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Comprising an area of about 1323.50 square kilometres between latitudes $24^\circ 12' 45''$ N. and $24^\circ 29' 30''$ N., and longitudes $87^\circ 18' 00''$ E. and $88^\circ 01' 00''$ E. in the districts of Bihar and West Bengal, in India, the present study, APPLICATION OF MORPHOMETRY IN GEOMORPHIC ANALYSIS OF THE BRAHMANI BASIN IN BIHAR & W. BENGAL has attempted to analyse in detail all the terrestrial features of the Basin's terrain on spatial and temporal scales and in terms of the processes which produced, sustain and transform them within these scales. The discussion in the preceding chapters reveals that the Brahmani Basin is a small museum of topographic features ranging from the tectono-genetic surfaces and forms of fluvial
processes to residual and depositional landforms.

Broadly speaking, geomorphology is the study of landforms, their materials which make them and the processes that shape them. The discussion concentrates, therefore, on these three main aspects - materials, processes and morphometric analysis endeavouring a complete geomorphic study of the Brahmani Basin. The morphometric analysis spreads in seven chapters. For materials and processes, one each chapter is devoted. Thus the work is divided altogether into fifteen chapters. Each chapter includes various aspects of discussion to achieve the goal how the landscape of the Brahmani Basin has been shaped out.

The foregoing chapters lead to the following conclusions:

(1) The upper catchment of the Basin is a granite-gneissic terrain with a host of igneous and metamorphic rocks. There is no evidence of well defined Caledonian cycle earth deformation in the Basin, but the Hercynian revolution probably resulted in small linear fractures, a series of fault troughs - the Gondwana coal-bearing basins, along the Gumra Nala and the Brahmani Valley. The study reveals that the Gondwanas were deposited in down-faulted rift-valleys in the Permo-Carboniferous age (Ch. 2.1.2.).
(2) Over the denuded Archaean country, the Talchir beds of sand stones and shales lie unconformably occupying a very small area. The Barakars overlie the Archaean surface and the Dubrajpur sand stones overlie the Barakars with slight unconformities. The Barakar outliers preserve coal seams and the largest coal field of the Santhal Pargana is the Brahmani coal field located on the north of the Dumka-Rampurhat road.

There has been considerable amount of well-marked N-S trending faults, which has developed conspicuous escarpments of the Dubrajpur sandstones and shales beds between the Brahmani and Dwarka river (Ch. 2.2.).

(3) Most of the Rajmahal hills is made up of the bedded volcanic trap with inter-trappean sedimentary beds. Basaltic flow overlies the upper Gondwana in the form of continuous sheet. But now due to erosion the rock is restricted to hilly tracts only with a typical flat-topped or terraced topography. The character of trap is determining the lines of drainage. Soft and non-resistant lavas have been eroded away and the valleys are occupied by the streams, while resistant basalts form the hillocks (Ch. 2.1.3.).

(4) To the east of 87° E. longitude the Archaean basement complex disappears below the alluvium with a gentle slope towards south-east. Geologically the alluvium is divided into
two types - the older and newer alluvium. The older alluvium zone is the older flood plain of the river and is found as higher terraces of the Pleistocene age. The newer alluvium is found in the recent flood plain and the adjacent terraces of the river.

(5) The Brahmani Basin has numerous joints which are produced during the Tertiary earth-movement. The joints of the Basin have clear-cut impact on the development of drainage system of the area and thereby the evolution of the Basin. Strikes and the relative density of the master set of joints seem to control the direction of some streams and their patterns. The major joints run north-west to south-east and south-west to north-east (Fig. 2.3). In all cases the arrangement of joints fits with the consequent and subsequent streams. The major rivers of the Basin follow the primary or major set of joints particularly in the upper reaches. Tributary streams seem to follow the secondary and minor joint-systems.

(6) The study of soil stratigraphy reveals that the Brahmani Basin consists of soils like red and yellow, red, laterite and lateritic, shallow black, colluvial, older alluvial and newer alluvial soils (Ch. 2.5).

In the Brahmani Basin belonging to the tropical humid climate, the main soil forming processes are to some extent
intensive chemical and physical weathering processes of which kaolinisation, laterization, colluvial soil formation and even soil formation on the aggradational plains are some of the predominant phenomena.

(7) Both endogenic and exogenic processes have been responsible in originating and shaping the landforms of the Brahmani Basin. The endogenic processes which has evolved in the Basin consist of many happenings involving uplift in the Pre-Cambrian, Permo-Carboniferous and Tertiary periods following the earth-movements; cracks, fractures, rifting and faulting in the Permo-Carboniferous periods; lava outpouring in the Jurassic and Cretaceous periods in the form of Rajmahal and Deccan trap; igneous intrusions; and tilting of the plateau mass and formation of foredeep in the eastern segment during the Tertiary earth-movements. All these endogenic processes have played important roles in the evolution and making of the landscape of the Brahmani Basin over which exogenic processes have worked from the Pre-Cambrian periods to the recent ones. It is important to note that the Basin has imprints of endogenic processes in the form of plateau, hills, traps, valleys, elevation & gradient, etc. (Ch. 3.1). But their original forms have been modified by exogenic processes. Extensive erosional plains, monadnocks, residual hills, dissected plateau, deep and narrow valleys, terraces etc., are
outcome of erosional processes, while depositional processes have formed flat valleys with flood plains (Ch. 3.2.2.3).

(8) The drainage pattern of the Brahmani Basin reflects the effects of geological formation and geographic history. The variid resistance in rocks, the erosional character of the Archaean terrain, the erosional lava plateau, the depositional plain and occasional tectonic disturbances are responsible for the 'complexity' in the drainage pattern of the area under study.

The most common patterns of drainage in the Brahmani Basin are dendritic, radial, rectangular and sub-parallel. Besides these, there are some examples of barbed drainage pattern (boat-hook-bend) and pinnate pattern. Similarly many individual streams of the area outline their individual patterns in the form of straight, meandering, rectangular and braided nature of their channel (Ch. 4.2).

Different periods of erosion, uplift and tilting have complicated the character of drainage here. The drainage lines in the upper catchment follow the lines of joints with the continual process of headward extension (Ch. 4.3).

(9) The study area includes a variety of surface features at different elevations. Important among them are erosional plain, monadnocks, tors, banded gneiss, bad lands,
laterite capped hillocks, waterfalls, springs, terraces, flood plain etc. Gullies are one of the dominant surface features in the Brahmani Basin forming bad land topography at several places (Ch. 5). Throughout the Basin soil erosion is in the form of gullies and hills (Plate 3.2).

(10) The bifurcation ratio of different orders and also weighted mean bifurcation ratio ranging between 3 and 5 indicate the mature stage of the Basin (Tables 7.1 & 7.2).

The high correlation coefficients between the drainage network variables also show the mature stage of the Basin (7.1).

The low value of circularity ratio (C) of the Brahmani Basin (0.25) indicates the late youthful or early maturity stage of the Basin. The elongation ratio (E) having 0.41 and the lamniscate ratio (K) having 1.89 indicates the elongated shape of the Brahmani Basin (Ch. 7.2).

(11) The analysis of meandering streams and sinuosity indexes reveals that almost all the bends measured in the river have both the hydraulic and topographic sinuosity (Table 7.7). The standard sinuosity index increases generally towards the lower reaches of the river. The study also shows that the streams of the Brahmani Basin are sinuous of low SSI and they are in the maturity stage of the cycle of  
erosion (Ch. 7.3).

(12) An analysis of drainage divides of the Brahmani Basin brings out salient features in relation to structure, drainage organisation and stage of landscape evolution. If the fluvial processes are working over a surface of homogeneous structure, the divides are indistinct in the youth, very distinct in the late youth and early maturity and again indistinct in the late maturity and old stage. The Brahmani Basin has distinct divides. This shows that the Basin is in the mature stage (Ch. 8.1).

(13) The study of hydrographic network (source-heads and confluences) of the Brahmani Basin points out that the Basin has a small percentage of the area under very high dissection (Tables 8.2 & 8.3). These areas of high density are physiographically a highly dissected terrain and hilly tract lying above 200 metres. The Basin is full of small and ephemeral rills and streams, which have provided initiations and confluences together on the same unit. The Basin is characterized mainly by dendritic, radial and rectangular patterns of drainage. Had the density zones not been coincident, the pattern would be different from dominating dendritic one. Since most of the streams are small, most of the streams must be intermittent or short-lived in character (Ch. 8.2).
(14) The discussion of the drainage texture illustrates that it does not seem related to the stage of landform development, i.e., youth, maturity and old for fine, medium and coarse textures respectively as generalized sometimes; but the drainage texture of the Brahmani Basin is probably the result of rock structure, relief and vegetation (Ch. 8.3).

The low values of the constant of channel maintenance imply terrain conditions and their nature favourable for drainage development. These low values are due to relative relief, average slope and precipitation condition (Ch. 8.4).

The stream-line surfaces of the Basin show that the area is under rather rapid denudation by a number of active rivers (Ch. 8.5). They also depict the amount of denudation to be achieved.

(15) The analysis of relief measures (viz., relative relief, absolute relief, average relief, dissection index, ruggedness index, roughness index, area-height analysis and altimetric analysis, etc.) leads to the conclusion that most of the area of the Basin is in low and moderate relief. A small area of the Basin is characterized by high relief. Therefore, the Basin is, most probably between youth and maturity stage, better to say, it is progressing towards late youth or maturity (Ch. 9.1 to 9.6).
The low value of hypsometric integral of the Basin (0.28) indicates that there are few relict of residual hillocks within the Basin and there is the equilibrium condition of the Basin as a whole (Ch. 9.7.1).

The altimetric analysis indicates the existence of more than one erosional surfaces and also points out that the most extensive erosional surface of the Basin has been seen within the classes 20 metres to 300 metres (Ch. 9.8).

(16) The analysis of slope gradient concludes that the Brahmani Basin is such a region where slope of various inclinations ranging from monotonous alluvial tracts to the steep-sided hills is observed. It can also be concluded that the method devised by Raisz and Henry is more suitable and acceptable than that of Wentworth for the areal analysis of slope on the basis of contour from maps (Ch. 10.4). The analysis of slope elements concludes that they are not a product of erosion alone. To a large extent the elements have been introduced by tectonic activity. Erosional processes have added some elements to the original slope.

The cross profiles across the Brahmani river (Fig. 10.5) indirectly suggest that the area is an uplifted peneplain. A series of meanders are also the signs of pre-uplifted peneplain. Several breaks as knick points in the
long profiles (Fig. 10.4) show the evidences of rejuvenation. It also indicates that the landscape of the Brahmani catchment is polycyclic in nature. Thus, all the expressions show evidence of maturity (Ch. 10.3.3.2.).

Each hill-side slope profile is characterized by convexity, concavity and rectilinear units; thus it is of composite nature and only the Hack model of landscape evolution interprets such features (Ch. 14.1).

(17) The analysis of bivariate relationship between morphometric variables reveals that there is high correlation among relief and slope properties. But between relief and drainage properties the correlation is relatively weak. This is because of the fact that drainage properties are not solely determined by the nature of relief properties of an area. Rather it is the cumulative effect of other variables such as structure and lithology, rainfall and rate of evapotranspiration, etc. (Ch. 11).

(18) The morphometric analysis of 10 sample drainage basins shows that the bifurcation ratio is very high between lower order streams in all the sub-basins. It is also observed that the large basins have higher value of bifurcation ratio than smaller basins (Table 12.1). The values of weighted mean bifurcation ratio for most of the basins fluctuate around 5.
It suggests that most of the basins are in the mature stage.

The calculated average circularity ratio \( C \) for selected sub-basins of the Brahmani Basin stands at 0.67 whereas the entire Brahmani Basin registers a low value of \( C \) (0.25). On the basis of the circularity ratio, these basins would be considered of mature and late mature stage, but it is not the reality. So, these parameters do not help us in understanding the landscape evolution in all the cases. The ratio may deviate owing to geologic structure and other factors (Ch. 12.2).

The study of elongation ratio \( E \) reveals that some basins are close to circular in shape and some basins are comparatively more elongated in shape. The Brahmani Basin registers most elongated shape. In fact, the geologic structure is responsible for these variations.

The high value of relief ratio of some sub-basins indicates the apparent gradational stage of the erosion and moderate relief ratio of other basins shows mature stage of erosion.

All sub-basins show the relationship \( \left( \frac{F}{D^2} \right) \) above 0.60. On an average these high values suggest the nature of maturity of the basins (Table 12.2).

Hypsometric integrals calculated for each sample
drainage basins (Fig. 12.4) separately show that most of the basins are passing through the mature stage. Some basins exhibit the stage of late maturity. Only one basin, i.e., the Jurguri nadi is passing through old stage of geomorphic development.

It has been observed in Chapter 12.4 (Table 12.4) that most of the morphometric variables are significantly correlated with each other.

(19) The Brahmani Basin has been divided into 8 geomorphic regions depicting the details of each region. It is a fact that the Brahmani Basin is itself a geomorphic region, but within the Basin there are variations in materials, processes and forms. Both endogenetic and exogenetic processes have evolved a variety of forms ranging from a near-flat alluvial zone to the steep-sided hills. The morphometric variables like relative relief, dissection index, ruggedness index, average slope, drainage texture, hydrographic network and many others clearly depict the variations within the Basin (Ch. 13).

(20) The discussion of the various features of the Brahmani Basin under the models of landscape development concludes that the Brahmani Basin shows neither slope reduction of Davis nor slope retreat of Penck-King in all aspects. Both
these phenomena are partially observed. They are most probably related to the state of dynamic equilibrium envisaged by Hack (Ch. 14.1).

On the other hand, the significance of tectonic history in the geomorphic interpretation is more than that of climatic changes (Ch. 14.3).

Thus, summarising all these we may say that the Brahmanian landscape has been subject to crustal movement; it was uplifted epeirogenetically during the Himalayan Orogeny; it has, probably, no palaeoclimatic fossilization; and it is proceeding towards maturity under the Hack model of landscape development related to the state of dynamic equilibrium.