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GEOMORPHOLOGY OF A PART OF HAZARIBAGH PLATEAU

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ABSTRACT The details of the Geomorphology of the erosion surfaces of Chhotanagpur uplands is a product of deep weathering of rocks of varying resistance and the subsequent exhumation of the irregular weathering front. This process of stripping seems to be due mainly to slow and steady uplift of this part of peninsula and more recently to deforestation which has accelerated the removal of weathering products. The landforms thus produced closely resemble those of the tropical regions of Africa, Australia, and South-America.

The Chhotanagpur upland has been the centre of attraction for geomorphologists since early times. A large number of scholars (Ahmad, 1948; Chatterjee, 1949; Singh, 1969) have worked on the geomorphic aspect of this region. Their studies are mainly concerned with the recognition of erosion surfaces and their genesis. Little attention has been given to the processes like weathering which is of prime importance in landscape making.

The present work is concerned mainly with the type and extent of weathering which has played a major role in the shaping of the landscape. The work is based mainly on field work.

THE STUDY AREA

The study area lies between Barhi and Hazaribagh towns,on Patna-Ranchi road, around village Padma (24 12N—85 22E). The region enjoys a tropical monsoon climate with three well defined seasons. Summer maximum temperature remains about 40 C and the winter minimum at 5 C. Mean annual rainfall is about 150 cm, major part falling during the rainy season (June-Sept).

The paper has been divided in two parts, the first part deals with the general process of weathering and the other part deals with landforms.

WEATHERING

Chemical weathering has been far more important than the physical. However, the latter is not negligible. Ample evidences were found during field work, exhibiting the importance of mechanical weathering in landform shaping.

Insolation weathering seems to have little impact on the rocks of the region which are mainly schists and phyllites. Being fine grained and soft they do not suffer expansion and contraction except the phyllite which crops out in the Kewta river channel. Hornblende schist, on account of being made up of black and white minerals, certainly weathers in this manner. The Quartz-schists which make up the whole of Ghiahi Pahar is massive but not tough. The cementing material is so soft that it would absorb any expansion on heating so preventing any tension in the rock. On the other hand the joints

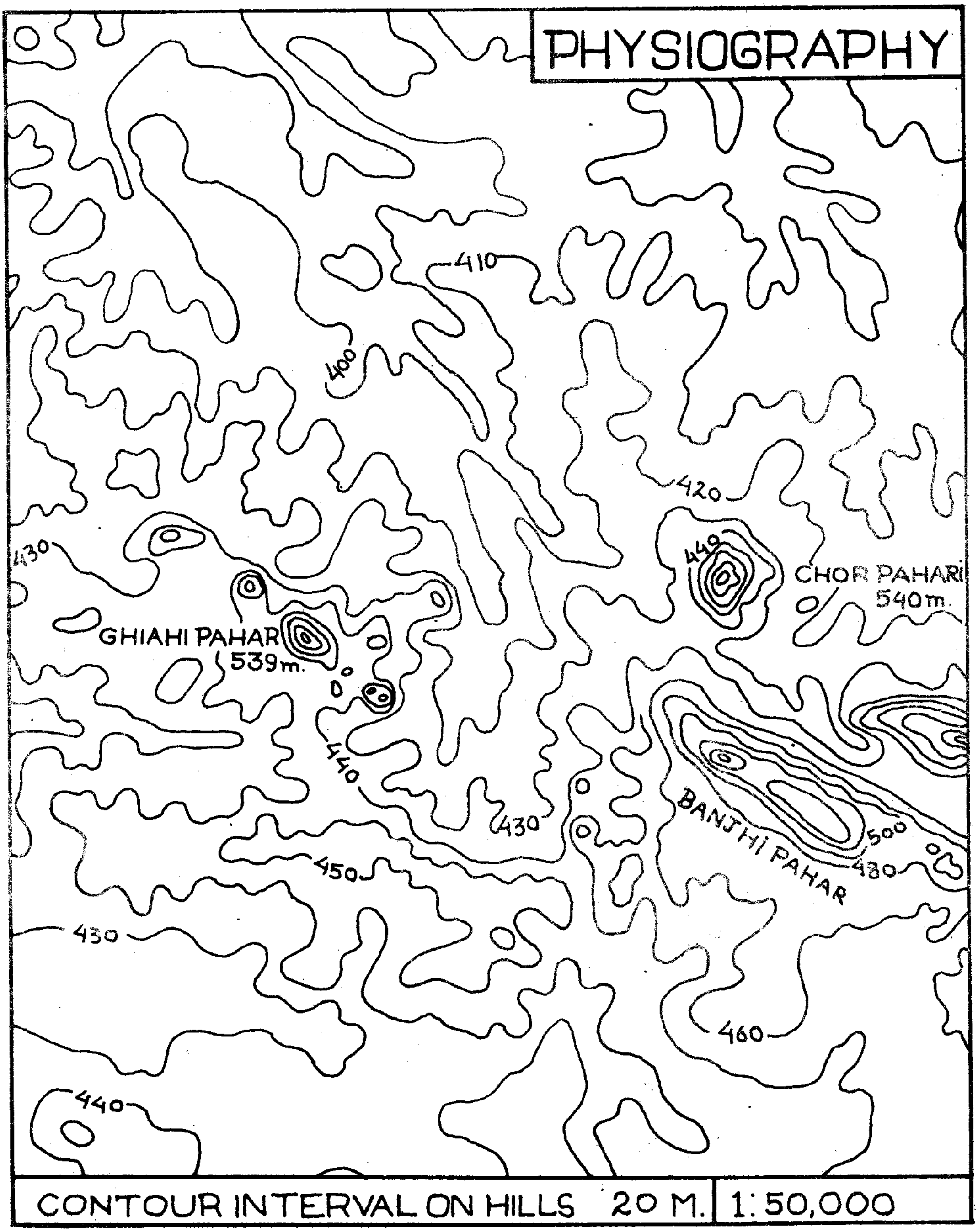

Figure-1- Physiography of the study area.

are numerous, so weathering along joints occurs even under subaerial conditions. The joints also favour mechanical break up due to tree root thickening. Another important way the rocks break-up into small pieces, is their fall from steep slopes.

Evidences of abrasion by sand during rainy seasons were found in the Ghiahi massif. During rains and laden sheets of water flows down slope doing a lot of abrasion on exposed rock surfaces. A feature looking like a "Shivling" about 8-20 centimetres high, almost certainly forms in this way. Initially a rounded boulder with a small base lies over a joint bounded rock platform. The sand laden stream finds its way along joints and quickly lowers it. A small dome is produced in this way. The part protected by the overlying boulder escapes erosion while the surrounding rock surface actively undergoes erosion. Gradually there emerges a narrow stool! Still later the stool becomes so narrow that it can not withstand the load of the overlying boulder; it gives way and the boulder rolls down slope leaving it's seat behind. Gradually this seat becomes rounded and thus looks like a "Shivling". It seems that this 'micro-landform' takes a very short time to develop. Its height clearly indicates the amount by which the rock surface has been lowered. So a careful record of its gradual development may help in calculating the rate of lowering of these hills.

From aerial point of view the mechanical processes are not much important, since there are limited exposures of rocks. Such exposures are limited to the two hills, the Ghiahi Pahar and the Ghorpahari, the Banjhi pahar and to some extent in the Kevta river channel. Debris covered part of the landscape undergoes chemical decay.

The climatic conditions of the region have been favourable for deep weathering of rocks of varying resistance. The chemical, mineralogical as well as structural properties of rocks determine depth and extent of weathering. A number of profiles seen in ravines, stone quarries, building foundation pits and road cuttings revealed that the depth of weathering is great. On the other hand continued erosion since pliocene(?) induced by the Himalayan orogeny, has stripped a thick cover of weathering products. A careful observation made across the region exhibited many interesting as well as problematic features reported also from the tropical regions of Africa, Australia, and South America. These features, namely, Inselbergs Stone-lines, Tors and Pediments have been studied in great detail by the western geomorphologists.

The following account of these features is more informative than investigative. However I have tried to trace out their possible mode of origin.

REGOLITH PROFILES AND STONE LINES

It could be possible to examine a number of profiles during field work. Fortunately exposures were available for examination at the crest, on the slope and at the foot of the Tanr (interfluvial upland).

The first profile (fig-3A) was seen at the top of a Tanr in a building foundation pit. This was about 1.5 mtr. deep and exposed every detail up to bed rock. The details may be summerised as follows :-

Yellow brown sandy soil -------- 8 - 15 cm
(becoming orange downward)

Red earth -------------------- 30 cm

Pea sized Quartz grains in ------ 20 cm
red clay matrix.

Quartz fragments 5-15 cm across -30 cm
with ferrugenous coating

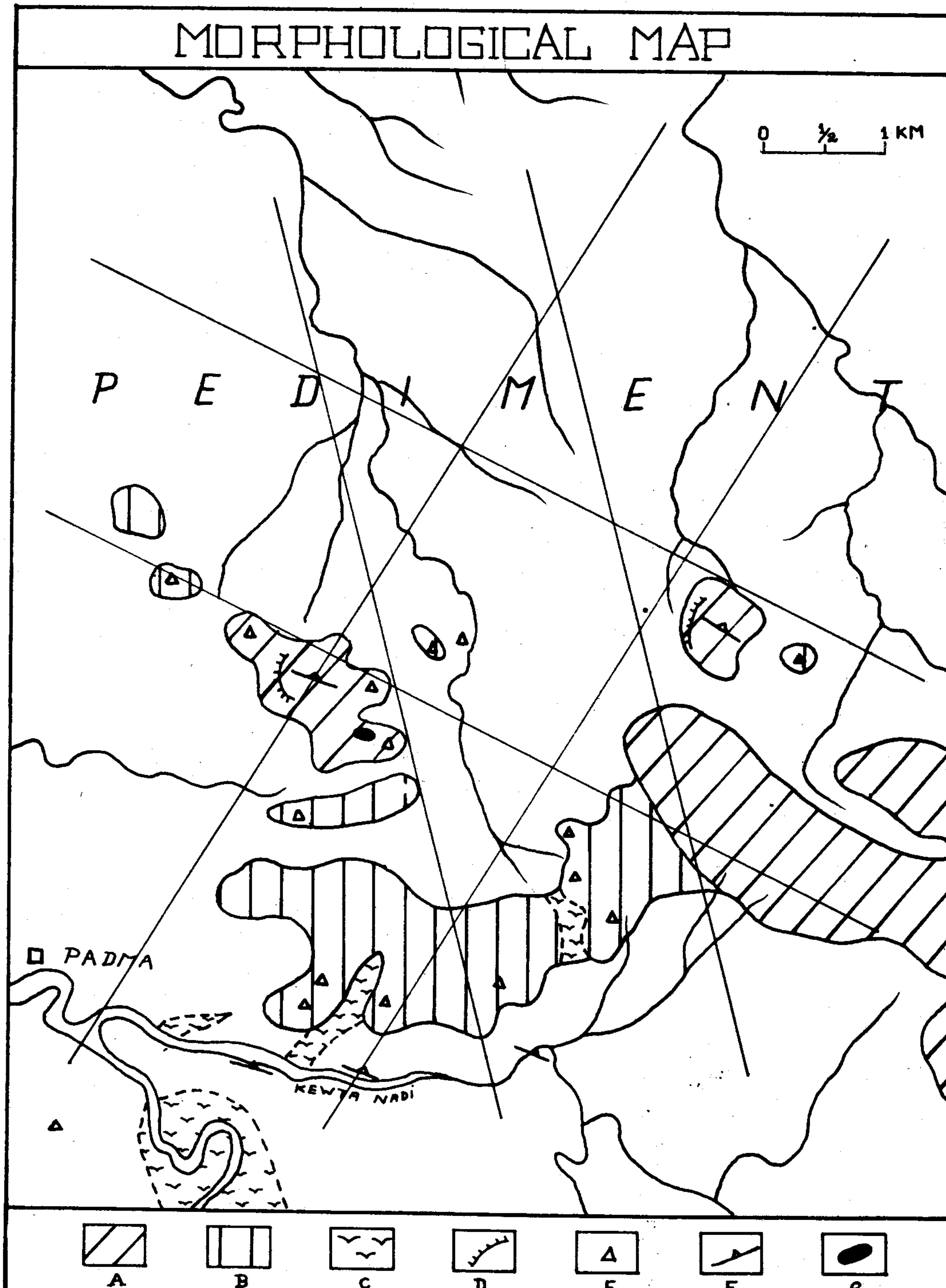

Figure-2- Morphology of the region. A - Hills; B - Interfluvial uplands; C - Alluvium; D - Scarps; E - Core stones F - Dip and strike; G - Rock exposure; Thin straight lines are the most prevalent joint directions.

Quartz fragments over 15 cm across 25cm

Thin layer of red clay ——— 5 cm

Quartz veins in strongly dipping Phyllites and thin bands of Mica-Schists sandwitched between the Phyllite beds.

There is a deficiency of iron and fine silt in the upper horizons and abundance of it in the profile lower down. This is because of the leaching of iron and eluviation of clay from upper horizon to be deposited lower down. This is possible under a much rainier climate than the present. The formation of stone lines seems to be due to redistribution of regolith material consequent upon a shallow incision of streams in the regolith. Thus the material in stone-lines has been derived from older regolith profiles.

Another profile, a complex one was seen on the middle segment of a Tanr slope, in many pits and ravines. This profile differed in its topographic position and arrangement of strata from the one previously discussed. A look at the figure (fig-3C) would reveal that there is a duplication of stone line. Here the yellow brown sandy soil is followed downward by stone-line with light red sandy clay below it, followed by another stone-line which lies over a thin bed of deep red clay. Below this clay layer lies the rotten bed-rock (phyllites and mica schist with Quartz veins). In the highest profile there is no soil bed, the second stone-line being sandwiched between beds of pea sized quartz grains. The thickness of the lower band was over 1.5 metre. Below it was the bed rock.

This duplication of stone-line clearly reveals a cyclic origin of the profile. Movement of regolith down slope can not be doubted here. In the proces of down slope movement, redistribution of regolith material would have taken place, the heavier component settling at the bottom.

Recently Fairbridge and Finkle (1984) have put forth their views regarding origin of stone-lines. According to them "they (the stones) are concentrated by differential winnowing by wind and water. Hill slopes provide an ideal environment for both mass wasting and winnowing.

At present on some Tanr slopes, stones of various sizes were seen strewn as a sheet. They have clearly been derived from the destruction of older regolith profiles. This sheet, under suitable environment, will be burried to form stone-line. Thus the theory of Fairbridge and Finkle sems to work here. But still now there is a problem. The particle size in this sheet varies greatly. The stone-line forming due to their burial would exhibit various sizes of stones in the profile. But the profiles studied here exhibits remarkable uniformity of size of stones in each band.

The third profile (fig-3B) was different from the former two. This was seen in a shallow pit dug at the foot of Ghiahi massif; for the purpose of irrigating the nearby field. Here stone line was found sandwiched between two beds of yellow brown sandy soil. There was no iron staining either in soil or in stone line. The stone-line was about 30 cms thick, the constituent quartz pebbles measuring 5 cms at an average. This stone-line was clearly of colluvial origin, the stones crept down the massif and were buried under the fine debris comming from the same massif.

Besides these profiles, depths of weathering was examined another topographic locations too. In a stone quary in phyllite bed, thoroughly oxidized joint planes, were gradually closing down, were observed. This oxidized plane seemed to extend at least up to 30 mtrs. The exposure itself was more than 15 mtrs. Even this figure of depth of weathering seems little, since the majority of hand pump borings in this region are over 60 mtrs. deep.

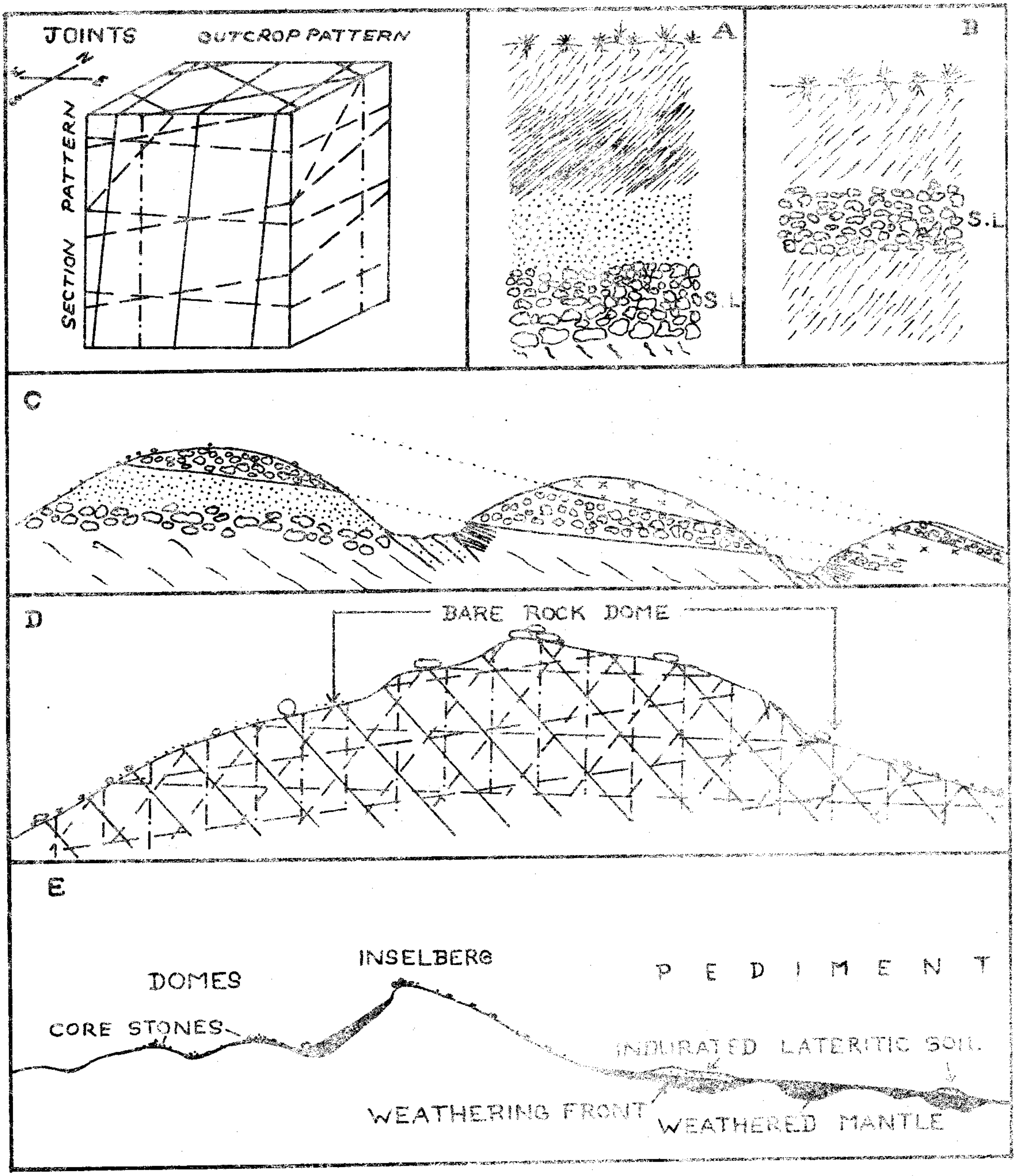

Figure-3- A-B-C- Regolith profiles;
D - The bare rock dome in the Ghiahi massif; influence of jointing on the morphology is quite clearly descernible.
E - Profile showing character of weathering front.

Obviously there is water table at that depth; and water table does not extend into solid bedrock. Thus the depth of these borings indicate the average depth of weathering of rocks. The Mica-Schists and Hornblende-Schists have no such wide joints so the depth of weathering is very shallow. It rarely exceeds 10 metres and the whole rotten rock is restricted to 2-3 metres. Since these two rocks do not constitute high ground, any natural section was not available for examination. At another location by the Patna - Ranchi road, Phyllites were observed to be weathered only up to 2 metres. This is more slaty in appearance and joints were very tight.

Thus the depth of weathering varies greatly within short distances, depending upon the type of rocks. Normally the depth of weathering is greater on uplands, made up of Phyllites, while the low lands are weathered to small depth. The thickness of the weathered mantle must have been greater in the past, at least on uplands, since at many places these uplands are crowned by huge spheroidally weathered boulders or core stones. Such core stones weather under a thick mantle of regolith. Stripping has exposed some of them complętly and some are still half burried.

INSELBERGS

The "Tongries" or Inselbergs were the most imposing features of the landscape. They rise abruptly from the surrounding gently rolling plain. They are steep from all sides and are actively undergoing retreat rather than decline. Two such Tongaries were studied in detail. They represent remnants of higher Hazaribagh plateau (550 mtr. surface) on the lower Hazaribagh plateau (450 mtr. surface) and have been detached from the main mass by the Kewta and Siwani rivers.

The Tongaries namely Ghiahi pahar (539 mtrs.) and Chor pahari (540 mtrs.) are the outliers of the Banjhi hilly tract of the east (fig. -1). The former is made up wholely of Quartz-Schist while the latter is made up of alternate bands of hard and soft varieties of Quartz, mica and Hornblende Schists. The quartz schist is exposed at the summit as with huge spheroidally weathered boulders or core stones. Dip in both the hills, varies from 50 - 70 towards NE, the strike being WNW-ESE. There are three major joint sets (fig-2); one running almost N-S, another NE-SW and the third NW-SE. These petrological and structural properties of the Tongries determine their morphology as well as processes of geomorphic development.

The two Tongries differ greatly in their Geology and topographic position so they will be treated one by one.

The Ghiahi Pahar lies in the same line as the Banjhi Pahar in the east. This is not a single inselberg but a complex of six domes and one inselberg, jointedly forming a massif. Out of these six domes there is one dome inselberg or Bornhardt dome (King, 1948). The entire massif is made up of massive quartz-schist with strong foliation. Quartz reefs were seen to traverse the massif at many places, irrespective of strike or joint pattern. Most of the domes of the massif are oval shaped, their longer axis running in the strike direction. The northern edge of the massif makes an abrupt fall from over 25 to less than 2 (fig-3E). The southern part is much dissected by nalas, headwaters of which have penetrated deep into the massif. The nalas have flat narrow beds filled with coarse sand. The gradiant is very low but suddenly the nala head becomes very steep at about 20, with 28-30 boulder controlled slopes bounding it on three sides. Quartz-schist boulders were not seen outside the outline of the massif, in the nala beds. Presence of such steep boulder controlled slopes revealed the fact that they are undergoing retreat, as weathering and erosion at the foot, consumes their bases. Most of the domes in the massif are covered with weathered mantle but some degree of stripping has exposed huge spheroidally weathered core stones at the top and the flanks, from where they roll down into the nalas, as erosion proceeds.

The hill presents a scarp towards NW and SW with a bamboo and bush covered debris slope. The free face is small (15 mtrs). The debris slope is very steep at about 40 . At the summit there are huge semi-spheroidal boulders weathered along joints. Away from the crest, to the North, there is a flat summit, about 10 metres lower than the highest point. Here spheroidal boulders of varying sizes are strewn over a thin veneer of coarse sand. Erosion along the edge of this sumit has given rise to a very rugged cliff, some very big boulders, of the order of 2 metres across, were seen overhanging it. Some of these boulders have dangerously narrow bases, only 40-60 cms in some instances.

The most interesting feature in this massif is a domed inselberg or Bornhardt dome. This is made up like other domes of the massif, of massive quartz-schists. There is clear evidence of structural control on the morphology of this dome (fig-3D). The dome is irregular convex in profile, that is there were minor breaks of slopes in the otherwise convex profile. All of these breaks were strictly joint controlled, however modified to some extent by weathering. Some of these breaks were caused by quartz reefs which traverse it on the Northern slope. The quartz veins weather much quickly due to insolation and frost action during winter months, and create a linear depression which also channelizes the water flow during rains. Some large blocks produced due to joint failure, were found at its foot. Leaving few as exceptions, all other joints were tightly closed, they appeared on the bare dome surface only as thin lines, so weathering along joints is prevented. However in the nala beds, on the North and South of the dome there is enough moisture to promote weathering of the dome base. The weathering products are gradually removed, thus the area of the bare rock has been increasing.

A perfectly rectilinear slope was observed on the North-Western side of the dome. This plane is undoubtedly a joint plane running N-S. Curiously, no big boulder which must have slid down on this plane was found at the foot of this slope. Only few small spheroidal boulders were seen, they measured not more than 30 cms across. This clearly reveals the great age of the joint failure, during which the big blocks have been reduced to very small sizes.

There were only a few core stones on the dome surface. Their relation with the joint system showed that they have never moved. They are rather slabby in shape than spheroidal, which is the common shape in phyilites and recently exhumed quartz-schist core stones. Around this dome, the slope away from the bare rock exposure was covered with quartz fragments 1 to 10 cms in size, resting on a thin veneer of brown sandy soil. The soil veneer is so thin that bed rock frequently perforated the cover.

The Chor Pahari lying about 2.5 KMS to the east of Ghiahi Pahar is a single inselberg, surrounded on all sides by low rolling rim pediment. This hill is made up of alternate bands of hard and soft varieties of Quartz, Mica and Hornblende-Schists. Only quartz schist is capable of producing boulders of huge diamensions which crown the hills. This hill is completely bare of vegetation. It is steep from all sides and presents a steep free face, much longer than that of Ghiahi Pahar, on the west. There is a very gently sloping debris slope (12°) below the free face as contrasted with very steep (over 40) slope of Ghiahi Pahar. This is because the Chor Pahari has no vegetation to protect its slope from erosion, while the Ghiahi debris slope has a thick vegetative cover. Huge boulders lying away from the free face and finer debris just at the foot suggest that once this debris slope was as steep as those of Ghiahi, but continued erosion due to deforestation has washed away the finer debris, hence the slope has greatly declined.

PEDIMENTS

The pediment is quite broad and apparent in this region. There is a sharp pediment angle at the base of both Ghiahi and Chor Pahari. In the former this angle is much sharper in the north than in the south. In the north the pediment is about 9 KM wide with a very gentle regular slope. There is a fall of 20 mtrs in the first 0.5 KMs which decreases to 10 mtrs per KM and still further to 10 mtr in 3 KMs. Thus the slope is smoothly concave near the inselberg. This slope continues till the main drainage axis of the region, the Barakar is reached. Local relief on this pediment rarely exceeds 5 mtrs which falls to less than 2 mtrs near the inselbergs. The debris cover is not very thick except near the inselbergs. Rock is exposed in every big or small channel.

On the southern and western sides of the Ghiahi pahar the pediment is much steeper with greater relief. This difference is due to the proximity of the main drainage, the Kewta river, to the massif. On the other hand alternate hard and soft rock exposures have favoured incision by even the small streamlet. On the contrary, the Chor pahari has a rim pediment. Thickness of weathered and transported mantle is much greater on the southern side, where bedrock was seen exposed in a 8 mtr. deep pond dug in the channel bed.

The origin of pediments has been much debated by the western geomorphologists. Some of them regard this as a replacement slope, extending as the hill slopes retreat (King, 1953; 1962) while Mabutt (1961) suggests that pediments are late stage features of exhumation, the process being "slight back trimming at the hill bases, partial levelling of an irregular exhumed weathering front, and imposition of the continuous concave profile of sub-alluvial and part-subaerial rock surfaces". (Quoted by Thomas in "Tropical Geomorphology", p.219)

Field evidences are in favour of pediment regradation process suggested by A. Young (1972). The low gradient and the seasonal character of nalas draining the pediment, accompanied by aridity, consequent upon complete deforestation, which favours surface wash of loose fine debris overloading the nalas, all prevent incision of nalas. Thus the pediment is fundamentally a transportation slope. On the other hand the structurally controlled hill slopes evidently retreat at the same angle, making room for the pediment extension.

So far weathering in this zone is concerned, there exists great variation in the depth of weathering. Unlike regions of homogenous crystalline rocks, this region is made up of alternate beds of hard and soft rocks, differing greatly in weatherability. The same process which would produce a smooth weathering front in homogenous crystalline rocks, has here produced weathering front too irregular in depth. So exhumation of this surface would give rise to a much rugged surface. But in the present case the pediment surface is remarkably smooth. This is due only to partial exhumation which has not as yet excavated deep into the weathered mantle.

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