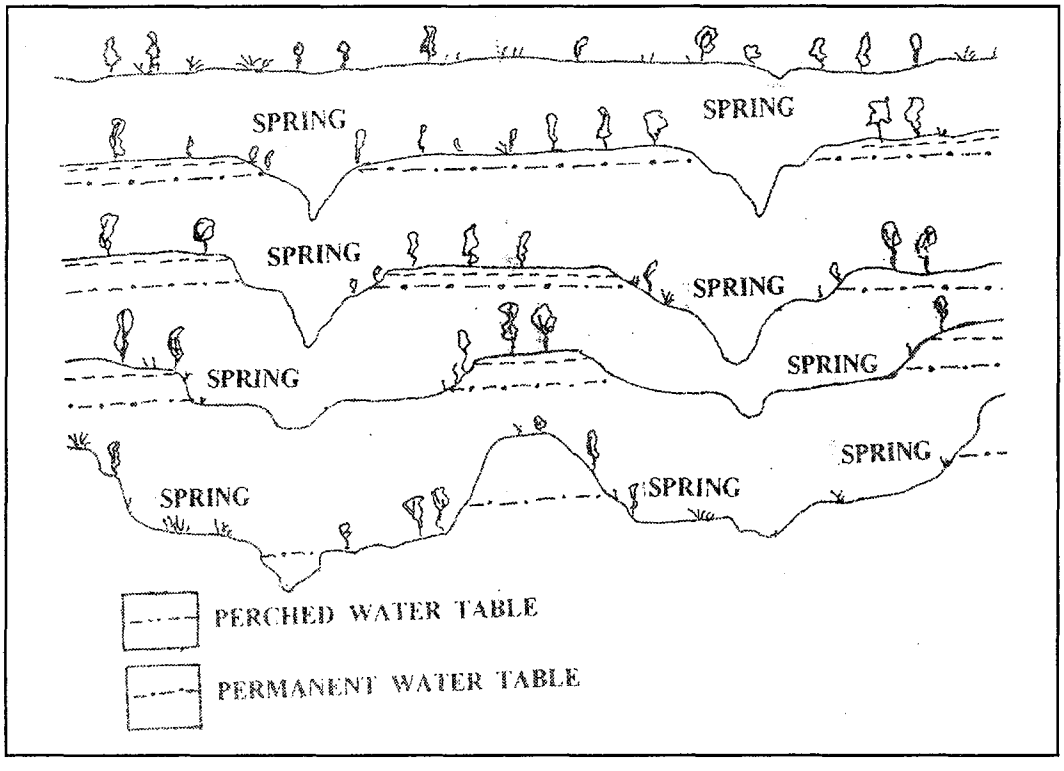


Fig. 2

Stages of Geomorphic Development of Lateritic Relief in Birbhum District

movement and erosional processes at varied spatial and temporal scales which have been lowering the strength, eroding the surface materials and ultimately breaking-up the lateritic plateau. The role of the base level of the two trunk rivers in breaking the initial surface in this part of the study area is very significant in this denudational processes.

Figure 2 shows the stages in the break-up and retreat of the consolidated laterite of Ballabhpur. Occurrences of two water tables in the study area (perched and permanent water) contribute significantly in the operation of the denudational mechanisms and in the development of resultant landforms. The other processes such as infiltration, leaching and percolation also play a vital role in denuding the region. The discharge of water and sediments due to overland flow and the interior movement of water ultimately reaches the Ajai river and Kopai river. The occurrences of two water tables in this area, one situated above the massive laterite and the other above the kaolinitic horizon at the base of the pallid zone, has been noted. The former is seasonal and the later permanent in nature. The process of spring sapping, guided by the permanent water table has led to break up of the lateritic plateaus and subsequent development of wide flat bottom valleys (Photo Plate I). The formation of gully is accelerated by denudational processes.

Table 1 shows the cross profile details of the channel widening and deepening over a period of two decades surveyed in 1986,

Table 1

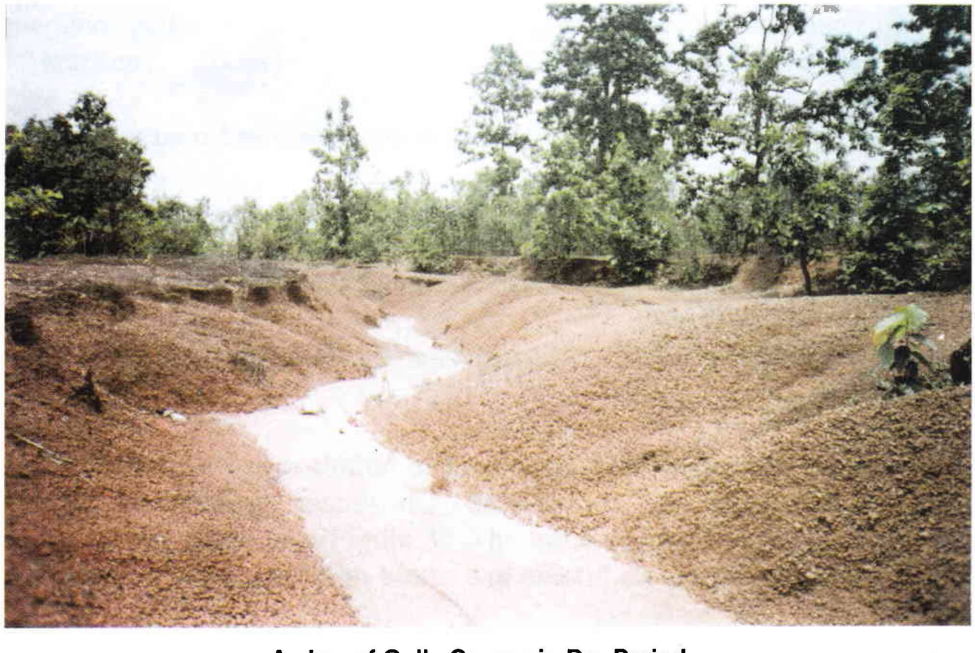
Shape, Size and Depth of Gullies in the Ballabhpur Lateritic Patch in 1986, 1996 and 2003

A Main Gully							
Location	**Depth (in metre)**			**Width (in metre)**			**Remarks**
	1986	1996	2003	1986	1996	2003	
Near Source of Gully	7.60	9.10	9.80	25.3	31.70	37.80	Wide 'V' shaped valley
Near Mouth of Gully	6.00	6.70	7.00	43.50	46.80	49.60	Super Wide 'V' shaped valley
B Gully developed on main gully left bank near source							
Location	**Depth (in metre)**			**Width (in metre)**			**Remarks**
	1986	1996	2003	1986	1996	2003	
Near Source of Gully	2.50	5.80	8.75	0.85	1.40	1.88	It forms narrow 'V' shaped and 'I' shaped valleys (Gorge type)
Near Mouth of Gully	2.00	5.20	9.68	1.15	1.80	2.25	
Source: Field Survey, 1986, 1996 and 2003.							

A view of Lateritic Plateau in Ballabhpur Lateritic Patch

A view of Gully Forming 'I' Shaped (Gorge Type) Feature in Ballabhpur Area

A view of Round Shaped Isolated Hills in Bunch looks like Basket of Eggs near Amar Kutir Area



**A view of Gully Course in Dry Period.
Variation in the Bed and the Valley Walls Materials is well marked**

1996 and 2003. The gully width was changing at a more or less constant rate. The main gully forms a super wide to wide 'V' shaped valley while the gully developed on the main gully left bank reveals the narrow 'V' shaped to 'I' shaped (gorge type) valleys (Photo Plate II). It has also been noted that several rills and gullies of different shapes and sizes and depths have been formed on the flat topped massive laterite surfaces in the area within two decades. The initial laterite surface has broken up and resulted in the development of characteristic laterite landforms. The processes of subsidence and slumping are very much in evidence in the lateritic terrain. Two lateritic patches very important in the study area from the point of view of denudational processes. These are Illambazar patch and the Bolpur patch. Since 1926-27, these two patches experienced lowering of the relief and development of a particular lateritic landforms (major and minor). The Bolpur patch is characterized by a lower relief than that of Illambazar. It indicates that rate of denudational processes is higher in Bolpur area due to the lateritic surface and the base level of Kopai and Ajai near the plateau, while in the case of Illambazar the base level of Ajai is nearer but the Kopai base level is quite away from the Illambazar lateritic plateau.

The two trunk streams in the southern part of the Birbhum District (Ajai and Kopai) formed the base level for the initiation of springs and gullies and their advancement towards the interior of the lateritic plateaus. In the beginning the springs and gullies are steep sided but with their advance towards the interior of lateritic plateaus the valley walls down-stream are affected by slumping and consequently the slopes characterizing the lateritic ridges have become rounded.

The initial surface is characterized by flat topped hard surface which is being broken-up by the development of rills and gullies of various types such as pointed shape, notched, circular and digitate gully heads. The longitudinal profiles of the gully shows however the existence of caves, vertical walls, armchair and inclined heads. Particularly, the caves play a vital role in denuding the surface where the slumping and subsidence materials are washed out by the stream. The development of rills and gullies is initiated by the intensity of processes of vertical and headward erosion in the area. The shape and size of the gully depends upon the rate of downward and headward denudational processes. It is evident that these processes have led to the development of 'V' and 'I' shaped gullies in the Ballabhpur laterite patch. Particular mention may be made of information of the round shaped low elevated isolated hills in bunch form which look like a basket of eggs (Photo Plate III). It is mainly found near Amar Kutir 5 km north-west of Santiniketan. This type of landform is characterized by 1.0m to 2.0m relative relief on 56m-57m absolute relief with 2m to 6m diameter of the rounded shaped, low elevated isolated hills. The geomorphic evolution of this type of landforms is mainly influence/caused by the denudational processes.

The morphological appearance of the landform is a good indicator in assessing the intensity of the morphoclimatic mechanism operating in the study area. The intensity of rain-wash action and soil creeping processes have been supported by the high rate of

weathering in the area probably since late Pleistocene times. The top surface had been broken and eroded resulting in the elongated ridges of lower elevation and rounded crests. These were further influenced by rain wash action and soil creeping mechanisms and all these have led to the development of a very typical geomorphic feature. A large area of the Ballabhpur patch near the Amar Kutir is characterized by this landform. Field evidences indicate that the slope morphology of ridges and rounded shaped low elevated isolated hills in the study area is the result of weathering, rain-wash action and soil creeping denudational processes. It is seen that at the initial stage, the retreat of hill slope angle is clear and ultimately the region is characterized by the wide flat-bottom surfaces. This ultimate product, the wide flat-bottom valley is characterized by thin layer of deposition of sands and silt. The presence of quartz pebbles and cobbles on the original surface, and later on disintegrated and spread throughout the wide flat-bottom valley in the area has increased the percentage of sandy terrain in the region. All these observations may suggest that the process of desertification is active in this region.

The extraction of top surface materials particularly from the ridges, isolated hills and flat-bottom valleys has been taking place in the area mainly through man-induced activity. This has accelerated the denudational processes in the study area. Other biotic mechanisms are also active in the study area resulting the development of termite mounds, earthworm mound and deforestation by man, while termites quite often eat up the young seedlings.

If the rate of denudational processes and deforestation (by men and termites) continue in the area, the landscape dynamics will certainly change both in the spatial and temporal scale ultimately affecting the landscape in this part of the world.

A special feature is noted in the Bhallabhpur forest lateritic patch where the top surface is being broken-up by gullies resulting the formation of the mesa and butte type features. Blind valleys, sinking creeks and sinkhole type features have also been noted in this part. The gully is about 500 m long and seasonal in nature. The slope of the valley wall of this gully is gentle to moderate (up to 150). The top hard surface is characterized by a scarp, which is subjected to rain-wash action and soil creeping mechanisms. There is a distinct change in the gully bed and the valley walls materials. Photo Plate IV shows that the gully bed is characterized by the fine sand and silt while the valley wall is characterized by nodules of the laterites in concretionary forms.

Thus the present lateritic landscape of the study area comprises

1. Flat topped lateritic plateau capped by massive lateritic terrain forming the highest level in the area.
2. Lateritic ridges affected by denudational processes of spring sapping, gullying and slope wash.
3. Flat bottom valleys or depressions occupied either by a very thin water channel or lying dry in post monsoon season.

4. Well developed rills and gullies with moderate to steep valley walls resulting 'gorge' shaped features.
5. The gully interiors comprise small water fall features.
6. Rounded small elevated isolated residual hills in bunch (like basket of eggs)
7. Occurrence of Ballabhpur reserve forest associated with flat topped undissectrted lateritic plateau about 2 km west of Santiniketan, is supported by perched reservoir of water above the massive laterite, which does not dry up even in hot summer season. At places, this plateau has been dissected and the perched reservoir of sub-surface water has been drained out as a consequence of spring and gullying. Thus, the dissected laterite ridges are no longer in a position to support forest vegetation.
8. Deforestation by man has also contributed to the disappearance of forest from the dissected lateritic terrain.
9. Programme of afforestation on dissected lateritic terrain undertaken by the Government of India has met with only partial success as termites quite often eat up the young seedlings, and
10. Extraction of top layer materials by man also give rise to the origin of a new surface.

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Prof. V.C. Jha
Dept. of Geography
Visva Bharati University,
Santiniketan