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SLOPE MORPHOLOGY OF PRE-CAMBRIAN RESIDUAL HILLS, MONGHYR

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ABSTRACT : The present paper is an attempt to analyse the profile characteristics of the Pre-cambrian residual hills of Monghyr district of Bihar with the help of few selected surveyed slope profiles. The general tendency of profiles and the stage of evolution have been attempted through the analysis of slope angles and the nature of slope mantle. Hills representing residuals of the Pre-cambrian quartzites not only display the lithological control over slope form but also display the human interference leading to rapid denudation and disposal of waste matters. The resultant micro relief forms and nature of weathered waste are intermittent. The paper also outlines in brief, the development model of slope profiles under the condition of instability.

The Abhayanath, Bhuika and Jalapa hills stretching between Jamalpur and Kiul, are residuals of ancient Dharwar Structure surrounded by alluvial tracts of north Monghyr. Hills significantly barren of vegetation reveal a series of minor ' ledges ' and ' bluffs ' (Robinsons, 1966) interrupting the thin venier of weathered slope waste. Hills are devoid of marked scree slope and conspicuous free face. The present paper is an attempt towards the understanding of the physical constants of surface waste, underlying structure and the slope character on the basis of surveyed slope profiles.

Geology and Morphological Background

The hills consisting mainly of metamorphosed sedimentary strata of quartzite, shale strongly display strike trends of ENE-WSW in the area of study, The three residual hills reveal a congeries of discontinous irregular flexture (Pascoe, 1950) with eastward dipping axial surface of nearly isoclinal syncline (B-fold). Structurally, hills also disply many smaller folds whose axial planes dipping steeply towards the S. W. (Hasan & Sarkar, 1967).

The residuals of the ancient structure present a typical hill slope where lithology, jointing in rocks and gravity display their influence over slope form. Quartzites are massive with well developed joints and their spacing seems to be inversal related to the slope gradient. Tabular blocks of out crops giving rise to micro free faces or risers causes irregularity in gradient over hill slopes. Slopes are thinly manteld by weathered waste in the forms of clitters, mixtures of rock rubble and sandy particles and coarse sands, all in loose state. Once continuous cover of regolith is still preserved in patches and gradually being eroded away by denudational processes. Water is the chief agent of transportation of waste matters over the slope. The absence of any dominate scree slope reflects that the down slope movement of weathered material over entire slope is intermittent and related more to the process of wash.

Methods

Ten slope profiles were measured with pantameter, (Pitty, 1968) of 1.5 metres lenth unit and nature of surface cover were also noted down with each measured slope unit in field book. The slope surface has been differentiated on the basis of denudation and deposite. Waste matters over slope are distinguished as clitters (approx. size less than 5 to 25 cm.), mixture of rock rubbles and sands (approx. size less than 5 cm), regolith and wash deposited coarse sands. Profile no. 1 to 5 are measured over Abhaynath hill (Fig. 1) no. 6 is the north facing slope profile of Bhuika hill. Remaining four are from Jalapa hill (Fig. 2).

Profile Characteristics

The ten surveyed profiles demonstrate the general convexo-concave forms of residual hills. The length of curved units and their terminal angle establishes the amount of convexity and concavity of profiles. The low average angle of profile units micro free faces or ledges and almost absence of scree over the slope are the testimony of the advanced degraded stage of these hills. Profiles through their length of curved slope units, provide a simple way to determine the curvature ratio of entire profile irrespective of its convex and concave units.

The numerical treatment, thus facilitate in establishing the probable tendency of profiles in the sense whether they are subjected to progressive decline or retreat. Numerical values of profiles are depicted in Table I.

TABLE-I

Pro-file No.	Unit length Percent Ix	Iy	Angular change in percent Ax	Av	Index of curve form Cx	Cv	Curve Ratio Cr	Location
Abhayanath Hill								
I	55.5	57.7	43.1	56.9	1.29	1.01	1.28	Facing South
2	61.5	69.2	68.0	32.0	0.91	2.19	0.42	,, North
3	59.3	75.2	51.2	48.5	1.16	1.55	0.75	,, West
4	57.8	64.8	49.5	51.5	1.17	1.26	0.93	,, East
5	66.7	51.2	45.8	54.2	1.46	0.94	1.55	,, East
Bhuika Hill								
6	70.5	54.3	58.4	41.6	1.21	1.30	0.93	,, North
Jalapa Hill								
7	69.2	71.8	53.8	46.2	1.26	1.55	0.83	,, North
8	74.5	78.7	46.3	53.7	1.61	1.47	1.09	,, South
9	52.6	54.9	49.1	50.9	1.08	1.09	1.00	,, North
10	72.7	84.1	39.8	62.0	1.83	1.37	1.34	,, South

X-convex, V-concave, Cx-Lx/Ax, Cv-Lv/Av, Cr-Cx/Cv

The numerical consideration of profiles first establishes that the length variation of curved elements is highest in two profiles, i. e. no 3 and 6. Whereas in the rest of profiles difference is not more than 13 per cent. But the tendency of profiles is apparent when their respective curve ratio is considered. Curve ratio depicted in Table-I reveals the concave tendency of profiles nos 2, 3, 7, 4 and 6 in decreasing order as their ratio value is less than 1. Whereas profile nos. 5, 10 and 1 reflect convex tendency of profiles. Curvature is least in profiles 9 and 8. The general tendency of whole length of

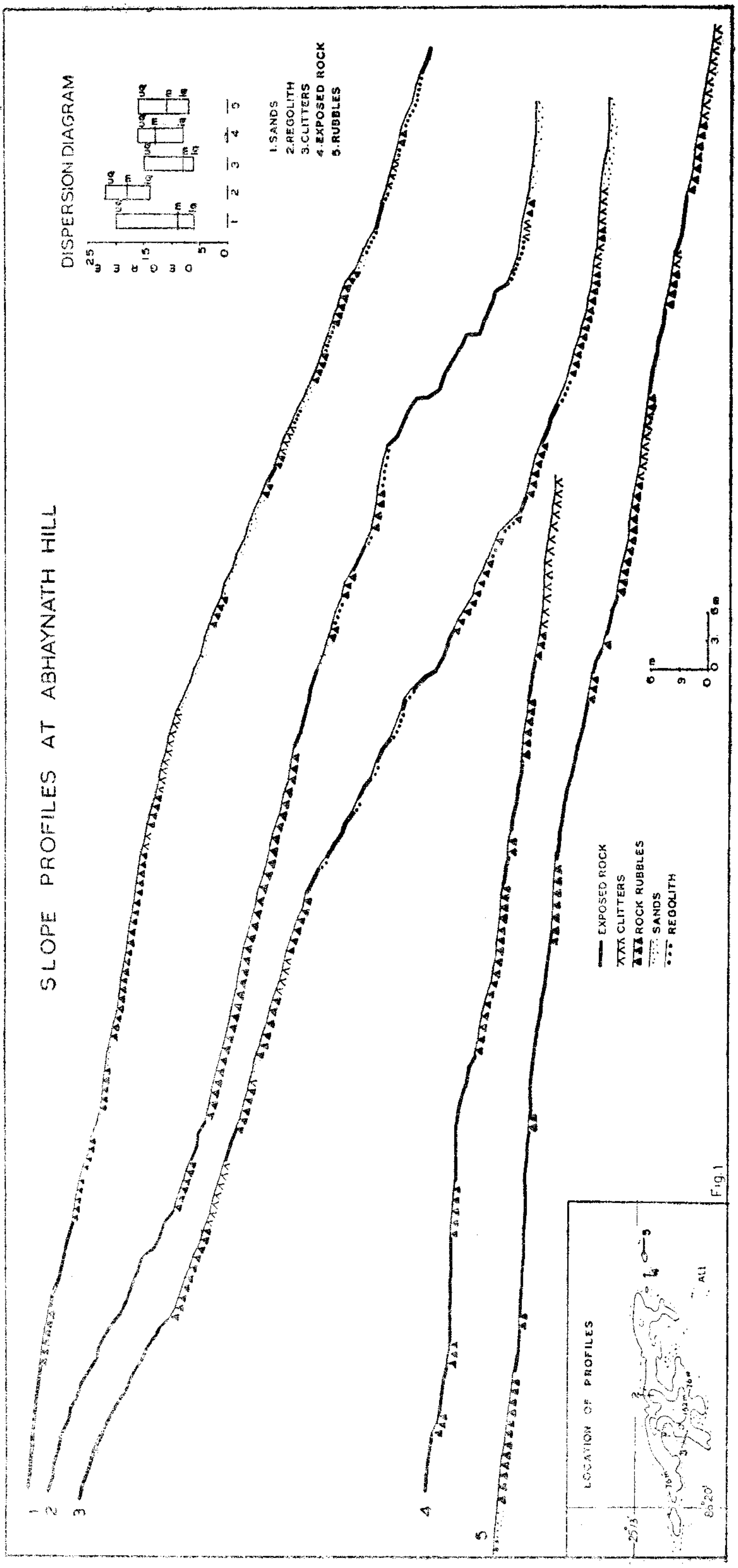
SLOPE PROFILES AT ABHAYNATH HILL
DISPERSION DIAGRAM
1.SANDS
2.REGOLITH
3.CLITTERS
4.EXPOSED ROCK
5.RUBBLES
EXPOSED ROCK
CLITTERS
ROCK RUBBLES
SANDS
REGOLITH
LOCATION OF PROFILES

Fig.1

profile is though revealed in curve ratio and it may be a good measure to determine the steepening or flattening tendency of profile it fails to explain the complex convexo-concave nature of profile forms of residual slope. These residuals are almost bare without having uniformally mantled regolithic cover. Any conclusion regarding the general tendency of its development cannot be safely established on the basis of curve ratio, particularly when hill side slopes are ungraded in the sense of classical Davisian concept. The residul patches or regolith give testimony to the former graded slope mantle and their subsequent rapid denudation. The present ' ungraded ' slope charaeter is closely related to some recent human interference and structural character of the underlying rock.

Similarly the rectilinear sections or maximum segment, do not provide any clear cut evidence of the steepening tendency of the slope profiles but apart from profile nos. 4 anb 6, percentage of rectilinear section is conspicuously low. The low percenatage in relative length ofthe profiles again establishes the advance stage of slope development (Kumar, 1978).

The rectilinear slope units are associated to the rock out crops in the profiles of strong concave tendency as we find in profiels nos. 4 and 3. The conditions ot slope replacement under active denudation is possible in profiles having more than 2.0 per cent. of the rectilinear segment. Conditions are more apparent over slope of profilcs no. 3, 6 and 10 (table-II).

The process of slope flattening is more obvious in the remaining seven profiles where the length of rectilinear units are limited in relation to convex-concave sequence. The study of the residual hill slopes also indicates the profile convexity prevailing over the crestal and mid slope sections of profiles such areas are invariably out crops. It may be expected that the mid slope micro free faces will be ultimately replaced by slope units of lower angle till an angle of stablity is acheived.

TABLE-II

Profile No	Length of slope segment in percent Convex	Max.	Concave
1	54.2	12.2	33.6
2	41.0	15.2	43.8
3	42.2	30.6	25.2
4	49.6	08.5	41.9
5	42.7	15.3	42.0
6	33.3	30.5	36.2
7	30.8	12.5	56.4
8	34.0	12.8	53.2
9	39.2	7.8	53.0
10	15.9	29.8	54.6
Total	36.8	22.0	41.2

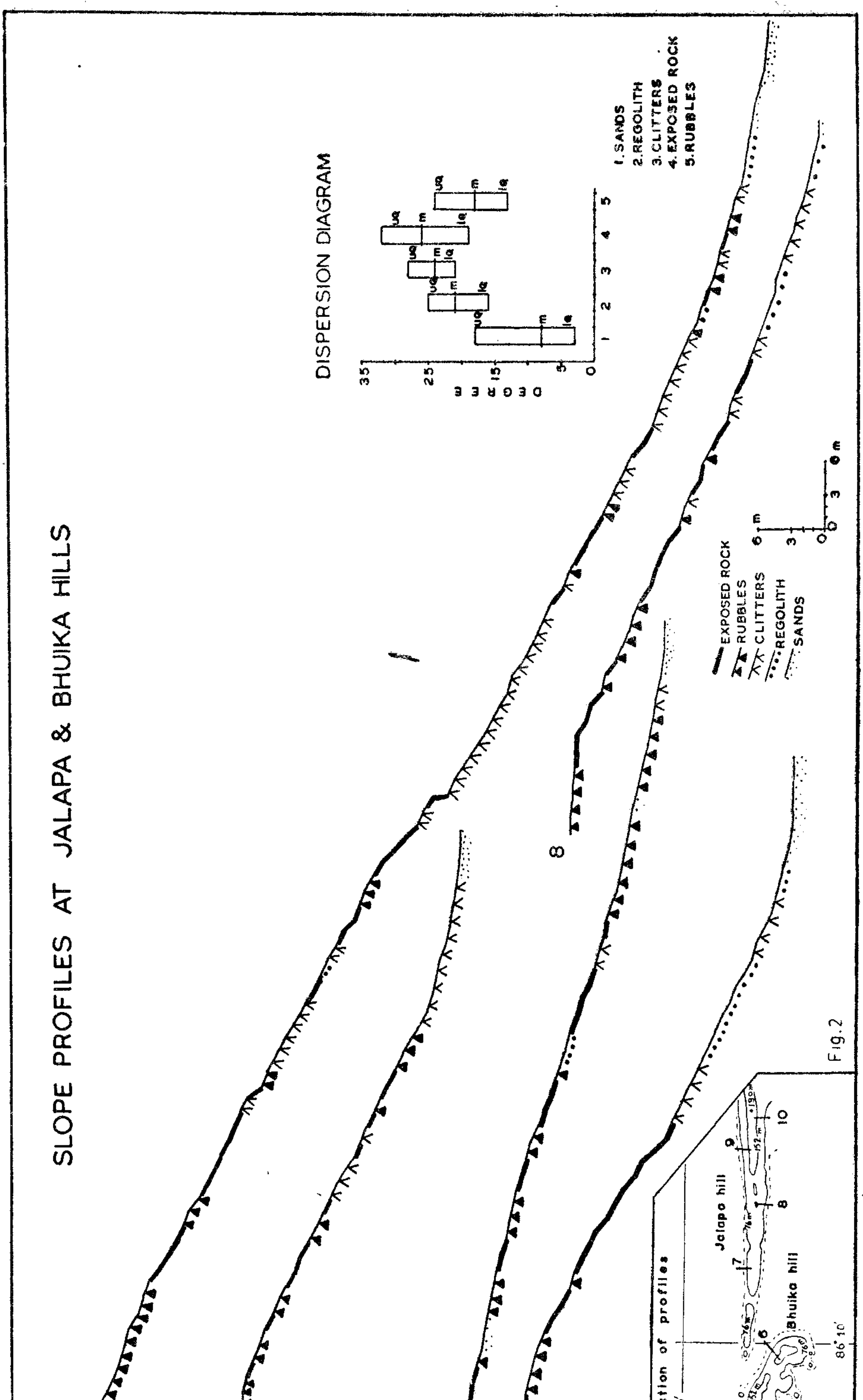
SLOPE PROFILES AT JALAPA & BHUIKA HILLS
DISPERSION DIAGRAM
DEGREE
1. SANDS
2. REGOLITH
3. CLITTERS
4. EXPOSED ROCK
5. RUBBLES
EXPOSED ROCK
RUBBLES
CLITTERS
REGOLITH
SANDS
Location of profiles
Jalapa hill
Bhuika hill
25°10'
86°10'

Fig.2

Angle Characteristics

The character of profiles and the stage of evolution can be deducted through the analysis of slope angles. The histograph (Fig. 3) showing trimodel character of slope angle, distinguishes characteristics angles in the angle range of 4°–10°, 14°–16° and 18°–24° It not only shows the litholigical control but also the complexity of slope development. Field analysis also supports the general conclusion regarding the association of slope angle with the development of profiles and nature of residual cover. It is easy to recognise the possibility of a number of angles of limiting stability and their association with a particular stage in the breakdown of the mantle. Wherever the underlying quartzite rockmass is jointed and weathered Through the release and disintegration, the stable angle of slope is usually more than 24°. Slopes in 18°–24° range are mantled by clitters and mixture of rock rubble and sandy particles in loose state. 35 per cent. of bed rock slope under this range reveals a state of transition and in due course probably will be mantled by low particles.

Angles of slope at 14°–16° are very common over these Quartzite hills which weather to produce taluvium mantles. About 14 per cant of slope profiles under this slope group, apart from bare rock surfaces, are presently mantled by mixture of rock rubbles sandy particules and regolity.

4°-10° angles are closely associated with materials forming loose mantle. Angles of 4°–10° are secondary slopes which have developed after a replacement of higher angles. They will remain longer than the slopes of higher angle values.

The analysis further reveals a number of threshold slope ranges although certain threshold slopes are especially common over the hills. The medians and quartiles clearly demonstrate the angle dispersions of given slope types. Regolith and sand covered slopes are significantly different. Bed rock slope, clitters and mixed rubbles and sand slopes overlap each other. Bed rock slope accounts for 34.6 per cent of all recorded slopes. In can be said that these slopes have three characteristic angles of 8°–10°, 24°–26 and 48° and limiting angle of 30 (upper semi quartile). But wide variation occurs in the slope profiles. In Abhayanath hill profiles the inter quartile range is 9 while over Bhuika and Jalapa range is significently higher. The characteristic angle is 5°–6₀ for two denudationally advanced profiles nos. 4 and 5 of Abhayanath hill. While for the rest of profiles it is steeper than 24° and 48°. Such bed rock slopes are distinct from other depositional slopes. Slopes are essentially an exhumed forms. Peaks defined at 8°-10° represent erosion surface remnants modified by present process. The second and third peak angles appear to correspond with renued denudation.

The fifty per cent. of clitter slopes range between 6°–15° and 21°—28° over Abhayanath and Bhuika-Jalapa hills. The inter quartile expresses and defines the characetristic angles of 8° and 24° and limiting angle of 30° Clitter grades up into mixed debris slope without any singificant break. Characteristic angles of 10°– 16° and limiting angle of 23° (upper semi quartile) reveal wide variation in angle dispersion. About 50 per cent. of mixed debris slope range between 10° inter-quartile range. None of the depositional slopes have 50 per cent. its profile units within a particular range of angle. It signifies that depositional slopes do not express any constant slope as their angle of repose is that of underlying bed rock.

The characteristic angles of 8° and limiting angle of 18° are associated with covered slopes. Regolith covered slopes are gradually denuded away both through slope decline and slope steepening near risers. In comparison to other slope types regolith slopes show negative skewed distribution indicating the operation of limiting factors like retreat of micro free faces and denudation of the exhumed rock

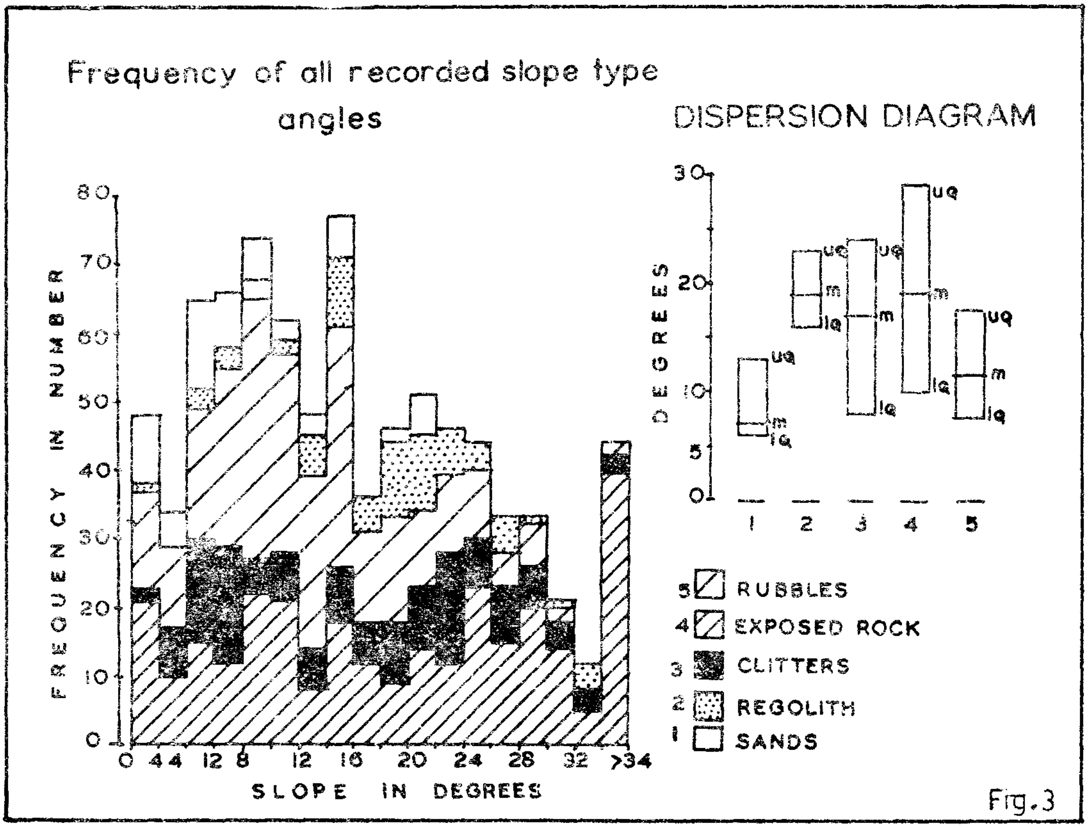

Fig. 3

slopes.

Presence of three depositional and one denudational slopes with wide variation in slope angles indicate that residual hills are actively denuded by the processes. This explains the non-existence of one predominent angle of rest for the debris and clitters. 'Risers' mark the joint plan of massive quartites where blocks have been dislodged either by gravity or wash. Near these sites parallel retreat of slope units aree taking place in accordance with jointing and strike plan, as rocks do not produce any angle of cohesion. Just below the site bed rocks are mantled by a shallow clitter and mixed debris.

The sharp fall in angles frequency at 82° further explains that higher angles are produced as a result of relatively active erosion by agencies under cutting a slope or rises. As risers are short lived forms, they are gradually transformed into slopes of less than 30°. The outcome of such slope replacement can be related to the groups of characteristic angles at 22°—28° and 8°—10°. The gentler slope angles are expected to retain their angle for a relatively longer period of time (Young, 1961).

The change from one threshold angle range to another is simply the replacement of one stability angle by another and there is no continual process operating which would result in indefinite flattening of the slope profiles. The study does not offer any support to the idea that slope flattening is a continuing process over these hills. Association of stability angles with both the protected and unprotected slopes could be due to slope flattening as well as due to slope retreat process.

The most pertinent point arising from the analysis of slope profiles in relation to processes of denudation and slope type is perhaps, related to the construction of slope profile development model under instability.

1. Development of straight slope with a particular angle of stability in response to the initial dip and strike of stratas. The evolution of slope over the hard Quartzites initated after the structural growth of the area. Development of drainage system provided rapid system incision and cliff faces may be formed along valleys. As streams approached base level the down cutting gradually slackened The initial cliff faces of valley become straight by acquiring a certain angle of stability. Under the early transport limitlng conditions weathering of rock surface may result in producing a slope in response to the angle of repose of the talus'

2. Once stream incision diminishes relative to the weathering of the rock mass, slope begins to develop independently of stream action. Three groups of processes mainly weathering and mass failure: soil wash and solution; and soil creep assume importance. Over the hard quartzite, weathering continues to thickens the surfac mantle. Because of resistant quartize there will be every possibility of a second straight slope under the transport limiting processes. At this stage slight conversion at the upper and lower limits may have initiated the growth of curved elements of slope.

3. The hill sideslope underwent progressive change due to weathering and ultimtly the stability of slope was affected. Thus a number of threshold slopes developed depending upon the phases of disintegration of waste slope mantle. The initial talus slope with the angle of repose in the range of 32°—40° because subsequently unstable as the frictional and permeability properties of talus changed under weathering processes. A second stability angle range of 18°—24° developed in response to the degree of weathering of mantle.

4. The angle of stability of mantle again underwent slope adjustment as soil creep and wash gained importance. A marked summital convexity and a basal concavity emerged over profiles in due course of time. Slope profile gradually acquired sigmoid form with straight slope still significant in the uphill mid slope.

5. The slope continued to decrease while maintaining its sigmoid profile. Wherever human interference has altered the pace of processes, secondary slope threshold developed under the increased rate of transporting and weathered limited conditions Secondary slope thus obliterate. Previous slopes thus being obliterated by these secondary slopes through retreat of slope units. Free faces and ledges are thus created over the slope and are thus succeeded by almost straight units of clitters and mixed rubbles down slope. The persent profiles of these residual hills, exhibit a complex bimoidal forms. It is difficult to distinguish threshold angles of various types of mantle cover at present. Wherever time had been available slope became subdued to produce slope profiles like profiles nos, 4 & 5. The process of siltation became associated with ledges, micro pondages over hill slopes and decreased gradient at the basal slope sections.

Conclusion

The interaction of structure, form and process is reflected in the complexity of the profiles under review. The numerical consideration of slope pofiles reflect an advance stage of their development. The slope type frequencies reveal that bare rock surface, mixed rubbles and sands, clitters amount for 34.6, 32.5 and 16.4 per cent. of slope. In most cases angle of repose of their depositional slopes is determined by the undermined bed rocks. The analysis of surveyed profiles reveals the general decline of entire hill side slopes and profile retreat near individual riseds or ledges.

The nature of profile form and surface cover provide ample evidence of relative rate of waste transportation over slopes.

Relative rate of transportation varies from fine sand to clitters. The surge flow which is common over the rough surfaces (Schumm, 1956) is probably responsible for 'ledges' and their pool of fine sediments in transitory deposition over the slope. The numerous shallow distributary treads, supporting only ephemeral flow, also characterises the mode of removal of debris particulary finer waste over lower mid and basal slope section. A narrow 'depositional upon' (Mabbut, 1955) of sediments around these residual hills bear testimony of waste disposal from the slope and their sedimentation. At present slopes of these residual hills are basically active and only temporari ly stablized where profile units are retaining regolithic cover.

References

Hasan, Zia-ul and *Sarkar, S. N.* (1967) : The Deformation of Dharwar Conglomerate in Monghyr District, India, *Norsk. Geol. Tidss*, **47** : 159-170.

Kumar, A. (1978) : Some Observations on slope profiles in the pat Region, Ranchi; symposium Volo. on Morphology and Evolution of Landforms, Deptt. of Geology, University of Delhi, : 41-54.

Mabbut, J. A. (1955) : Pediment Land forms in Little Namaqua land; *Geog. Jr.*, **121** : 77-83

Pascoe, E. H. (1950) : *A Manual of the Geology of India and Burma,* I; Calcutta.

Pitty, J, F. (1948) : *An Introduction to Geomorphology*, London.

Robinson, V. (1966) : Some Residual Hill slopes in the Great Fish River Basin, South Africa, *Geog. Jr.*, **133** : 386-390

Schumm, S. A. (1956) ; Evolution of Drainage Systems and slopes in Bad Lands at Perth Ambay New jersey. *Bull. Geol. Soc. Am.* **67** : 597-646

Young, A. (1961) : Charecteristic and Limiting slope Angles *Zeitch. Geom.*, **5** : 126-131.

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