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PHYSIOGRAPHIC PROVINCES OF EASTERN INDIA

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ABSTRACT : Delineation of physiographic provinces help in understanding the physical basis of life, as this paper demonstrates for Eastern India. It is an exercise in regionalisation of landforms in terms of their common origin. The research has lead to the identification of 10 types of physiographic provinces. The paper demonstrates a method which can be gainfully applied on the Survey of India maps to yield the above mentioned results.

INTRODUCTION

A physiographic province gets identified through the application of a comprehensible method of clustering contiguous but diverse landforms which have been sculptured through somewhat common natural process. For example, spurs, ridges and gorges may represent descrete landforms on their own merit, while their contiguity and the factors contributing to their common origin may let us cluster these into a physiographic province, say, that of a mountain. This means that through the application of the methods of regionalisation of landforms, having an accent on the processes contributing to common origin we get the physiographic provinces. Such an exercise is seen useful for identifying some of the attributes of natural environment which might play critical roles in influencing social practices in the so delineated regions.

Our primary objective in this paper is to demonstrate a method for delineation of physiographic provinces based on the Survey of India maps, supplemented by limited field checking. We are applying this method upon Eastern India, which covers the territories under the three states of Bihar, Orissa and West Bengal. This has helped us to identify a set of discriminant attributes of the various physiographic provinces and to speculate on the different ways the physical basis of life has been unstable in this part of the world.

LOGIC OF THE CHOSEN METHOD

The problem confronting all scientific inquiry is to identify the required information which shall prove sufficient to reach any given objective. It is necessary that we state how this problem has been resolved in the context of the present enquiry. We may begin by recalling that in the perception of geomorphologists, landscape is process bound. This perception emerges and gets reconfirmed through factual verification of three assumptions. There is, in the first instance, an assumption about the existence of a structure oriented initial landscape, which is given by the contents and dispositions of lithofacies. Secondly, there is the assumptions about the persistence of different agencies engaged in sculpturing the landforms. This means that the different agencies, by virtue of their persistence, alter in phases the topographic expression of the earlier landforms. This leads to the third assumption about time, which really means that an investigator can observe the attributes of landforms of only a given stage or phase of evolution. An investigator concerned about delineation of physiographic regions or provinces is primarily concerned with this reality. If this argument appears acceptable, then it will be easier for us to demonstrate, which information, amongst all that the geomorphologists are concerned with, can be seen as marginal as against those which are substantial in the contest of our present enquiry.

We have sufficient evidence to indicate that some parts of Eastern India are as old as 3500 million years or older still. There are also substantial parts of this region which are as recent in origin as of today. The initial landforms emerged through the formation of plutonic, igneous, sedimentary and metamorphosed rocks. Some of the sedimentary rocks and their metamorphosed expressions suggest terrestrial and marine environments of deposition. There are also the evidences on periods of discontinuties, when erosion overshadowed deposition. During this prolonged period of formation and sculpturing of the land, there had been the phases of vulcanism, faulting, folding, subduction, upthrow etc. Evidences on eustatic and epirogenic changes are no less pronounced, as these are still retained in the long-profiles of many rivers. such a variegated history of rock formation has undoubtedly left its marks upon the landforms of today. While we have mapped these variations to construct a geo-tectonic history of Eastern India, primarily to enrich our understanding, we consider it unnecessary to present the results of this study in this paper. We have, however, drawn from this study on geo-tectonic history some information to describe only the visible attributes of the differentiated physiographic provinces.

It is convenient to believe that the current phase of landscape sculpturing in Eastern India has re-started in the Holocene period. This is evident from the long-profiles of many rivers. This only means that some of the attributes of the landforms of the Quarternary Era may still be discernible in somewhat altered forms in many parts of Eastern India. But the attributes of the older geologic periods are less likely to be retained today, even in their altered forms, except in hard-rock geology. In short, the attributes of the more ancient landforms have largely been overshadowed by what happened in the Quarternary Ear or in still recent time. Since delineation of physiographic provinces can proceed without constructing a full story of the evolution of the provinces, it was decided to lay little emphasis on the initial landforms. We are more concerned to see what the physiographic provinces look like today.

The arguments regarding initial landforms suggest that less emphasis is needed on the agencies of landscape sculpturing of the earlier geological periods than on those of today. It is, however, useful to remember that the climate of the past geological periods was sometimes extremely humid as it was extremely dry in other period. But the effects of these climatic phases have been largely overshadowed by the conditions prevailing in the post-Pliestocene period. Fluvial processes now dominate over the major part of Eastern India. In coastal areas marine forces are seen to dominate fluvial forces. During dry seasons, wind as an agent of landscape sculpturing plays not quite insignificant a role. Unless restrained by the sub-surface groundwater table, leaching is pronounced during wet season. There is no glacial field within Eastern India.

The arguments given in the context of agents of landscape sculpturing suggest that we are to interpret the concept of time primarily in terms of fluvial process. Now, we know that time expresses itself through alteration of landscapes in different stages. We know that the initial landscape passes through stages of phases of evolution that are ordered sequentially. Since all processes of landscape sculpturing smoothens out all irregularities of slope, the final stage is conceived to represent a peneplain, which is assumed to have graded profile along sections in all directions. Prior to this stage, we notice the effects of actions of running water in the shape of valley side widening. In still earlier phase, the effects of valley bottom deepening are noticed. Then, of course, we may get ungraded profiles sustaining similarity with initial structure in very early stage.

From what we have stated above, it follows that, for delineating physiographic provinces, the required information is on the nature of slopes and this should permit us to ascertain the breaks in the topographic grades. The line along which break between two orders of topographic grades occur should represent the boundary line between two types of landforms. The regional orientation of such boundary lines will define the locations of the different physiographic provinces, their character being given by the nature of the graded topography. Other evidences to supplement understanding can be obtained from the nature of drainage system, the relative heights of the banks of the streams and, certainly, by the knick points on the long-profiles of the rivers. All such information are available from the ordnance maps as produced by the Survey of India. For this exercise, we have used the maps on the scales of 1:64,360 (one inch to a mile) and 1:257,440 (one inch to four miles). Not that these maps provide adequate information for landscape analysis; yet, in the absence of anything better, these maps appear dependable as source of information.

Analysis of the given information was handled in several stages, of which the first stage has been the most critical. At this stage, we used the maps on one inch to a mile scale with contours drawn at intervals of 50 feet. In a given map, covering 15 minutes of longitudinal and latitudinal spread, a section was drawn along the line joining the points of the highest and the lowest elevations. This section clearly identified the location of the points where slopes of distinctly different grades met. by referring to the given map, we checked whether this point of intersection of slopes separated two different types of landforms. Normally, the contour spacings on either side of this point of intersection are not equal. By honouring this attribute of topography, a line was drawn on the given map to separate the two distinct landforms in terms of their regional orientation. This exercise was repeated for all other points of intersections of different slope characteristics observed along the line of section. It is necessary to mention that elevation of any boundary line was not the same at all points. The elevation increases up a valley, since all fluvial valleys have a downward slope.

The second phase of the work consisted of transferring the boundary lines form the one inch to a mile maps to the relevant map drawn in one inch to four miles scale. These were subsequently merged to cover the whole of Eastern India. Figure-1 was constructed by reducing the whole map through photographic means. This represents the physiographic provinces of Eastern India.

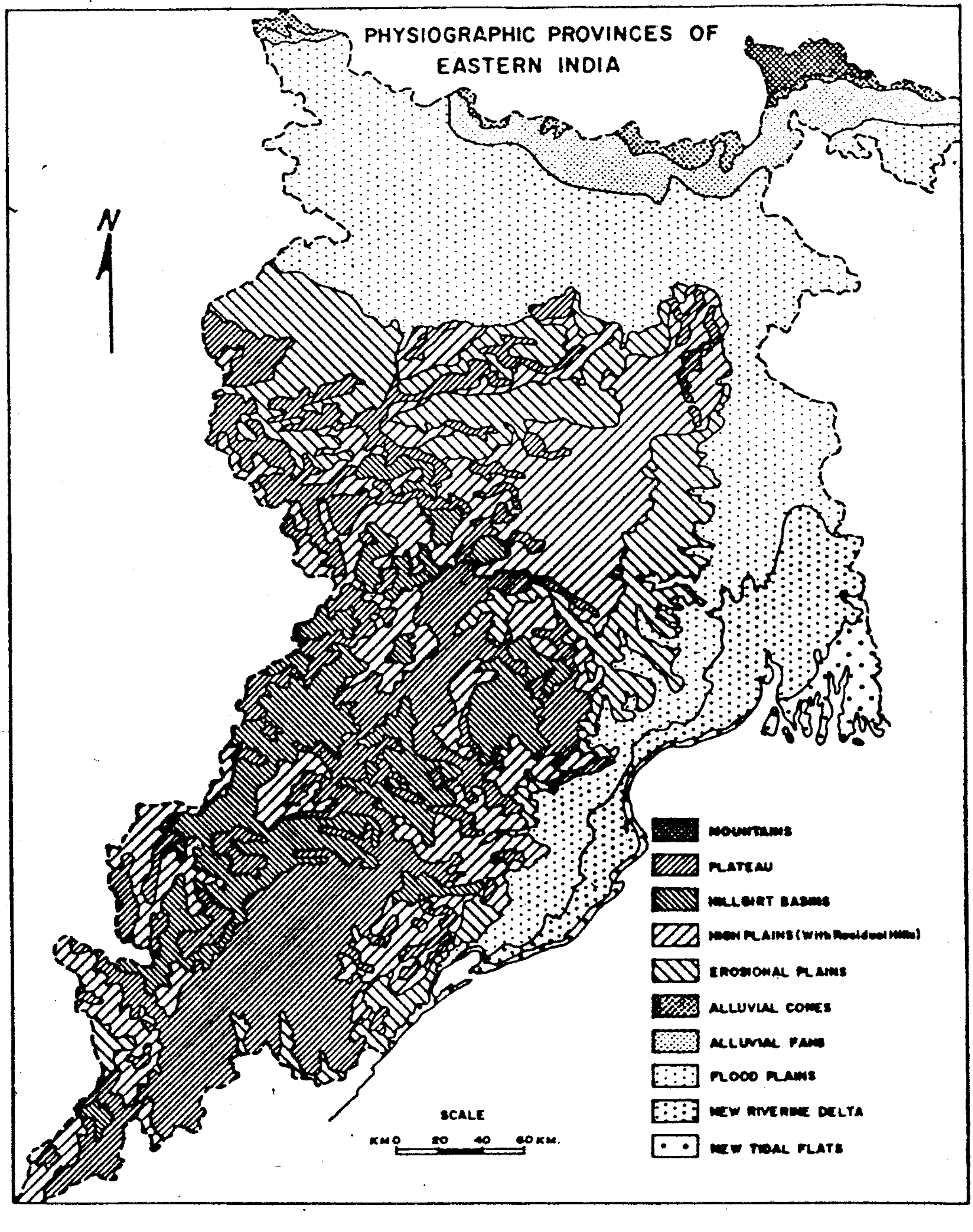
It is necessary to mention that all the boundary lines in Figure-1 were derived from the above mentioned exercise, excepting two. The boundary line that separates the province of the flood plain from the new riverine delta has been given by the high-water line of the tidal zone. The other boundary line that separates the new riverine delta from the tidal flats was given by the distinctiveness of drainage lattices in these two provinces. This only means that physiographic provinces are not given by slope alone. Many other expressions of the landscape, like the nature of drainage channels, the character of materials constituting land, the intensity of erosion or deposition undergoing, etc., have also been taken into account to construct the map on physiographic system of Eastern India. Some of these features were no doubt obtained from limited field checking.

ATTRIBUTES OF THE PHYSIOGRAPHIC PROVINCES

The land forms of Eastern India, as we can see, are classified into ten physiographic provinces. The taxonomy thus produced is much more discriminating than what the text-books on Indian geography ordinarily prescribe. We shall presently describe the distinctive characteristics of each of these physiographic provinces. But, before that we shall remind our readers to accept the boundary lines as zones of transition, however sharp these may appear to an observer. We shall further insist that the neighbouring physiographic provinces should be seen as successive phases of the works carried out by the finality as given by the concept of a peneplain. We shall not, however, speculate on the time that would be required to arrive at such a finale.

1. Plateaus

We may begin by describing the attributes of the physiographic province of the plateaus. These are formed of very old rocks laid during many geological periods, known for their variety and prolonged degradation. Here the topogra-


PHYSIOGRAPHIC PROVINCES OF EASTERN INDIA
N
MOUNTAINS
PLATEAU
HIGH PLAINS (With Residual Hills)
EROSIONAL PLAINS
ALLUVIAL CONES
ALLUVIAL FANS
FLOOD PLAINS
NEW RIVERINE DELTA
NEW TIDAL FLATS
SCALE
KM 0 20 40 60 KM.

phy is highly dissected, which in places look like hills of narrow width. From lower ground, however, the plateau tops appear gentle with accordant swells. The more massive blocks of plateaus are generally found in Orissa and South Bihar. But, there are three distinct blocks of plateaus whose tops are nearly flat, conditioned by local lithology. For example, top of the Rohtas plateau is formed of near horizontal beds of quartzitic sandstone. The Neterhat plateau is formed of massive plutonic rocks which had spread like lava traps. Similar traps, but of more recent dates, support the Rajmahal plateau.

The micro-relief of th plateaus are largely structure controlled. By structure, we not only mean the lithology, but also the folds, fractures and the order of metamorphism experienced by the constituent rocks. For example, hill like plateau elements are sometimes nothing but the stump of ancient folded mountain as in the Dalma Hills. In many other instances, the ridges are formed of dykes and other intrusive structures. However, the most pervasive element of structure that has imparted its influence on micro-relief is the order of metamorphism affecting the rocks. As a general observation, we may say that it is the rocks of intermediate order of metamorphism that support the higher relief features. The reason is obvious. The rocks of lower order of metamorphism cannot resist mechanical degradation as the higher order metamorphics cannot resist chemical degradation effectively.

The valleys of the province of plateaus are steep sided whose floors are strewn with boulders of various sizes. Soil cover is thin on the top of plateaus. The valley sides suffer from soil-creep and soil-wash, which have in many places exposed the rocky walls. Rock-falls have produced screes at the base of the valley walls. The depth of soil at the valley bottom is generally oxidised and highly leached. The parent rocks, being highly jointed, retain not too insignificant amount of water. The water table, however, recedes down to great depth during the dry months.

2. Hill-girt Basins

Skirting the plateaus, generally on the countryside, we have the province of the hill-girt basins. These are found in patches of different sizes, shapes and at different elevations form the mean sea level. There are unmistakable signs of a regime of deposition to which these basins belonged in the recent past. Skirted on all sides by escarpments of plateaus, ridges or a chain of residual hills, the basin floors are invariably covered with oxidised alluvial soils of varying depths. The surface of deposition is nearly flat, unless scoured by the river channels, The channels are well graded, except where these cut through buried dykes of hard rocks. These have fairly high banks on either side. The drainage leaves the basins through narrow defiles cut through the adjacent physiographic provinces.

It is difficult to account for the origin of this province. However, all the attributes of this province as given above, when head together, suggest as if the terrain had experienced a phase of vigorous deposition in the recent past and is now slowly moving into a regimen of erosion. We may consider that the troughs had been exhumed in ancient time, which, during the wet phases of the Pleistocene period, got filled up by sediments brought from the adjacent physiographic provinces. The quantum of annual rainfall was probably high; yet it contributed to enormous increase in sediment load that was much in excess of the capacity of the narrow defile like channels, which are found at the margins of the troughs, to remove. Within this speculative frame of reference, we need to believe that these hill-girt basins once used to look like shallow lakes or swamps by functioning as retention reservoirs of water. Such a speculation can be defended by three facts. In the first instance, during the cool phases of the Pleistocene period, when the valley glaciers in the Himalayas got enlarged, the whole of Eastern India experienced rather heavy rainfall. Secondly, the intensity of erosion is more pronounced at the margin of the hill-girt basins than in their median sections. Finally, the spacing between the channels within this province is rather wide.

Although the soil is oxidised and suffers from leaching, because of its friable property, these basins support extensive farm lands or dense tropical deciduous forests. The underground aquifers are reasonable rich. Many springs are found in this province.

3. High plains with Residual hills

Skirting the province of the plateaus there is yet another physiographic province which we have named as high plain with residual hills. The map (Fig.1) shows that the province of the plain command two types of location. By areal extent the larger patches exist between the plateaus and the province of the older alluvial plains, i.e. towards the ocean side of Eastern India. The smaller patches are located between the provinces of the hill-girt basins and the plateau, i.e., towards the country side.

With reference to both types of locations, the province of the high plain opens out towards the lower physiographic provinces. The margin between the high plain and the older alluvial plain is usually marked by chains of low residual hills or broken mounds of shattered rocks. The boundary line between the high plains and the hill-girt basins is given by the difference in the magnitude of local relief between the two provinces. In all other respects, the landscapes in either locations are similar. It is undulating, studded with sharply rising residual hills and supporting a dense dendron of river channels.

This province of high plains have a distinct regional gradient, which is steeper than the adjacent province of the hill-girt basins or the older alluvial plains and gentler than the plateaus. Evidences of extensive and persistent erosion are many. The stream banks are broken, often leading to formation of bad lands through extension of gully erosion. Soil wash is pronounced, leading to the formation of stoney wastes, rocky pediments near the residual hills or swells formed of chipped stones (tors). The residual hills are small, isolated and almost devoid of soil cover. These are comparable to the South African inselbergs, having screes or talus of broken rocks at their bases. All these are evidences on a long and continued history or erosion that has sculptured this physiographic province. The stream beds are unusually broad in relation to the volume of discharge that passes through these. This is a clear evidence on the quickness of the run-off that is contributed by this highly eroded topography.

The soil is once again oxidised and contains a remarkable concentration of ferrugenous materials. The swells have thinner and relatively sandy soil than in the troughs, where the proportion of clay is decidedly high. All varieties of soil found in this province are singularly incapable of retaining moisture for long. The underground aquifer is rather poor. Once cleared, the dry tropical deciduous forests take a long time to regenerate and often get replaced by thorny shrubs.

4. Older Alluvial Plains

The high plains grade into the lower province of older alluvial plains. Although the surface is gently undulating, this province is devoid of residual hills. The soil is oxidised alluvium, which in many places is highly ferrugenous. This type of soil is commonly referred to as detrital laterite. Here the clay horizon is well developed. Fragments of diverse types of rocks are also found in different layers of this soil. These facts can be explained, if we assume the whole province had developed from deposition of sediments by rivers at or near the base level of erosion given by an ancient sea. Today, this sea-front is found in quite far off places. This shift of the shore line has been possible due to upliftment of the basement complex of the Bengal basin in the recent period as is indicated by geophysical survey data. Due to the rise of the foreshore land, the sea has receded from its earlier location.

The speculation presented above tells us, in the first instance, that the province of the older alluvial plains originated through a depositional phase of landscape evolution and, secondly, that it is now affected by its boundary with the younger province of the flood plains. With salients and re-entrants, this boundary line extends from south to north. This suggest that this province, through erosion, is gradually contributing to the extension of the province of the flood plains. If we assume that this province had once formed deltas at the confluence of the rivers with the ancient sea, then these must be now underlying the more recent deposits of the province of the flood plains. Ample lithological evidences derived from the ground water surveys lend support to the above assumption.

The province of the older alluvial plains supports extensive agriculture except on the valley crests, where the ferrugenous materials tend to develop hard crusts. The soil can retain considerable amount of moisture when it rains. But only a few days of dry spell can produce deep cracks in the soil. In many places, concretions of lime develop on the upper horizons. River bank erosion is observed in almost all parts of this province. While in some places gulley erosion is pronounced, the major mode of degradation is however sheet wash, part of this province had a cover of tropical deciduous forest-vegetation. This has been largely cut off since then, which may explain why the pace of erosion has accelerated in the recent decades.

5. Mountains

To the north of West Bengal, we have the Himalayan mountain system, only a tiny part of which is contained within Eastern India. It is the most rugged of all the physiographic provinces of Eastern India. A number of pre-Himalayan (antecedent) rivers have cut deep gorges, within the valleys of which there are little evidences of recent sedimentation. There are, however, quite a large number of terraces formed of different assortments of pebbles, boulders and alluvium. These are believed to be fossil-landforms, bearing evidences of different environment of the past which had contributed to their origin. These are not the normal terraces which form in entrenched valleys consequent upon upliftment of the terrain.

It is necessary that we mention that hypothesis about the origin of these terraces in the antecedent valley of the Himalayas, for this may help us to understand the origin of some other physiographic provinces of Eastern India. The materials constituting these terraces contain boulders with clear striation marks on these. This is seen as evidences on their glacial origin. However, the problem of assuming the existence of valley glaciers in such a low elevation is there, because the rest of the materials constituting these terraces are decidedly related to fluvial geomorphological process. Hence the hypothesis is that during the Pliestocene glacial epochs, especially during the wet phases, heavy rainfall caused huge quantities of glacial debris to wash down the pre-Himalayan river valleys. Since the snow line at that time also was located further afield, these glacial debris got mixed up with fluvial debris and together chocked up the valleys. Later when the climate normalised, the rivers cut into their own beds by exhuming the deposited materials. These rivers have removed almost the whole of the so accumulated debris, excepting some remnants, which occur presently as terraces.

The province of the mountains supports a variety of vegetation, which, at the base, is humid tropical deciduous type. As the elevation increases, the composition of the forests successively changes to temperate deciduous, temperate coniferous and Alpine meadow types. Inspite of thick vegetative cover, landslides often reach cataclysmic proportions as the underlying lithology facilitates it. The soil type varies over short distances, but are generally rich in organic content. The underground aquifers are rich, but difficult to exploit.

6. Alluvial Cones

To the south and leaning against the province of the mountains, we have the physiographic province of alluvial cones. These are really magnified talus, quasi-conical in shape, pitching against the mountains. Formed of materials of diverse chemical composition and size, varying from fine silt to huge boulders, these cones have apparently formed by the fluvial agencies over a long-time. Possibly the constituent materials were contributed by the destruction of fluvio-glacial terraces that we have mentioned while describing the province of the mountains. The axis of these alluvial cones extends from the mouth of the gorges. The major actors are obviously the Himalayan rivers, which, while building up such a depositional landform, had enough energy left with them to establish entrenched channels for themselves. However, there are many small streams which have developed on these cones, which together describe a radial drainage pattern, betraying their young age, and actively eroding down the cones.

Since these alluvial cones are composed of unassorted materials, agriculture becomes an inappropriate activity. Most of the land is under thick tropical deciduous forests of humid type. The ground water resource is rich, although its lèvel fluctuates in consonance with local rainfall. The different species of plants grow inaccordance with the water retentative capacity of the local soil. Thus, in sandy banks, grass is the dominant species, whereas in pockets of silty soil tall woody trees grow. Once the forest cover is removed, stream bank erosion proceeds and the area under sandy soils expands. In every instance, the river channels are cluttered with boulders of all descriptions.

7. Alluvial Fans

Degradation of the province of alluvial cones has contributed towards the formation of the province of alluvial fans. the hydraulic behaviour of running water is similar in these two physiographic provinces. The difference lies in the magnitude of the work done by running water on those two provinces. As soon as the constricted channel in a gorge in the province of mountains ends, water spreads over a larger area and loses velocity. As a result of which, most of the traction load is deposited to form the alluvial cones. The Himalayan streams, relieved thus of the load, cut into its own deposits to maintain a defined course. However, the alluvial cones retain a gradient and receive rainfall to sustain numerous other, by young streams. These are actively sorting out the finer materials form the alluvial cones and spreading these in the form of an apron in front of the cones. These aprons look like expanded cones of fans.

The sediment loads of these streams are extremely heavy compared to the volumes of water these carry. As a result, channel checking is a common phenomenon in the province of alluvial fans. In the following season of floods, these streams, while failing to clear the channels, often overflow into the adjacent valleys, and become tributaries of the neighbouring streams. In consequence the drainage pattern is braided. During the drier months, the run-off disappears from the surface and emerge at the ground level at the base of the alluvial fans.

The ground water resource is extraordinarily rich. Nevertheless, it is hazardous to tap this on account of the fluctuations of the water-table with seasons. The entire area has been opened up for agriculture, except where stands of trees have been preserved by regulation. These trees belong to humid tropical deciduous type of vegetation.

8. Flood Plains

The province of alluvial fans, as we have stated above, is not a stable landscape. Numerous streams are further sorting out the finer materials to create the province of flood plains. This province covers the largest territory in Eastern India. The entire drainage system, except in the north-east, belongs to the Ganges. The terrain appears seemingly featureless, excepting for the natural levees clinging to the channels, extremely tortuous meander loops, abandoned meander loops forming ox-bow lakes, abandoned channels, and swamps. All these types of landforms indicate that floods are recurrent and the landscape is exclusively within the domain of fluvial aggradational phase. If there are instances of stream bank erosion, then these are merely the expression of the efforts of a heavily loaded stream to maintain its hydraulic gradient.

Discerning scholars would, however, find it difficult to explain the origin of this gigantic province through a single hypothesis. Geodesic and geophysical surveys have generated enough data to suggest that there once existed a very ancient landmass in the middle section of this province of flood plains. This block of old crust foundered and sank towards the middle of the Tertiary Era. The location of this sunken block of ancient crust has been determined through bore-hole investigations and is found to extend along the margin of the Meghalaya plateau. This means that during early Tertiary Era, when the Himalayas were rising, there existed an inland sea or a very large lake to the south of it, which was cut off from the southern sea by this currently sunken block of ancient crust.

Into this inland sea or lake, enormous amount of sediments, yielded by the young Himalayan mountain, got deposited. The shallow water was consistently pushed against the more ancient southerly coast by such sedimentation. We are not too certain if th rivers debouching into the inland lake had brought enough water to spill across the now sunken block of land, which had then formed a barrier. Quite possibly, the processes of sinking was slow, which ultimately provided an outlet for the accumulated water into the sea of that period. Such a hypothesis can explain the origin of the low bluff like landforms of the interfluves of almost all left-bank tributaries of the Ganges. Between these fingers of bluffs and the main channel of the Ganges, we have chains of marshy land. The soils constituting the floors of these marshes are decidedly different from those forming the interfluves in the north. The latter are sandy, while those of the lowlands are clayey. Such a disposition of the grain-size of the alluvial deposits lends support to the given hypothesis on the origin of the flood plain of north Bihar and north Bengal through filling up of a lake.

The event that provided an outlet to the Ganges to the sea in south has not yet been charted out adequately. But one can be certain that soon after this event, perhaps in response to Naga-Lushai Orogeny, the entire basement complex of south Bengal got uplifted. In consequence the sea face receded to the south and east, exposing a huge foreshore as a landmass. The delta that the Ganges had built up, had to accommodate a new process of entrenchment of the river channels.. As the Padma carried the principal discharge, this process of entrenchment became more rapid along that channel when compared with the situations obtaining in many of the right bank distributaries of the Ganges. This caused these distributaries to lose the supply of water form the Padma, except in the seasons of high flood. This will perhaps explain why the part of the province of flood plains located to the south of the now sunken block of ancient crust, has so many moribund rivers. These moribund streams still retain the landscape of flood plains, because the process of entrenchment has been arrested, and the terrain receives very high rainfall so as to cause spilling of water from the channels.

The entire province of flood plains is formed of deep alluvial soil and is endowed with rich surface and ground water resources. Flood alluviation ensures annual enrichment of soil. The entire province has been opened up for agriculture. The slope of the land is towards the country side, i.e., away form the channels in West Bengal. This is towards the channel in north Bihar. Along the main course of the Ganges in north Bihar, however, the slope of the land is away form the channel. Most of the towns and large villages are located on the banks of the rivers because of such orientation of the slope of the terrain. In the rest of north Bihar, where the slope is towards the river, the major settlements generally avoid the immediate river banks.

9. New Riverine Delta

To the south and east of the province of flood plains in West Bengal and Orissa, we have the province of new riverine delta. This province has a number of interesting geomorphological features. The gradient of the land is very gentle and the streams flowing through the terrain are non-perenial. These are also required to negotiate with a tidal regime. Bore-hole data demonstrates that, below a thin veneer of sandy or silty deposits, there exists a thick layer of stiff clay. This sandy/silty blanket is thinner in the south and east than in the north or west, at the seaward front of which we have chains of brackish swamps. All these suggest that, after the upliftment of the basement complex of the Bengal basin in the sub-recent geological time, a vast land mass emerged. Probably, most of this exposed land was marshy initially. The drainage system of the country side had to extend their channels through this marshy land to reach the sea. The weakness of their hydrological characteristics sustained a very slow process of alluviation extending from the seaward margin of the older province of flood plains. This has very slowly, but persistently, led to a gradual reduction of the size of the marshes. In fact, the prograded courses of the streams, through the formation of natural levees, could cut up a hethertofore extensive marshy land into smaller patches. On all considerations, we should describe this as the province of active riverine delta. But, one must bear in mind that this activity is indeed very faint, not vigorous at all.

This province suffers from waterlogging. Yet, it supports extensive agriculture. The surface soil, except at the edges of the swamps, is friable and soil drainage is fairly efficient there. However, near the marshes, stiff clayey soil, because of impeded drainage, restricts profitable agriculture. The underground water resource is rich, although saline interfaces impinge upon it from south. This requires skillful and cautious exploitation of the fresh-water aquifers.

10. Tidal Flats

To the south and east of the province of riverine delta, we have the province of tidal flats. Her the marine processes supercede the fluvial process in creating a highly complex landscape. This part of the world was once a part of a shallow continental shelf until the en masse upliftment of the basement complex converted

If we now look at the Chilka Lake, located in the south-western margin of this province, then we can easily appreciate how it has formed out of a bay being cut-off from the main sea through the extension of an off-shore bar. The origin of this off-shore bar cannot be explained unless we agree to account for the supply of materials from the coastal drift. Then, from the eastern tip of the estuary of the Subarnarekha river, we find a series of parallel sand-dunes extending eastwards. It is true that the sand contributing to the formation of these dunes have been derived from the beach. However, the bases of these dunes are formed of stiff ferrugenous sand mixed with clay. Their structure and orientation suggest as if these were originally the hooks or off-shore bars. As the basement complex rose, these off-shore bars provided the foundations for the dunes to accumulate. Behind these dunes, we have the typical elongated lagoons which normally form between the shoreline and the off-shore bars. The most noteworthy example of such a fossil lagoon is the Dubda Basin. One may also agree to consider the entire channel of the Rasulpur river as such a fossil-lagoon. Further to the east, the ancient continental shelf was obviously in deeper water. Therefore, no off-shore bar could form here. Facies change in sedimentation took place with the proportion of clay increasing. Estuarine sediments were carried further into the newly exposed land. Since the source of the sediments was in the south, the area under the marshes decreased from the south.

This part of the world was, however, prematurely colonised by constructing circuit embankments. This has altered the hydraulic behaviour of the tidal water leading to drift of estuarine sediments up the river channels. These sediments get deposited in the channels at the southern margin of the province of riverine delta. Such a hypothesis on the dynamics of land building process adequately explains the phenomenon of continued deterioration of the navigable properties of the Hoogly river through the formation of shoals and bars.

Almost all parts of this province have been brought under plough by destroying the original mangrove vegetation. Only in a small part, such vegetative cover still exists under the protection of the law of the country. The circuit embankments prevent land building activity. Consequently, the river beds are rising. The fertility of the soil confined within the land guarded by circuit embankments is declining. The soil is saline.

PHYSIOGRAPHIC PROCESSES & REQUIRED SOCIO-TECHNICAL ADJUSTMENTS

Landscape analysis is important to derive understanding about the way a given society can make opportune use of the physical base of environment. The short descriptions on the attribute of the different physiographic divisions of Eastern India as given above may have already suggested to some of our readers about the potentials of this field of enquiry. It should now be clear to them that the techniques of managing land for agriculture in the province of the flood plains would be quite different form those that are useful in the province of the mountains, or for that matter, in any rapidly eroding landscape. The latter types of physiographic provinces, to survive from otherwise inevitable consequence of erosion, must deploy appropriate technology of field-terracing, which the province of the flood plains can do without. We may find that the societies living in the different physiographic provinces and those amongst them who are now credited with sustained stability over the decades have already discovered fairly differentiated technologies between the physiographic provinces. But some other, amongst these societies, have not done so well. There are two basic reasons which may explain their failures.

In the first instance, we may realise that population movement from one tract to the other has been a fact of history of Eastern India. This has required colonisers to move from one physiographic province to the other. If these acts of colonisation did not entail adequate modification of the socially conditioned technologies borrowed from the home province to suit the conditions of the colonised province, the relationship between the social base of technology and the imperatives of the physical base of life may have become out of balance.

Examples of such societies as victims of disjunction between technology and physiography are indeed many in eastern India. The consequences of premature reclamation of land in the province of the tidal flats have already been mentioned in this paper. Expansion of area under cultivation up the slopes in the province of mountains, with or without terracing, has also enhanced the frequency of landslides in the recent decades. The rice fields, we may note, store a lot of water and, thereby, induce increased percolation. This endangers the stability of the soil on steep slopes.

There is yet another set of factors which is known to have increased the vulnerability of many sedentary societies. These factors are conditioned by the very processes which give rise to the different landscapes. For example, the boundary line between any two physiographic process would always remain, but its location will shift over time. Societies caught by this phenomenon of shifting physiographic boundaries, especially on the boundary zone may find their socially conditioned technology of land-management going out of joint over time.. Such shifts of boundaries take place slowly, imperceptibly and irreversibly. It is in this context that the concept of relative stability of landforms assume importance.

It is true that the process of landscape evolution operates over a very long period of time, which is considerably longer than what a generation of human memory can encompass. It would, therefore, be unwise to expect a layman to anticipate such changes. Nevertheless, the science of geomorphology can assist us in apprehending the shape of things to come to some extent in a meaningful way. We may touch upon some of the major issues that a scholar may find useful to note in this regard.

In the first instance, we may admit that the landscapes of Eastern India are being sculptured by running water. This fluvial process is bound to run its full course in order to reduce the relief to create a peneplain. The nacent peneplain first develops at or near the base level of erosion and, over time, expands to cover the rest of the territory within a given catchment area. The expanding boundary of a peneplain travels up stream. Along with it, the countryside-boundaries of all other physiographic provinces that are located on higher grounds also travel upstream in a concordant fashion, unless these are the products of earlier cycles of erosion. This tells us that the characteristics of the physiographic province of the adjacent lower region will substitute those in any given province.

The above observation needs to be qualified in some way. While the topographic features of the adjacent lower province gradually take over those of the upper province, this substitution will not be same in all respect. The primary factor that governs variation is the distinguishing lithology of the upper provinces. For example, in Eastern India, the climatic terraces of the Pliestocene period in the province of mountains have influenced the lithology of the three provinces of alluvial cones, alluvial fans and the adjacent parts of the flood plain. Similarly, the lithology (detrital laterite) of the province of the high plains with residual hills have imparted distinctive marks on those of the province of the older alluvial plain and also the immediate parts of the flood plain.

We may thus realise that any classification of landforms into a physiographic system must not miss the element of continuum that binds that parts with the whole. Substitution of the topographic features of the upper provinces by those of the lower provinces is just one dimension of this element of continuum. Modification of the lithological character of the lower provinces by those of the upper provinces is another dimension of this element of continuum. The landscapes of today are thus attached to the situations of the past as well as those of the future. It is this element of continuity, if properly understood, provides considerable elbow room to the societies to accommodate the relatively unstable physical base of life.

It is useful for the societies of Eastern India to recognise that the stability of any given physiographic unit is process bound and this process in the humid tropics is quite distinctive from any other climatic zone. Take for example, the nature of the hydrological cycle of the humid tropics. The rainfall is extremely seasonal, which means that the transport of weathered or eroded materials get conspicuously slackened down during the dry months. Since the debris derived form the upper reaches of a given river valley cannot get transported along the whole length of the channel in one wet season, with the reduction of rainfall, a considerable amount of it remains within the channel till the next wet season. When rain comes next year, the passage of running water through the channels gets hindered by the previous year's debris. The rivers respond to this reality by cutting the banks and creating rather wide channels compared to the volume of discharge through these. We may also get a dry weather channel cut within broader wet-weather channel. The shape of the shoals also change in the successive years and the rivers look senile when compared with those of the humid temperate region experiencing equivalent rainfall.

We may take a closer look into the nature of precipitation that the humid tropics experience during the wet months. On any given day or hour, rainfall occurs in highly localised fashion. This means that all the tributaries of any given river system may not have discharges full to the brim at the same time. A chance synchronisation of full discharge from two tributaries at the confluence may cause flooding in the immediate down-stream section of the river even though the province may not belong to a flood plain. Similar flooding may occur, if the channel was already choked with debris transported during an earlier spell of heavy rain.

The conditions of dry weather months are also important to reckon with. During these months, microbial decomposition of the hard rock or soil is not suspended. Therefore, the first run off of the wet month get invariable over loaded with sediments. When such run-off moves in the form of sheet-wash, any variation in the local relief cause talus like micro-landforms to originate at the meeting point of varying slopes. such instances of lateral spread of sediments contributes towards a high rate of absorption of run off and creates subterranean flow of water. This water reached the permanent channels long after the flood discharge has passed down. Hence for a few days after a heavy shower, one can find a series of non-perennial springs contributing sediment-free water into the river channels. These springs assist in stream bank erosion. The water contributed by the springs, being sediment free, is capable of developing or maintaining a narrower channel within a wider channel. Thus in the humid tropics all rivers have double channels, one embedded within the other.

We have already mentioned that the humid tropics support a rich biotic cover. Not every place should we expect to get cover from forests. There may be the grasses. Whatever vegetative cover is there, their soil binding property may not be ignored. This retards soil erosion. Once this vegetative cover is removed, say though human intervention, the rate of soil erosion increases. Thus, at the margin of the land under vegetative cover and that without, a scarp like micro-relief may originate. Such a scarp like feature may not necessarily imply that the process of landscape evolution has been rejuvenated. These bear testimony only to maladjustments between society and landscape.

We should, however, suggest that the phenomenon of soil erosion, especially for assessing its impact upon society, be carefully reviewed. Obviously it is a bad thing to happen, for the soil is lost for ever from a given province. But it becomes available to another province. Thus, within river basin a core-periphery relationship develops, the lower province becoming richer in soil and water endowments in relation to the upper provinces. Its impact upon the social relationship between the people occupying the core and the periphery is not inconsiderable.

Soil erosion is bad, because the transported soil leads to channel choking and, in succession, to stream bank erosion and flooding. However, in some physiographic provinces, especially where the surface soil is heavily leached, deep gulley erosion provides some benefit. It exposes the soil horizon where the bases had accumulated over the years. these are rich and with appropriate land dressing, can support a healthy agricultural practice. This we are mentioning not to plead for gulley erosion per se. Our intention is to say that even a saddest reality may call for wise seekers of opportunities.

We may conclude by observing that the vulnerability of the territorial base of a given society can be reduced by adjusting to the elements of the process that gave rise to the physiographic system. In the humid tropics, we have to take steps to reduce the intensity of mass wasting of soil and hard rocks. We also need maintain the narrower embedded channels of every river free of sediments. Actions on both accounts will certainly prove expensive. But where is that promised land on our earth that permits human survival without any effort?

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