

GEOMORPHOLOGICAL STUDIES AROUND UMIAM LAKE AND
ADJOINING AREAS, EAST KHASI HILLS, MEGHALAYA

ABSTRACT

Ms Mandira Agarwal

DEPARTMENT OF GEOGRAPHY
SCHOOL OF ENVIRONMENTAL SCIENCES

DISSERTATION

SUBMITTED

IN

PARTIAL FULFILMENT OF THE REQUIREMENT OF THE DEGREE OF

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INTRODUCTION

Within the contemporary concern for environmental management, many problems relate to the interaction between man, land and water. Geomorphology normally involves study of land and water and frequently recognises that when man uses land, he has to accommodate its relief, material and water resources to his purpose, for which man has to understand the geomorphology of the area he desires to harness.

Geomorphology is the study of evolution of landforms. It is the science, which is concerned with the study of landforms at the surface of the earth. Geomorphology plays a vital role in developmental programmes and projects. Hence, the understanding of geomorphology of an area is of paramount importance before any developmental activity is initiated to have long term goals.

Geomorphology is so dominant a factor in human environment resource management that its influence on the pattern of development at a particular place is immense. The land use pattern differs in different geomorphic domains. Accordingly,

remedial measures differ to overcome a common problem occurring in different geomorphic domains.

The slope characteristics, the relief of an area, the physicochemical characteristics of soil, the hydrogeological conditions and the subsurface geology are some of the parameters controlling the landform configuration and denudational history of an area. The same parameters determine suitability of a location for construction of dams, railways, highways, electrical powerlines, industries, townships, irrigation distribution channel, network, defence strategic installations etc. In a way, geomorphology helps in rationalising and integrating developmental schemes with the land resource.

Thus the importance of geomorphology in any developmental activity cannot just be overruled. Environmental management calls for understanding the geomorphology of an area before the land is used as a resource. The main idea is to identify individual landform or landform complexes as either favourable or unfavourable to a particular type of economic activity. In areas, where developmental activities underestimate or ignore geomorphological characteristics, it is bound to create serious environmental imbalances.

It is in the light of this relationship between

geomorphology and landuse that the present study "Geomorphological studies around Umiam Lake and adjoining areas, East Khasi Hills, Meghalaya" has been taken up to understand the impact of geomorphology on Umiam Lake and the surrounding areas.

CHOICE OF THE AREA

The hydro-electric project on Umiam Lake in Barapani is one of the most important developmental scheme in Khasi Hills. The area around Umiam Lake has been selected for the present study mainly because it offers variety of landforms in diverse geological mileu. The area is also landslide prone and offers excellent opportunity to study landslide hazards under varied geological conditions and, the impact of developmental schemes in initiating them.

The hydroelectric project in the area has exposed many new geological segments to understand geomorphology and its impact on environmental resource management.

The area of study falls in the Survey of India Topo-sheet No.78 0/14. The area is bounded by coordinates $25^{\circ}34'$: $25^{\circ}41'$ and $91^{\circ}49'$: $91^{\circ}56'$ around Umiam Lake. The area comprises parts of Bhoi C-D Block, Mawphlang C-D Block, Myllem C-D Block and Shillong U.A.

OBJECTIVE

The aim of the present study is:

- 1) Identification and classification of different landforms and geomorphic domains in the area. To Study their characteristics and evaluation.
- 11) To study the nature of various geomorphic processes involved in developing the diverse landforms in the area.
- 111) To have weathering characterisation in the area.
- iv) To study the fluvial morphology and drainage system characterisation.
- v) To study the environmental degradation in the area.

PLAN OF WORK

The work was carried out in three phases viz:

- (1) Pre-Field Phase
- (2) Field-Work Phase
- (3) Post-Field Phase

To understand the geomorphology, the following inter-related aspects were studied, (1) Geology, (2) Landforms, (3) Relief, (4) Slope, (5) Weathering, Soil and Mass Wasting, (6) Fluvial Processes and (7) Environmental degradation.

Geology: Physiographically, it forms part of the Peninsular shield lying south of the northeastern Himalayas. It is

a horst forming plateau region block uplifted since Mesozoic. The Kernel of the plateau comprises the oldest rocks in the state i.e. the Gneissic Complex along with Shillong Group of rocks. The southern fringe of the massif has Cretaceous-Tertiary Sedimentary pile.

The Meghalaya Plateau has a chequered evolutionary history of emergence, submergence and peneplanation with several phases of erosion, sedimentation, diastrophism and intrusion.

The rocks of this shield area has experienced complex folding and faulting which is very clearly evident from the lineament map.

The landscape of the plateau is controlled mainly by its geological history.

The area of study falls in the central part of the plateau comprising mainly Shillong Group of rocks. However, its northwestern corner is represented by Gneissic complex. Significantly the varied geology has controlled the evolution of landforms in the area.

Landforms: Geomorphologically, the area is divided into two domains.

(1) Plateau Domain

(2) Hill Domain

Each domain is characterised by distinct landforms. The plateau domain is divisible into dissected plateau and plateau plain depicting following landforms:

(1) Plateau Relicts, (2) Linear Ridges, (3) Escarpments (4) Gorges, (5) Stream valleys and (6) Quaternary Terraces.

The Hill domain depicts the following landforms:

(1) Hummocks, (2) Dissected Hills, (3) Hummocky Ridges, (4) Escarpments, (5) Gorges (6) Elongated Valleys, (7) Lake and (8) Recent Terraces.

The important minor Landforms and micro relief features identified in the area are (1) Subdued Ridges and Elongated Depressions, (2) Colluvial Fans, (3) Gullies and Spurs, (4) Terracettes, (5) Micro scarps, and (6) Gully and Stream channels.

Relief: The different geomorphological features in any area have relief manifestation on different scales. The relief is based on differences in elevation. The important relief elements are absolute relief, relative relief and altitudinal

distribution. The relief analysis of the area has helped in revealing the evolution of different relief features in the area.

The area has lowest elevation (880 m) in the north-western corner of the area. Significantly this is underlain by Gneissic Complex. In general, the absolute relief rises towards south. The height group of above 1600 m occurs as patches towards the southeastern corner of the area only.

The lowest relative relief of less than 50 m is confined in the northwestern corner, the central part and southeastern corner of the area. In the area of study, the relative relief increases with rise in absolute relief.

The altitudinal distribution reveals erosion surfaces occurring at different levels. These topographic terraces appear to be structurally controlled. The relief analysis also brought out a hidden or concealed graben^e structure.

Slope: Slopes are fundamental elements of landscape. Slope analysis revealed seven categories of slope in the area as per classification of Young (1972).

The level to gentle slope (5°) category is mainly

confined in the central part of the study area. Significantly this is the sector where the Umiam Lake is located and the river Umiam debouches into the Lake. Rest of the categories are distributed throughout the area.

The co-efficient of correlation between absolute relief and slope is +0.46 indicating moderate correlation. It implies that the slope does rise to some extent with rise in absolute height in the area. A general pattern of slope rise is exhibited (moderate to steep slopes). However, elevation above 1600m do not have steep slopes but, have only moderate slope. This is typical of plateau regions where the ridge tops have smooth sky line or profiles. The co-efficient of correlation between relative relief and slope is +0.774 indicating fairly good correlation. This value of co-efficient of correlation is due to the fact that the area forms part of a dissected plateau with deep incision i.e. high relief.

The natural slope profile is seen at places modified due to the interference of 'man'. The sections in the vicinity of developmental schemes show modified slope profile particularly in the areas which have been denuded of vegetation and where there are unsystematic slope cuttings.

Weathering, Soil and Mass Wasting: These three phenomena occur in nature in a sequence. Weathering is the initial phase in the denudational history of any landscape as, rocks must be weathered before the debris can be transported. The difference in physical weathering is more pronounced than the difference in chemical weathering in the area. It is attributed to the variation in lithotypes and their structural disposition.

The study area shows little variation in respect of climatic factor (rainfall, temperature and humidity). Geologically also, the different rock types show gross homogeneous characters and more or less similar uniform weathering phenomena. Consequently, the resultant soil profiles more or less have similar characteristics. The soil has predominantly formed by the in situ weathering of the rocks. They have variable colours both at surface and subsurface depending upon the degree of oxidation of Fe-Mg-Mn bearing mineral phases. The soils are strongly acidic throughout the solum.

Mass wasting is an important gravity controlled movement of materials over the earth's surface. In the study area, the landslides prone zones are confined within the Shillong Group of rocks. About 22 slides have been recorded

in the area. The slides are mostly slumps, debris slides and rock slides. Landslides are more frequent where the developmental activities have modified slope profiles. This makes the slopes unstable with a tendency to fail as and when the equilibrium is disturbed.

Fluvial processes: The area by and large forms part of Wah Umiam basin. fluvial parameters help in evaluating landforms, landforms evolving from same geological processes and material possess a high degree of geometrical similarity. Understanding these processes helps in recognition and classification of landforms.

The different morphometric characteristics have been evaluated in the area. The highest order stream, is the 6th order Wah Umiam. The drainage network in the area show structural adaptation in conformity to the dominant structural trends (lineaments). The drainage density, drainage frequency maps have been prepared. It is seen that the northern half of the area has relatively lower drainage density and drainage frequency in comparison to the southern half. The drainage density and relief variables show low correlation. It is due to the fact that the terrain has suffered rejuvenation and the drainage is yet to stabilise.

Environmental Degradation: The uncoordinated exploitation of land resources has led to serious environmental degradation of the area. The area has suffered large scale deforestation of primary forests during the last five to six decades. Coupled with this is the problem of garbage disposal attendant with rapid urbanisation.

The study has brought out the variation in land use between the census period of 1911 and 1961, the attendant upland erosion has threatened the life span of the Umiam reservoir due to sedimentation and silting.

CONCLUSION

From the present study, the following conclusions can be drawn:

- 1) The area has two distinct geomorphic domains (Plateau and Hill domains), each having its characteristic landforms.
- 2) The relief (absolute as well as relative) rises from north to south. The Umiam lake low land is confined in the Graben, located in the central part of the area.
- 3) Seven slope categories varying between below 5° to above 30° have been identified in the area. A general pattern of slope rise with rise in absolute relief is observed. But, elevation above 1600m does not have steep slopes. The slope also rises significantly with rise in relative relief.

- 4) The selva climate of the area has formed deep chemical weathering and undifferentiated soil profile. Twenty-two number of landslides are identified in the area which are linked to developmental activities in the area.
- 5) The drainage network of the area show strong structural adaptation in conformity to the lineaments of the Meghalaya massif.
- 6) Indiscriminate land resource exploitation during the last 5-6 decades in the area has resulted in serious ecological imbalances. The attendant upland erosion coupled with unscientific garbage disposal associated with rapid urbanisation is posing serious threat to Umiam Lake environment. After formation of the Lake, large segments of agricultural land has been submerged under the lake.

RECOMMENDATIONS

To check further environmental degradation in the area, following strategy is suggested:

- 1) Terrain characterisation should be made, based on geomorphic parameters to identify different hazard prone zones for rationalising land use in the area.
- 2) Ban on all constructional activities along NH-40 to avoid initiation of landslides.
- 3) The landslide (much) should not be dumped down slope as it enhances silting problem of Umiam Lake. Suitable schemes may be formulated to dispose off this muck.

- 4) The existing garbage disposal system may be stopped forthwith. Alternative available technologies may be utilized for disposal or biogas/compost conversion.
- 5) In the catchment area of the Umiam Lake, to check vigorous soil erosion, large scale planned afforestation programme should be undertaken by the MSEB authorities.
- 6) Keeping in mind the seriousness of silting problem of Umiam Lake the Meghalaya Government should initiate a correct assessment of silting taking place per year and accordingly take the remedial measures to minimise the silting problems.
- 7) The expansion of settlements in the Umiam Lake catchment should be allowed as per terrain "characterisation" only.
- 8) Modern technology should be utilised for waste disposal to avoid silting and pollution in the lake ecosystem.

ACKNOWLEDGEMENT

I am indebted to Prof. R.K. Rai, Department of Geography, North-Eastern Hill University, Shillong for his valuable guidance during this work.

Thanks are due to Dr. R. Gopalakrishnan, Head of the Department of Geography, North-Eastern Hill University, for providing necessary facilities to complete the work.

Dt. 29 September 1989

Mandira Agarwal
Mrs. Mandira Agarwal

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Prof. R. K. RAI

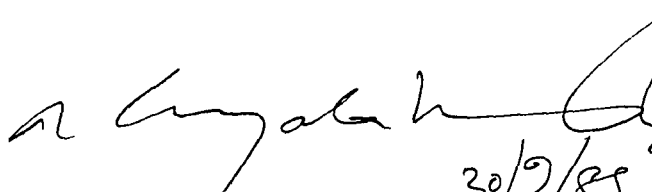


DEPARTMENT OF GEOGRAPHY
North-Eastern Hill University
Nongthymmai, Shillong
PIN 793 014

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Certificate

This is to certify that the dissertation entitled "*Geomorphological Studies Around Umiam Lake and Adjoining Areas, East Khasi Hills, Meghalaya*" submitted by Mrs. Mandira Agarwal in partial fulfilment of the degree of Master of Philosophy of the Department of Geography, School of Environmental Science, North-Eastern Hill University, Meghalaya is a bonafide study of the author carried out under my supervision and guidance. The matter embodied in this dissertation has not been submitted by her for the award of any other Degree or Diploma.


30/9/89.
R.K. Rai
(R.K. Rai)
SUPERVISOR

 R. Gopalakrishnan
HEAD
Department of Geography
North-Eastern Hill University
Shillong- 793014

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SHILLONG
The 29th September, 1989

Mandira Agarwal
Mrs. MANDIRA AGARWAL

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INTRODUCTION

Within the contemporary concern for environmental management many problems relate to the interaction between man, land and water. Geomorphology normally involves a study of land and water and frequently recognises that when man uses land he has to accommodate its relief, materials and water resources to his purposes, for which man has to understand the geomorphology of the area he desires to harness.

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The area around Umiam lake has been selected for the present study mainly because it offers variety of landforms in diverse geological milieu. The area is also, landslide prone and offers excellent opportunity to study landslide hazards under varied geological conditions and, the impact of developmental schemes in initiating them.

The hydroelectric in the area has exposed many new geological sections in an otherwise covered terrain. Thus the study area offers better and accessible geological segments to understand geomorphology and its impact on environment resource management.

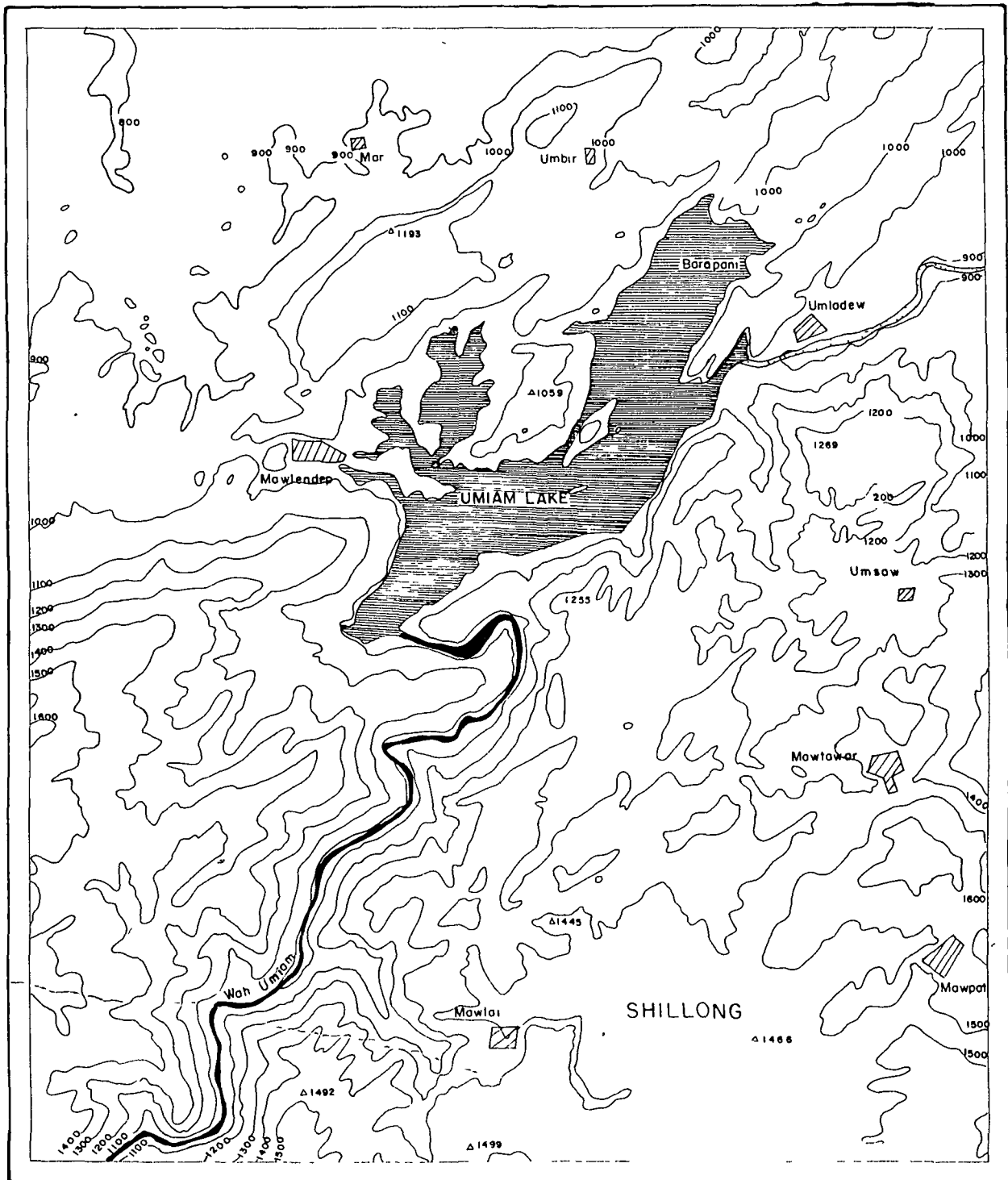
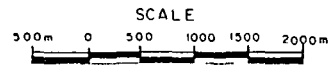
THE AREA OF STUDY

The area of study falls in the Survey of India toposheet No 78 0/14. The area covers 143 sq.km. around Umiam Lake. It is bounded by coordinates $25^{\circ}34':25^{\circ}41'$ and $91^{\circ}49':91^{\circ}56'$. The area comprises parts of Bhoi C-D Block, Mawphlang C-D Block, Myllem C-D Block and Shillong U.A. (Fig.1). Physiographically the area is bounded by Um Rileng in the northwest, Um Tru in the north, Wah Tamdong in the east. Um Khen in the southeast, Upper Shillong-Laban-Laitkor ridge in the south and Um-Diengdoh in the southwest. Some of the important villages in the study area are Barapani, Mairung, Mawlai, Mawlong, Umbir, Umladew, Umraleng, Umsaw, Umsawlum etc. The general topography of the area is shown in Fig.(2). The important township of Shillong falls in the south east corner of the study area. It is connected with Gauhati by National Highway No.40. Barapani is about 18 km. from Shillong and is easily accessible by the National Highway No.40.

PHYSIOGRAPHY

Physiographically, Meghalaya represents a remnant of an ancient plateau of pre-cambrian Indian Peninsular shield, block uplifted to its present height of about 600-1900 metres above sea level. Shillong peak, the highest spot over the plateau is 1951 metres above mean sea level.

GENERALISED TOPOGRAPHY OF BARAPANI AREA



INDEX

Fig (2)

- | | |
|---|-----------------------------|
| Village | Spot Height in Metres |
| Triangulation Station
Height in Metres | Umiām Lake |
| Wah Umiām | Contour Interval 100 Metres |

The Kernel of the Plateau is comprised of the oldest rocks in the state, the Gneissic Complex along with Shillong group of rocks.

The ancient peneplaned surface of the plateau is still preserved, with marks of different cycles of denudation, in the central and northern part. It is hidden beneath the Mesozoic traps along the central southern fringe and Cretaceous Tertiary and post-Tertiary sediments over the south, southern and southwestern parts. The plateau forms a watershed between the Surma Valley of Bangladesh on the south and Brahmaputra valley on the north. It is severely dissected by several rivers and a network of their tributaries and lateral streams.

The Shillong plateau is a horst which has been block uplifted during post Mesozoic time (Mazumdar, 1978) to its present height and its tectonic history begins with the effusion of Sylhet-traps- through fractures and faults in the basement and uplift and subsidence of adjacent basement blocks. In the western part of plateau in Garo Hills, the Tura range is a horst which is bounded to the south by the Dapsi Fault.

Thus, Meghalaya plateau has indeed a chequered evolutionary history of emergence, submergence and peneplanation

with several phases of erosion, sedimentation, diastrophism, intrusion, movement of land and sea. The plateau has experienced the influence of an alternate phase of transgression of sea waters from mesozoic to early tertiary.

Based on the above facts, Meghalaya plateau has been divided as upper, middle and lower plateau (Fig.3). The upper plateau ranges from 600m to 1900m. elevation above mean sea level. The middle plateau is ranging from 300m to 600m. elevation above mean sea level and the lower plateau ranges from 100m to 300m elevation above mean sea level. Some high undulations having very steep slopes are present over the plateau at some places which is due to local horst and are full of pine trees in eastern part of Meghalaya. The western part have mixed forest with bamboo as a common species. On the north, broken ranges of irregular hills are stretching across Assam. Low round topped hills are present in the south and southeastern border of the entire plateau. At some places in central and south eastern plateau, magnificent gorges, more than 600m deep are present. Thus the main physiographic units in the entire plateau are based on the degrees of undulations and slopes which is the net result of severe dissection by streams, rivulets and rivers. The undulations mostly have rounded tops in the northern part of the plateau which represent gneissic complex.

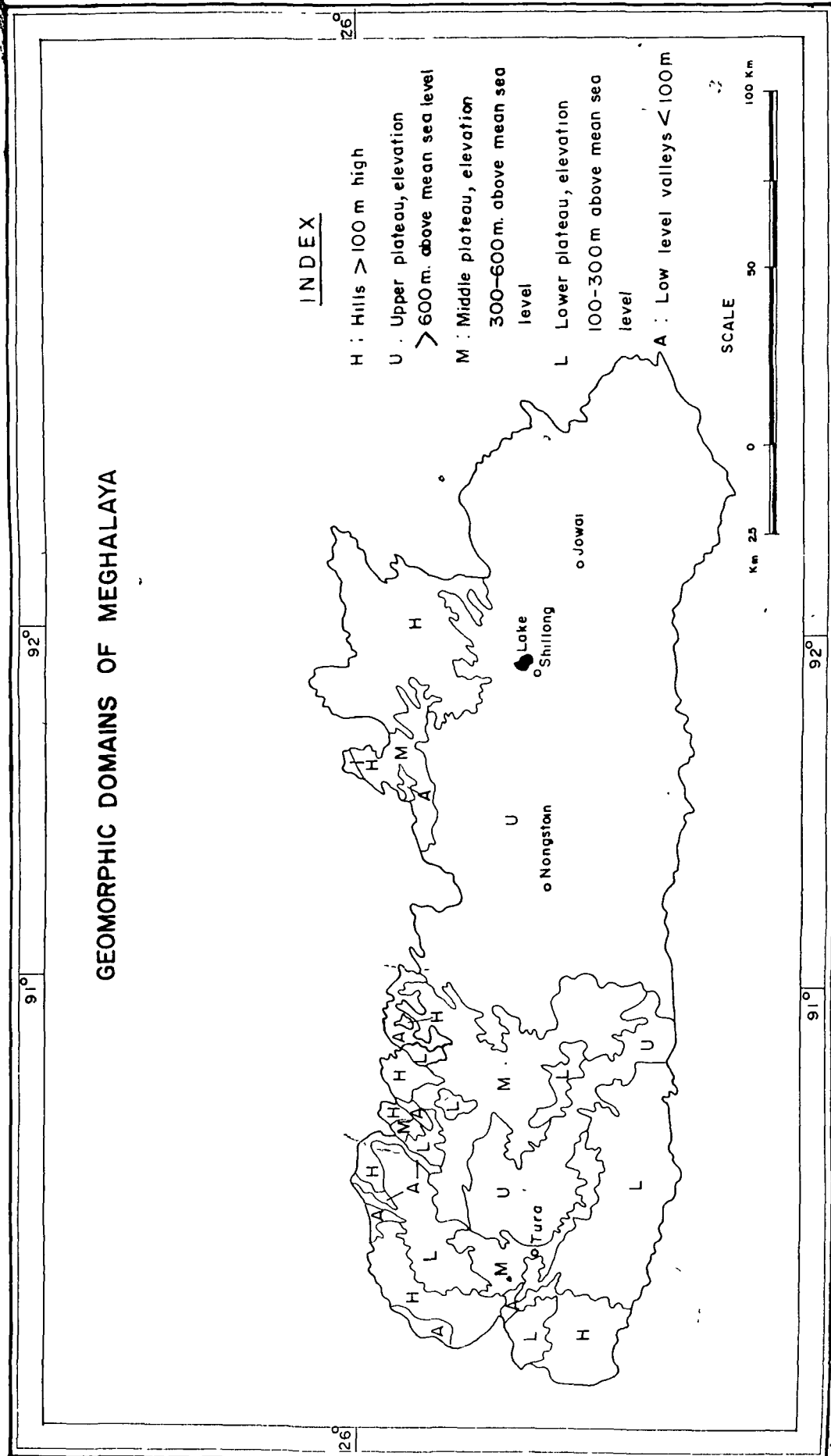


Fig (3)

Fig. (P1)

Umiam Lake formed
by damming Wah
Umiam (left corner).
Fore ground showing
slope 'forms'.

Fig.(P2)

Pine forest devoid of
undergrowth (north
of Mawlai).

The major physiographic units are as follows:

- A. Upper Plateau, Middle Plateau and Lower Plateau of Gneissic Complex.
- B. Upper Plateau of Shillong Group.
- C. Upper Plateau, Middle Plateau, and Lower Plateau of Granite.
- D. Upper Plateau, Middle Plateau and Lower Plateau of sedimentary sequence (Cretaceous-Tertiary), mostly concentrated on southwest, south and southeastern part of the plateau.
- E. Valleys.
- F. Piedmont zone - mostly concentrated on the northern border of the plateau.
- G., Alluvial Plains.
- H. Hills.

FLORA AND FAUNA

Most of the ridges in the area comprising Shillong Group of Quartzite and sandstone support luxuriant vegetation. In general, the ridge slopes above 900m have mainly pine forests (*Pinus Longifolia* and *Pinus Khasiaea*). These pine forests largely are devoid or are poor in bushy undergrowths (Fig.P2).

The ridge slopes below 900m generally contain mixed forests of Bamboo, rhododendron, camellia and bushy undergrowths. Large tract of the hill slopes have been deforsted

by "Jhuming" or shifting cultivation and timber exploitation.

The fauna is represented by bears, deers, leopards and wild cats and different species of birds.

CLIMATE

The area experiences tropical monsoon climate. It has two seasons for rains i.e., from May to September and December to February. The average monthly rainfall at Barapani for last 32 years (1957 to 1988) is given in Table (1).

A perusal of Table (1) reveals that for the period of last 32 years, the average annual rainfall in the area is 2176 mm with highest rainfall of 3317 mm in 1988 and minimum rainfall of 1537 mm in 1975. It is seen that the months of May to October (6 months period) have contributed maximum rainfall (87.6%). During the last 32 years, the month of January has contributed minimum rainfall of 11.6mm and the month of June has contributed the maximum rainfall 402.2mm.

The mean monthly minimum and maximum temperature at Barapani for last 3 years (1986 to 1988) is given in Table (2). The average minimum and maximum temperature for the period is 7.2°C during January and 27.2°C during

TABLE - 1
Monthly rainfall(mm) at Barapani (Meghalaya) India from 1957-1988

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1957	88.9	9.9	13.3	-	155.7	405.1	148.8	508.3	513.6	177.8	22.1	7.1	2051
1958	1.3	58.7	43.2	196.1	214.6	417.8	200.2	375.7	412.8	269.2	17.8	2.5	2210
1959	17.8	53.6	61.7	148.6	157.2	416.8	240.0	245.1	437.6	480.1	42.7	0.8	2302
1960	-	17.8	37.6	15.7	188.7	221.7	359.7	236.2	598.2	87.4	63.5	4.6	1831
1961	4.3	15.0	35.8	46.2	454.9	311.4	215.9	294.6	303.5	185.4	105.2	9.7	1982
1962	12.2	74.4	24.4	180.3	197.6	297.2	215.9	399.5	236.7	135.6	14.0	-	1788
1963	3.0	-	68.1	163.1	343.2	762.0	397.0	255.2	433.3	254.0	98.8	4.8	2783
1964	-	-	76.5	196.6	328.2	225.0	417.1	274.1	364.0	298.7	124.0	2.0	2306
1965	3.6	21.1	63.8	81.3	409.7	282.2	181.6	325.4	297.4	137.9	61.5	2.3	1868
1966	18.8	-	4.1	35.8	147.6	561.8	265.2	467.1	113.8	359.9	65.3	10.2	2050
1967	14.2	7.1	64.3	116.6	190.0	309.4	475.5	175.5	439.4	121.2	90.9	-	2004
1968	4.6	9.9	77.0	142.2	191.5	499.1	484.4	370.3	322.6	67.3	11.9	1.3	2182
1969	6.9	-	87.6	65.5	355.1	273.8	416.3	264.2	295.7	183.9	19.6	8.4	1977
1970	27.2	9.7	0.8	32.0	156.7	771.7	611.4	339.9	334.5	414.5	34.3	9.1	2741
1971	4.1	1.8	4.6	214.9	241.8	352.3	226.8	206.0	462.3	205.0	166.4	4.1	2090
1972	10.4	25.4	19.6	104.4	122.9	576.8	279.4	292.6	362.2	103.6	1.0	2.3	1901
1973	0.5	55.9	17.0	105.2	261.1	571.0	296.7	221.5	198.1	217.4	82.3	21.8	2049
1974	12.2	-	113.8	71.1	434.3	324.1	649.7	301.8	307.6	472.4	-	-	2687
1975	-	14.2	13.2	7.4	125.0	351.8	320.3	116.3	370.1	192.5	15.7	10.9	1537
1976	26.2	15.2	2.3	77.2	261.4	456.4	214.4	314.6	241.3	155.7	15.5	27.7	1808
1977	-	4.8	41.4	240.0	414.5	296.7	298.5	261.4	191.3	244.6	134.4	50.3	2178
1978	13.7	7.1	18.8	77.7	310.6	370.3	403.6	199.6	180.8	148.3	85.1	-	1816
1979	-	19.3	0.5	148.6	19.3	327.4	452.9	178.1	344.9	291.1	23.1	72.4	1878
1980	1.0	28.4	27.2	27.8	360.2	573.0	299.0	275.1	298.2	217.7	-	17.0	2125
1981	39.6	14.7	79.2	172.0	331.0	352.8	418.1	401.1	285.2	7.1	5.6	61.0	2217
1982	2.3	1.0	31.9	131.3	110.0	522.2	467.1	553.5	253.5	140.2	148.6	6.6	2368
1983	5.1	32.0	39.9	106.9	196.3	224.3	561.8	327.9	365.0	313.4	34.8	31.8	2239
1984	20.8	-	12.7	104.6	226.3	196.3	761.2	331.2	376.2	170.7	3.0	14.5	2218
1985	0.6	31.1	40.0	211.5	205.8	423.3	296.7	403.5	372.6	190.8	42.3	16.2	2234
1986	4.9	3.8	19.4	141.0	328.9	195.0	203.9	334.1	455.5	516.6	101.6	4.4	2309
1987	11.1	79.9	106.7	161.6	122.2	420.6	511.1	536.9	451.9	117.9	27.6	28.7	2576
1988	14.1	38.4	44.8	116.8	640.5	579.4	619.1	594.7	262.8	183.0	196.4	26.6	3317
Average	11.6	20.6	40.4	113.8	257.9	402.2	372.2	324.4	340.1	220.7	58.0	14.4	2176

Source: MSEB & ICAR Research Complex, Barapani, Meghalaya.

TABLE - 2
Mean monthly temperature (°C) at Barapani

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1986	4.7	6.6	12.0	16.1	17.6	20.4	26.1	19.8	19.0	16.3	10.0	7.0
	20.3	21.3	25.3	26.1	25.8	27.6	27.1	28.4	26.0	25.0	21.8	19.9
1987	8.1	10.3	13.4	17.3	19.2	21.2	22.3	21.2	20.8	17.1	14.1	9.0
	18.7	20.7	21.7	25.7	26.7	26.4	27.4	26.8	25.6	23.7	22.6	19.8
1988	8.7	10.6	13.8	18.3	18.9	21.1	21.4	21.7	20.6	18.1	13.0	9.0
	18.4	21.4	24.0	27.1	26.1	27.1	26.8	26.5	26.5	25.4	23.7	20.2
Average	7.2	9.1	13.0	17.2	18.6	20.9	23.3	20.9	20.1	17.2	12.4	8.3
	19.1	21.1	23.7	26.3	26.2	27.0	27.1	27.2	26.0	24.7	22.7	20.0

TABLE - 3
Minimum relative humidity (%) at Barapani (0830 hrs.)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1986	90.0	67.0	57.0	69.0	72.0	77.0	82.0	84.0	81.0	78.0	79.0	81.0
1987	74.0	69.0	69.0	69.0	71.0	78.0	82.0	83.0	82.0	76.0	81.0	80.0
1988	75.0	70.0	63.0	67.0	79.0	79.0	82.0	84.0	80.0	82.0	78.0	80.0
Average	79.6	68.7	63.0	68.3	74.0	78.0	82.0	83.6	81.0	78.7	79.3	80.3

Source: MSEB & ICAR Research Complex, Barapani, Meghalaya.

August. However, for this three years period, January 1986 had the minimum mean temperature of 4.7°C and August 1986 had the maximum mean temperature of 28.4°C .

The mean monthly minimum relative humidity variation at Barapani for last three years (1986 to 1988) is given in Table (3). The lowest monthly minimum relative humidity is recorded 63% during March and highest monthly minimum relative humidity is recorded 83.6% during August. However, the lowest monthly minimum relative humidity has been recorded as 57% in March 1986 and monthly maximum relative humidity of 90% is recorded in January 1986.

The temperature and rainfall variations are shown in Fig.(4). The average monthly rainfall for last 32 years and minimum-maximum temperature for last three years are plotted over the climate process curve of Fairbridge (1968). It indicates that the area represents 'Selva climate process system' Fig.(5).

PEOPLE AND OCCUPATION

The area (Fig.1) of study comprises parts of Bhoi C-D Block (21%), Mawphlang C-D Block (0.5%), Myllem C-D Block (64%), and Shillong Urban Agglomeration (14.5%). Hence the study area population consists of people from these four components. Religion wise the people are repre-

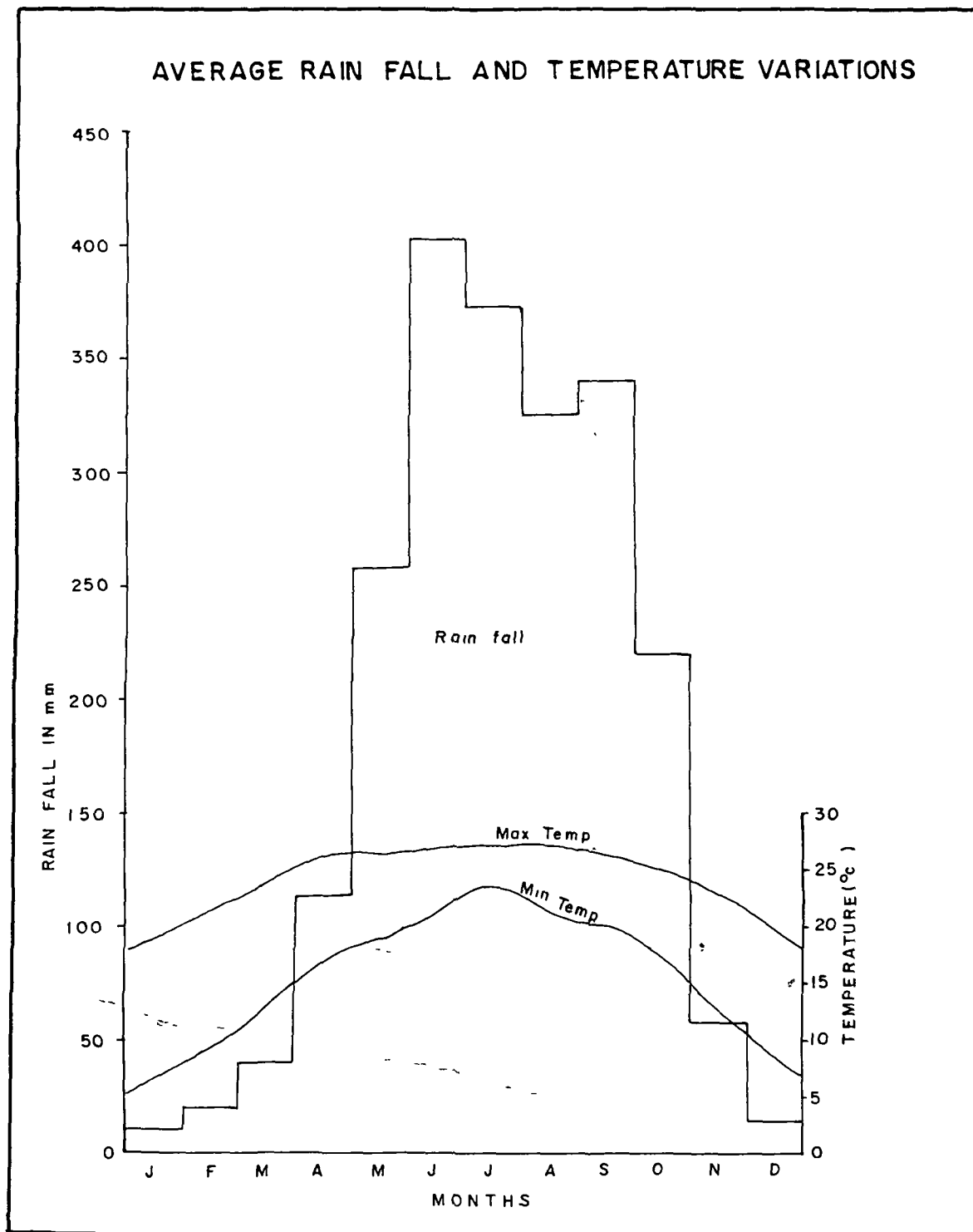
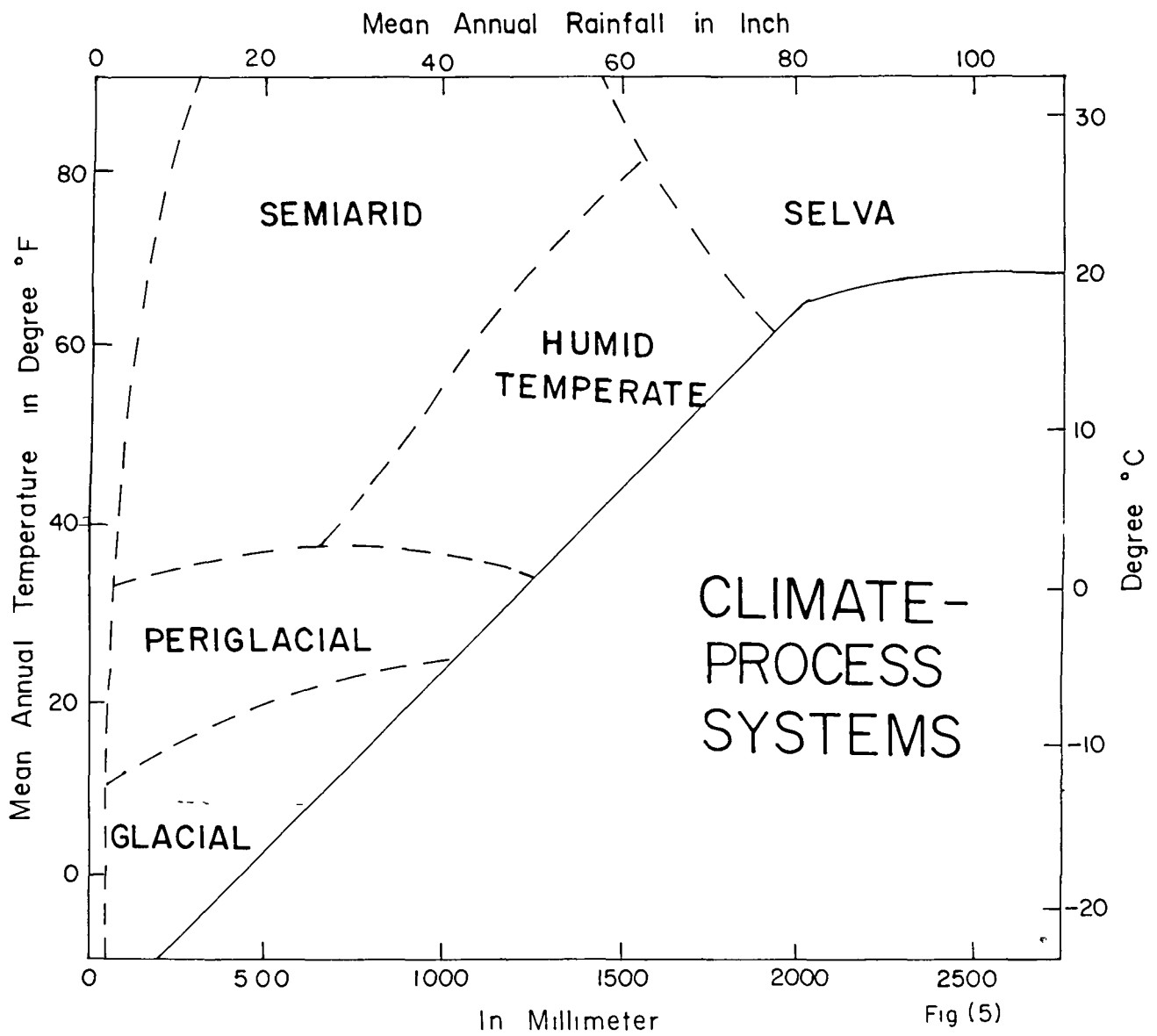


Fig (4)

POSSIBLE CLIMATE PROCESS SYSTEMS

(After Fairbridge, 1968)



sented by Christians, Hindus, Khasis etc. Language wise the people can be differentiated as Khasi, Garo, Bengali, Nepali, Assamese and Hindi speaking.

The population distribution with comparative population statement is given in Table (4). About 78% of the area falls in Myllem C-D Block and Shillong U.A., showing highest density of population (290 & 6878 respectively) of 1068 against the State average of 60 and District average of 98. The decadal change in population is lowest in Myllem C-D Block while it is highest in Shillong U.A. in comparison to State and District averages.

Significantly Myllem C-D Block together with Shillong U.A. represents higher S.C. population ratio and lower S.T. population ratio. This is mainly due to large segregations of 'other' denominations in the area.

The working population is also lower in comparison to State and District averages. It comprises agriculture labourers, cultivators mainly in Myllem C-D Block and industrial workers, processing & repairing workers and 'other' workers engaged in miscellaneous activities. The rural working population is by and large engaged in 'Jhuming' or shifting cultivation activities as low level plain agriculture land is hardly available.

TABLE - 4

Block wise population distribution

Administrative Unit Parameters	Meghalaya State	East Khasi Hills District	Bhoi C-D Block	Mawphlang C-D Block	Mylliem C-D Block Excluding Shillong U.A.	Shillong Urban Agglomeration
Area	22,429 sq.km.	5,196 sq. km.	1,225 sq. km.	249 sq. km.	189.8 sq. km.	25.40 sq. km.
Persons	13,35,819	5,11,414	60,378	29,455	55,089	1,74,703
Male	6,83,710	2,62,952	31,374	14,804	28,221	91,728
Female	6,52,109	2,48,462	29,004	14,651	26,868	82,975
Persons	10,94,486	3,30,614	60,378	29,455	55,089	-
Male	5,56,958	1,68,158	31,374	14,804	28,221	-
Female	5,37,528	1,62,456	29,004	14,651	26,868	-
Persons	2,41,333	1,80,800	-	-	-	1,74,703
Male	1,26,752	94,794	-	-	-	91,728
Female	1,14,581	86,006	-	-	-	82,975
Density Per sq.km.	60	98	49	118	290	6,878
Decadal change in population (1971-1981)	+32.04	+32.64	+44.33	+39.66	+21.61	+42.32
Sex Ratio	954	945	924	990	952	905
Total	965	966	924	990	952	-
Rural	904	907	-	-	-	905
Urban	5,048	1,227	256	113	64	-
Total	4,902	1,189	248	112	64	-
Inhabited	146	38	8	1	-	-
Uninhabited	6,13,441	2,12,853	28,082	15,544	22,195	57,285
Total	45.92	41.62	46.51	52.77	40.29	32.79
Work Force	4,55,191	2,23,618	16,474	7,602	22,796	1,14,697
Total no. of literate persons	34.07	43.73	27.28	25.81	41.38	65.65
Literacy %	5,492	1,480	21	-	272	1,063
S.C.	0.41	0.29	0.04	-	0.49	0.61
Total	10,76,345	3,74,081	46,451	28,945	38,369	85,833
%	80.58	73.15	76.93	98.27	69.65	49.13
S.T	2,53,982	1,35,833	13,906	510	16,448	87,807
Total	19.01	26.56	23.03	1.73	29.86	50.26
Others						

Source: Census of India, 1981, East Khasi Hills district, Series 14, Part XIII-A&B.

PREVIOUS WORK

Oldham (1858) was first to visit Khasi Hills to document the geology of this part of the region. Subsequently Medlicott (1869), Palmer (1923), Evans (1932), Das Gupta (1934), Khedkar (1936), Ghosh (1952), Gogoi (1975), Mazumdar (1976, 1986) have unravelled the geological history of Khasi Hills. But, so far, not much published information is available on the geomorphology of the area. Mazumdar (1986) has however given a very generalised regional physiography of Meghalaya.

WORK PROCEDURE

The present study comprises the following three component activities.

- (a) Pre-Field Phase
- (b) Field Work Phase
- (c) Post-Field Phase

(a) Pre-Field Phase:

Initially the available literature was consulted which contributed significant data. This helped in the planning for the subsequent work. The basic objective during this stage was collection of secondary data (Geological, Meteorological, Climatological etc.), procurement of relevant toposheets, aerial photographs, maps and relevant literature

and synthesis of data. Preliminary database was prepared aided with photointerpretative map. During this stage of work, general landform units were identified in the area with the help of aerial photographs and satellite imageries. During this phase, pre-field laboratory work was carried out for relief analysis, slope analysis and drainage analysis.

(b) Field Work Phase:

On the basis of Pre-field work database, field work was carried out in critical sectors to collect primary data particularly lithological, structural, soil-weathering characteristics for the synthesis and interpretation. During this phase micro-relief features and land slide zones were also identified and documented. Representative landforms, geological sections and related features were photographed for documentation.

(c) Post Field Phase:

In this phase all data were classified and tabulated wherever necessary. The preliminary photogeomorphic maps were corrected and supplemented with the field data and final maps were prepared depicting distribution of geological units and geomorphic characteristics. The data was synthesised for interpretation and presentation of results.

SCOPE OF THE PRESENT WORK

The main objective of the present study is enumerated below:

- i) Identification and classification of different landforms and geomorphic domains in the area. To study their characteristics and evaluation.
- ii) To study the nature of various geomorphic processes involved in developing the diverse landforms in the area.
- iii) To have weathering characterisation in the area.
- iv) To study the fluvial morphology and drainage system characterisation.
- v) To study process of silting of Umiam Lake and make environmental appraisal.
- vi) To make a comparative study of the area before and after the formation of the lake.
- vii) To assess the impact of geomorphology on developmental schemes in the area and to evaluate the effects of these schemes on existing landforms.

PLAN OF WORK

For the appraisal of different landforms in the area, the study has been divided into nine chapters. The first chapter defines the nature of work, location of the area, its physiographic entity in relation to the Meghalaya plateau.

In the second chapter, geological setting has been described. The regional geological framework and regional tectonic evolution of Meghalaya plateau is discussed. Subsequently the geology of the area is described.

Chapter three deals with geomorphic characters of the area. Different landforms, erosion surface and micro relief is discussed. The evolution of different landforms is described in this chapter.

In chapter four, relief analysis is discussed. Absolute Relief, relative relief, of the area is described in relation to geology of the area and both the relief variables are correlated.

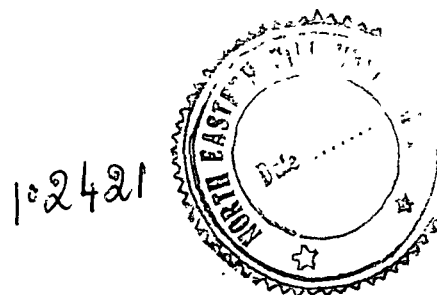
The chapter five deals with slope analysis. The average slope categorisation of the area is discussed and the slope categories with absolute relief and relative relief are correlated, quantitatively.

In the chapter six weathering, soil characteristics and mass wasting are discussed. The lithogroup wise weathering and soil characteristics are described. The different land slides seen in the area are enumerated.

Chapter seven deals with fluvial morphology of the area. It describes the drainage analysis and enumerate the important morphometric parameters in relation to geology of the area.

The chapter eight deals with the processes of environmental degradation in the area. An attempt has been made in this chapter to evaluate the silting of the Umiyam Lake based on empirical parameters.

The last chapter i.e. chapter nine synthesises the summary and conclusions for harnessing land resource in the area in a meaningful way.



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CHAPTER - II

GEOLOGICAL SETTING

(A) REGIONAL GEOLOGY OF MEGHALAYA

Geological framework of Meghalaya is now well known. Geographically, the state covers an area of 22,429 sq.km. Physiographically it is part of peninsular shield lying south of the North Eastern segment of the Himalayas. It forms a prominent geomorphic unit stretching across the Garo-Khasi-Jaintia Hills in E-W direction. According to Murthy et al. (1976) and Mazumdar (1986) Meghalaya massif is a geomorphic arch bounded on all sides by faults. The southern boundary is the famous Dabki fault. The northern boundary is marked by the Brahmaputra lineament. To the west the massif is detached from the main Indian shield by the N-S trending Rajmahal Garo lineament. The eastern boundary is a NE-SW lineament separating the massif from the sediments of Bengal-Assam shelf. As such the Meghalaya massif is a horst, forming a plateau region block uplifted to its present height about 600 m to 1900 m above m.s.l.

Oldham (1858) was the first to initiate the geological work in Meghalaya after the inception of Geological Survey of India in 1851. He came to Cherrapunji from Rangpur in the erstwhile Bengal State now Bangladesh. He was followed

by Medlicott (1869). In the post independence period large areas of Meghalaya have been mapped by the officers of the G.S.I. and the geology of Meghalaya is very well established (Fig.6) by now. However, due to restricted area provisions much of the information is classified and unpublished. The compiled geological framework of Meghalaya is given by Anon (1974), Murthy et al. (1976a, 1976) and Mazumdar (1986). The generalised stratigraphic succession is given in Table (5). The different lithostratigraphic groups are described below.

THE GNEISSIC COMPLEX

The Gneissic Complex is exposed in the central and northern parts of the Meghalaya Plateau. This has often been referred to as "Archaean Gneissic Complex" or "Precambrian Gneissic Complex" (Anon 1974, Murthy et al. 1976). As per the Geological Society of America, Geologic Time Scale, 1983 'Archaean' has to be used only for rocks older than 2500 m.y., which calls for geochronological data. In absence of such data this complex is being preferred to be called herein as **The Gneissic Complex**. It comprises schistose members as well as gneisses of varying composition. Gneisses are by far the dominant constituents of the complex represented by Biotite gneiss, Biotite granulite, biotite-hornblende gneiss, quartz-sillimanite gneiss etc., locally containing cordierite, garnet, clinopyroxene and chondrodite.

TABLE - 5

Generalized stratigraphic succession of Meghalaya
(modified after Anon 1974 and Majumdar 1976)

Recent	Newer Alluvium (Thickness not known)	Represented by sand, silt and clays
Pleistocene		Unconformity
	Older alluvium (Thickness not known)	Represented by sand, clay, pebble, gravel and boulder deposits
Mio-Pliocene		Unconformity
	Dupi Tila Group (approx. 1050m.)	Represented by unclassified mottled clays, feldspathic sandstone and diamictite.
Oligo-miocene		Unconformity
	Garop Group	Chengapara Formation : Represented by sand, siltstone clay & marl. (approx. 700m.)
Eocene		Baghmara Formation : Represented by feldspathic sandstone, pebble diamictite, clay, silty clay. (approx. 530m.)
		Simsang Formation : Represented by siltstone-sandstone alterations, sand. (1150m.)
	Jaintia Group	Kopli Formation (500m): Represented by shale, sandstone, marl.
		Sheila Formation : Represented by alternations of sandstone-limestone. (600m.)
		Langpar Formation : Represented by calcareous shale, sandstone, limestone. (100m.)

Table contd..

Table-5 contd..

Upper Cretaceous	Khasi Group	Mahadek Formation (150m.) Bottom Conglomerate : Represented by arkose (Glauconitic) (25m.) : Represented by conglomerate, arkose. Jadukata Formation : Represented by sandstone-conglomerate alter- (140m.) nations. Unconformity
Upper Cretaceous	Sung Valley Complex	Pyroxenite, serpentinite, syenite, carbonatite etc. Unconformity
Jurassic	Sylhet Trap (approx. 600m.)	Basalt, alkali basalt, rhyolite, acid tuff. Unconformity
Permo-Carboniferous	Lower Gondwana Group (approx. 200m.)	Sandstone, shale, conglomerate, coal. Unconformity
	Porphyritic Granitoid	These dot the Meghalaya Plateau. Those entirely within the Gneissic Complex and those intrusive into the Shillong Group, are of the same age. Because the South Khasi batholith transects both the older sequences. Intrusive Contact
Proterozoic	Khasi Greenstone	Basic sills and dykes mostly within the Shillong Group. Intrusive Contact

Contd....

Table-5 contd..

Proterozoic	Shillong Group	Formerly termed the 'Shillong Series'. They are a Conglomerate-sand stone - siltstone - shale rhythm. Weakly metamorphosed in the northern parts. Metamorphosed in Proximity with Porphyritic granitic plutons. Occurs as a cover on older rocks. Strike persistently NE with open folds alternating with zones of steep dips.
		----- Unconformity -----
Archaean	Nonporphyritic Migmatitic Granitoids	They are a variety of textural and compositional types developed exclusively within the gneissic complex where grade of metamorphism reaches amphibolite facies.
		----- Diffused Contact -----
	Gneissic Complex	Formerly described as "older gneisses" or "Gneiss series" or "Archeans". A telescoped sequence of stratigraphic, deformational and metamorphic events which needs further elucidation, mostly show only one phase of recrystallisation, probably due to a late major regional metamorphism. Augen gneisses, pre-tectonic with respect to this phase of deformation and recrystallisation, are considered relicts of a still earlier orogeny.

The schistose members are represented by amphibolite, mica schist, quartz-sillimanite schist, metabasite etc. locally with garnet, andalusite, sillimanite etc. The mineral assemblage within the gneisses and the schistose members indicate high P-T regime of regional metamorphism (upper amphibolite-granulite facies).

Structurally the Gneissic Complex shows very complex and polyphase folding concurrently with multistage metamorphism. Three phases of folding have been identified by Murthy et al. (op.cit).

- (i) The earliest is an isoclinal phase of broad recumbent-reclined folds regionally having E-W axial surfaces.
- (ii) The superposed tight isoclinal folds having ENE and NE axial surfaces.
- (iii) The third phase is marked by broad N-S warps.

The dominant S-surfaces within the Complex show NE-SW, E-W, N-S and NW-SE strikes in different sections due to the complex folding. The Gneissic Complex was cratonised prior to the initiation of the Shillong Basin.

NON PORPHYRITIC MIGMATITIC GRANITOIDS

This class of rocks occur throughout the Gneissic

Complex in all scales as veinlets, interfolial permeation, patches, lenses and small irregular bodies. Conspicuously it shows diffused boundaries with the rocks of Gneissic Complex often producing "Nebulites". These granitoids show the following three important variants and represent mobilizates of Mehnert (1969). These mobilizates have not permeated the Shillong Group of rocks implying that the attendant migmatization to be pre Shillong Group.

a) Dioritic Mobilizates:

It is a spotty or speckled rock. The spots arise because of aggregates, clots and knots of biotite, epidote, hornblende, magnetite, quartz, plagioclase and sphene etc. This texture is caused by decussate arrangement of the above minerals. Rest of the constituents of the rock are the same minerals that form the clots but, in random orientation.

b) Grano-Dioritic Mobilizates:

With the diminished proportion of the mafics particularly hornblende and relative increase of potash feldspar and quartz, the dioritic mobilizates pass into Grano-dioritic phase. It shows texture similar to Dioritic mobilizates.

c) Granitic Mobilizates:

These are typical granites, with or without foliation.

These rocks are medium grained and represent the latest (youngest) "Plutonic" magmatites. By far this is the dominant migmatite type within the Gneissic Complex and forms "Domes".

THE SHILLONG GROUP

It overlies the Gneissic Complex with an unconformity and comprises friable quartzite with subordinate phyllites, sandstone, siltstone, quartz-sericite schist and minor diamictite. The rocks occur in an NE-SW elongated tract in Khasi hills and extend upto the northwest fringe of Karbi-Anglong district (Mikir Hills) of Assam.

By and large the Shillong group of rocks are weakly metamorphosed except at few places showing higher grades. The primary sedimentary structures are well recognizable such as bedding, laminations, current bedding ripple marks and penecontemporaneous deformational structures etc.

The Shillong Group of rocks show a zone of subvertical dips with local reversals from west of Mawphlang to Barapani and its NE extension, away from this zone the dips show gentle rolling disposition. Such folding represents "Intermediate crestal type folding" of Belousov (1962).

THE KHASI GREEN STONE

The Khasi Green Stone occurs as isolated linear

bodies in the Shillong Group of rocks. These are intrusives both in the argillaceous and arenaceous facies of Shillong Group. The overall structural pattern suggests their phacolithic nature about a NE-SW axis, sending dikes and appophyses in the Shillong Group of rocks. The Khasi Green Stone are represented mainly by dolerite, epidiorite and amphibolite. The Khasi Green Stone has so far not been recorded from outside the Shillong Group of rocks (Murthy et al. 1976, Chattopadhyay and Awasthi, 1981). These metabasites appear to have been emplaced along tensional fracture system. At places granitoid leucosomes are seen premeating the Khasi Green Stone.

PORPHYRITIC GRANITOID

These occur as a large number of plutons of varying shapes and dimensions throughout Meghalaya. Some of the important plutons are -

- 1) Myllem Pluton
- 2) South Khasi Pluton
- 3) Nongpoh Pluton
- 4) Rongeng Pluton
- 5) Mawhati Pluton

These plutons are porphyritic, potash rich depicting large megacrysts of microcline in a groundmass of plagioclase, quartz, biotite and microcline.

Physiographically these plutons have domal expressions. Some of the Plutons particularly South Khasi and Myllem show intrusive relationship with Shillong Group of rocks. Available geochronological data has given an age of 607 ± 13 Ma (Chinote et al., 1988) to Myllem Pluton. The plutons exhibit crude foliation locally and homophanous nature at places. It is seen that some of the plutons have straight boundaries with the enclosing rocks viz., Gneissic Complex and the Shillong Group indicating diapiric emplacement along pre existing megafractures. According to Mazumdar (1976), these plutons are comparable in composition and diapiric emplacement to the porphyritic plutons of Assam, representing late tectonic events. As per Mazumdar (op.cit) the materials for these plutons were spread in the lower levels of the crust as thin sheet of appropriate composition and the event occurred after the emplacement of the Khasi Green Stone.

THE LOWER GONDWANA GROUP

It occurs in the Singrimari (Hallidayganj) area, at the western tip of Garo Hills, within 4 km. of Indo-Bangladesh border. The outcrop extends over a length of 1 km. and a width of 400m just east of Manikarchar road, Fox (1934) was the first to report the lower Gondwana rocks in the area.

The lower Gondwana Group is represented by Talchir and Karharbari Formations. The former is represented by basal tillites, sandstone with conglomerates, siltstone and shale. The latter is represented by very coarse to coarse grained-sandstone with conglomerate, siltstone, shale and coal.

The Talchir Formation unconformably overlies the Gneissic Complex and granitoids. It is conformably overlain by Karharbari Formation. The beds show a general N-S strike with dips of 10° - 20° towards west. West of Singrimari, the Gondwana beds get concealed under thick Brahmaputra alluvium.

THE SYLHET TRAP

The Sylhet Traps are exposed in a narrow E-W patch between latitudes $25^{\circ} 15'N$ and $25^{\circ} 12'N$ and longitudes $91^{\circ} 15'E$ and $92^{\circ} 15'E$ (Medlicott, 1869). They are of the nature of plateau flood basalts. The strip is about 80 km. long and 4 km. wide along the southern border of the Shillong plateau. The maximum exposed thickness is about 550 m-600 m. The traps overlies the eroded precambrian basement and underlie non-conformably the upper Cretaceous-Eocene sediment sequence. The sediments and the traps form a monocline becoming a flexure. At places the sediment cover is eroded away exposing traps as inliers.

The Sylhet traps comprises predominantly basalts and minor alkali basalts (nepheline tephrite), rhyolite and acid tuffs. They occur as flows and are 5m-7m in average thickness. They show flow breccias at their top. Texturally the traps show following variations:

- 1) Non porphyritic
- 2) Micro porphyritic
- 3) Mega porphyritic

The vesicles are filled by secondary quartz, calcite and zeolites. Basalt dikes are fairly common within the flows and in the adjoining in the Gneissic Complex. The dikes occur as swarms within the trap rocks. The general trend of the dikes is NNE-SSW, NE-SW and E-W in the Khasi and Garo Hills. At places alkaline rocks (Lamprophyres) are also seen as dikes in association, possibly related to the same event. The Sylhet traps are considered to be equivalent to the Rajmahal Traps (Jurassic). Radiometric ages vary from 92 ± 3 Ma for lower part to 138 Ma from different parts of the trap as per officers of G.S.I.

ULTRAMAFIC - CARBONATITE COMPLEX

This complex occurs in Sung valley in East Khasi Hills as an oval shaped body covering about 26 sq.km. It is intrusive into proterozoic Shillong Group. The complex is emplaced along the junction of two prominent lineaments

trending E-W and NNW-SSE of which the latter appears to be a major fault. Fission track dating of apatite from carbonate has given an Upper Cretaceous age (84 ± 13 Ma to 90 ± 10 Ma) for the complex (Chattopadhyay & Aashimi, 1984).

The major rock types in the complex are serpentinite, pyroxinites, syenite, carbonatite, etc. The body shows zoning and partial development of ring structure. A number of NE-SW trending faults effect the complex.

THE CRETACEOUS-TERTIARY SEDIMENTARY SEQUENCE

The Cretaceous-Tertiary Sedimentary pile occurs along the southern fringe of the Meghalaya Plateau. It is a thick and extensive sedimentary sequence, physically continuous with the Cretaceous-Tertiary sequence of the Bengal Basin. This sedimentary sequence is divisible into three groups, viz. Khasi Group, Jaintia Group and the Garo Group, respectively (Table-5). The interformational contacts within the pile is continuous without any sedimentological or faunal break. Recent work of the geologists of G.S.I. has placed the contact between the Cretaceous and the Tertiary at the base of the Langpar Formation of the Jaintia Group. This is based mainly on palaeontological studies as per U.K. Mishra of G.S.I. (Per. comm.).

The Khasi Group :

The Khasi Group represents the Cretaceous section of the pile and is represented by Jadukuta Formation, Bottom conglomerate Formation and the Mahadek Formation. The Jadukuta Formation overlies nonconformably the Sylhet Traps and represents an arenaceous facies composed of conglomerate at the base overlain by pebbly sandstone, coarse grained sandstone with carbonaceous streaks. This formation is limited to the north of the Raibah fault which formed the limit of the shore line. The progressive migration of the shoreline towards north is marked by the presence of thick conglomerate bed, north of the Raibah fault, known as the Bottom conglomerate Formation. These two Formations are overlain by Mahadek Formation with continuous contact. It is well exposed in Mawsynram area. The Mahadek Formation represents an arenaceous sequence made up of fine pebbly sandstone at the base grading upwards to coarse to medium grained sandstone which is mainly quartzwacke. The upper part of the Mahadek Formation is often Glauconitic imparting it a greenish colouration (Anon 1974).

The Jaintia Group:

The Jaintia Group marks the onset of change in depositional environments. It is best developed in Cherrapunji area. It represents commencement of calcareous facies deposited in a stable shelf segment of the basin. This group is divisible

into three Formation viz. Langpar Formation, Shella Formation, and the Kopili Formation.

The Langpar Formation represents the beginning of the Tertiary segment of the sedimentary pile of Meghalaya Plateau. It overlies the Mahadek Formation with a gradational contact. The Langpar Formation represents a sequence of carbonaceous siltstone, calcareous shale, sandy limestone, and marks a distinct change in sedimentary facies. The base of the Langpar Formation marks the boundary of Cretaceous-Tertiary sequence in Meghalaya. The succeeding Shella Formation conformably overlies the Langpar Formation and comprises alternations of three sandstone and limestone members (Murthy et al. 1976). These have been designated successively as the Lower (Therria sandstone/Lakadong limestone), Middle (Lakadong sandstone/Umlatdoh limestone), Upper (Nurpur sandstone/Parang limestone/Siju limestone and Sylhet sandstone/limestone) member. The Shella Formation definitely represents a distinct calcareous facies deposited in a shelf environment. The Shella Formation is succeeded by Kopili Formation with a gradational contact. The rocks represent alternations of thin sandstone and shale with minor thin bands of limestone. The base of the Kopili Formation represented by a shale horizon often contain phosphatic nodules.

The Garo Group:

The Garo Group represents the upper Tertiary sequence and is well exposed in Garo Hills. It is divisible into three Formation viz. Simsang Formation, Baghmara Formation, and the Chengpara Formation. The oldest of the three i.e. the Simsang Formation overlies conformably the Kopili Formation and represents a cycle of massive festoon cross bedded sandstone, siltstone members. The succeeding Baghmara Formation has gradational contact with the underlying Simsang Formation and is mainly confined in the eastern tracts of Garo Hills. It is represented by impersistent beds of feldspathic sandstone with minor mudstone. Pebbly sandstone - conglomerate, massive clay and silty clay - sand beds. The overlying Chengapara Formation also has gradational contact with the underlying Baghmara Formation. It comprises poorly cemented fine grained micaceous sand, blue to brown siltstone and clays with thin beds of marls at the base.

A prominent angular unconformity marks the top of Chengapara Formation in the western parts of Garo Hills. This angular unconformity is well exposed in the Tura-Dalu road section near Nokchi and north of Mahendraganj (Anon, op.cit.). The Chengapara Formation is overlain by the Dupitila Group with an angular unconformity. It consists of alternations of coarse feldspathic sandstone with thin layers of pebbles of vein quartz and mottled sandy clays.

THE QUATERNARY AND RECENT DEPOSITS

Isolated patches of older alluvium overlies unconformably the eroded top of the Tertiary rocks along the Southern and Western borders of Garo Hills and along the Southern flanks of Khasi Hills. These patches consists of assorted pebbles with coarse and loose sand and brownish clay. The patches usually occur as flat topped hillocks and mounds with red soil cover. Recent alluvium consisting of fine silty sand and light to dark grey clay with rare pockets of coarse sand and shingles occur in river valleys. The sands invariably contain abundant mica. These recent alluvium occur along the northern and southern flanks of Garo and Khasi Hills.

PALAEOGEOGRAPHY AND PALAEOENVIRONMENT

The Archaean-Precambrian basement of Meghalaya is a remnant of the northeastward extension of the Indian peninsula. It remained a positive landmass experiencing orogenic movements leading to complex folding and fracturing of the ancient rocks till precambrian times. The central part of the plateau during the precambrian time developed a linear trough into which the Shillong Group of rocks were deposited. Subsequently these were uplifted and folded and metamorphosed due to the intrusion of acid magmatic plutons and basic-ultrabasic bodies (Khasi Green Stone).

The post precambrian landmass suffered peneplanation till Jurassic times resulting into the formation of flat levelled surfaces preserved over the uplifted plateau till today. By the end of Jurassic the southern flank of the plateau had eruption of plateau basalts along linear E-W fissures, known as Sylhet traps. The close of eruption marked the subsidence of southern block and uplift of northern block along the E-W trending Raibah fault. At the same time the Cretaceous (Maestrichtian) sea transgressed into the rapidly sinking southern block. The sea extended from Baghmara to Mahadebkhola in the Jadukuta river and lashed against fault bounded high cliffs eastwards, south of the Shillong Plateau. The sea encroached north over a large fault bounded depositional basin traceable upto Jaintia Hills.

At the end of Mahadek times a differential tectonism raised Garo Hills marine shelf into a positive area while in the Shillong plateau, part of the sea transgressed Mawkma.

TECTONIC EVOLUTION OF MEGHALAYA

Tectono-stratigraphically Meghalaya can be divided into three domains each having distinct evolution.

- a) The Peninsular Shield Extension comprising the Gneissic Complex.
- b) Intracratonic sedimentary basin represented by the Shillong Group.

- c) The Mesozoic-Tertiary sedimentary sequence along with the Sylhet Trap occupying the southern fringe of the plateau.

Satellite imagery, aerial photographs and topographic maps of Meghalaya reveals long and persistent lineaments segmenting the plateau. According to Murthy et al. (1976), these lineaments are manifestations of deep seated fracture systems having repeated reactivation. The various lineaments have been classified as per their activity and geological domain. The lineaments have been grouped into four classes with interval of 20° on either side of N-S, NE-SW, E-W and NW-SE alignments (Fig.7). The important lineaments are given below:

Domain wise Important Lineaments:

I) Precambrian Gneissic Complex

NE-SW dominant	: Fold axes and fractures.
E-W dominant	: fold axes and fractures.
N-S minor	: fold axes and fractures.
NW-SE minor	: fractures mainly.

II) Precambrian Shillong Group

NE-SW dominant	Fold axes, long axis of the basin fractures, trends of intrusions of basic bodies.
E-W minor	fractures.

III) Precambrian Porphyritic Granitoids

NE-SW dominant	Granitoids spread on both sides of the NE trend.
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LINEAMENT MAP OF MEGHALAYA

(BASED ON SATELLITE IMAGERIES)

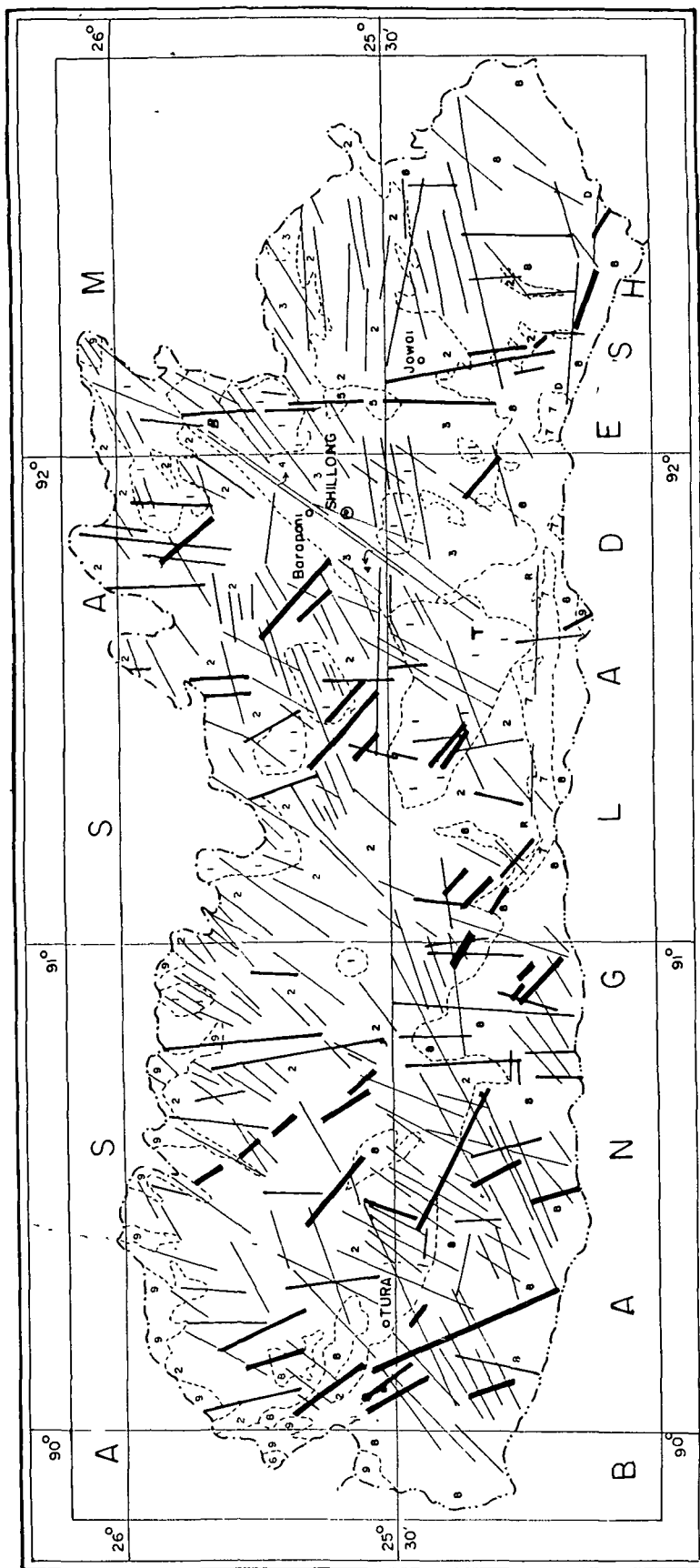
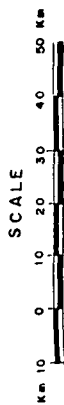


Fig.(7)

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1

2

LINEAMENTS

N-S Set (340°-20°) Archaean Proterozoic

With Recent Reactivation Events

E-W Set (70°-110°) Archaean-Proterozoic

With Tertiary Reactivation Events

NE-SW Set (25°-65°) Archaean-Proterozoic

With Tertiary-Quaternary Reactivation Events

NW-SE Set (295°-335°) Archaean With

Reactivation During Tertiary-Quaternary

NW-SE dominant	Granitoid distribution controlled to some extent about this trend.
----------------	--

N-S minor	Fractures.
-----------	------------

IV) Mesozoic Sylhet Trap (Jurassic)

E-W most dominant	Line of effusion, dikes and flexures
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NW-SE minor	Dikes in the northern parts of the upland
-------------	---

NE-SW minor	-do-
-------------	------

V) Jurassic-Cretaceous Sedimentary Pile

E-W dominant	Raibah lineament
--------------	------------------

VI) Tertiary Sedimentary Pile

E-W dominant	Facies contact, Dauki fault zone to the south. Jorhat-Tezpur fault zone to the north.
--------------	---

N-S strong	Dhubri Fault
------------	--------------

NW-SE minor	Borchi Fault
-------------	--------------

The fundamental and earliest lineament trends are E-W. Later in the Precambrian this trend was superseded by NE-SW trend which probably persisted during the intrusion of the porphyritic granitoids. The Precambrian is thus marked successively by the dominance of E-W trend. The porphyritic granitoids appear to have been emplaced along the NE-SW trend. The Khasi Green Stone is also emplaced along the NE-SW lineament within the Shillong Group. This lineament appears to be

a deep suture along which major vertical tectonics has played vital role in shaping the evolution of Meghalaya Plateau. The boundary between the Precambrian and the Jurassic Sylhet Traps is an important E-W lineament. This E-W trending lineament is the famous Raibah Fault dipping towards south. According to Murthy et al. (in Murthy et al., 1967) this fault was active till Cretaceous. Further south, the Dauki fault also a E-W lineament is known to have been active till Tertiary and has been responsible for the uplift of Meghalaya.

The Precambrian Gneissic Complex is the Northeastern extension of the peninsular shield. This segment forms the core part of the plateau. It is the basement for the subsequent events. The central part of the complex covering Khasi and Jaintia Hills, developed a linear and narrow NE-SW trending basin during the late Proterozoic. This basin was the repository for the detritus which later on formed the Shillong Group of rocks. These sedimentary rocks experienced low grade metamorphism and gentle warping. The Khasi Green Stone and Porphyritic Granitoids subsequently intruded these rocks.

The Precambrian terrain remained more or less a positive mass till the early Carboniferous period and was subjected to degradation. However, Permocarboniferous period saw development of a minor intra cratonic basin where the

Gondwana were deposited as evidenced from the western tip of Garo Hills - Halidayganj. The terrain remained more or less dormant till the beginning of Jurassic when Sylhet Traps were erupted towards the southern margin of the plateau through E-W fissures i.e. Raibah fault system along which the southern block subsided and the northern block upheaved. The end of Jurassic saw deposition of thick sedimentary pile (Cretaceous-Tertiary) along the southern boundary. Sedimentation continued till Miocene along the southern and western fringe of Garo Hills and the southern part of the Khasi Hills. But, the Jaintia Hills got uplifted as a block and formed a positive area. However, the principal block upliftment of Meghalaya commenced at the end of Miocene. As a result all along the southern Khasi and Garo Hills, shallow lacustrine basins were formed. In these basins the Dupitila sediments (Pliocene) were deposited. Over these the subrecent to recent (Quaternary) deposits were laid along the various fluvio-lacustrine regimes.

Many of the lineaments are still active as evidenced by the high micro seismic activities in and around Meghalaya plateau. Some of the lineaments when traced towards north into the Brahmaputra plains as well as towards south into the Surma plains show evidences of Neotectonic movements. Probably these activities are the manifestation of release of built up stress mainly through vertical movements coupled

with little or no lateral displacement.

(B) LOCAL GEOLOGY OF THE AREA

The area forms part of the Central Shillong plateau, by and large exposing the Shillong Group of rocks (Fig.8). The generalised Lithostratigraphic sequence is given in (Table 6).

TABLE - 6

Lithostratigraphic succession around Barapani

		Recent Terraces
		----- Unconformity -----
		Quaternary Terraces
		----- Unconformity -----
		Khasi Green Stone
		----- Intrusive contact -----
Late Proterozoic	S H I L L O N G G R O U P	Cyclothem of arenaceous and pelitic metasedimentary facies represented by an association of sandstone/phyllitic quartzite and siltstone-shale-slate-phyllite with basal conglomerate. Locally mica schist and feruginous quartzite. Basal conglomerate.
		----- Unconformity -----

GEOLOGICAL MAP OF BARAPANI

SCALE
Km 10 0 10 Km

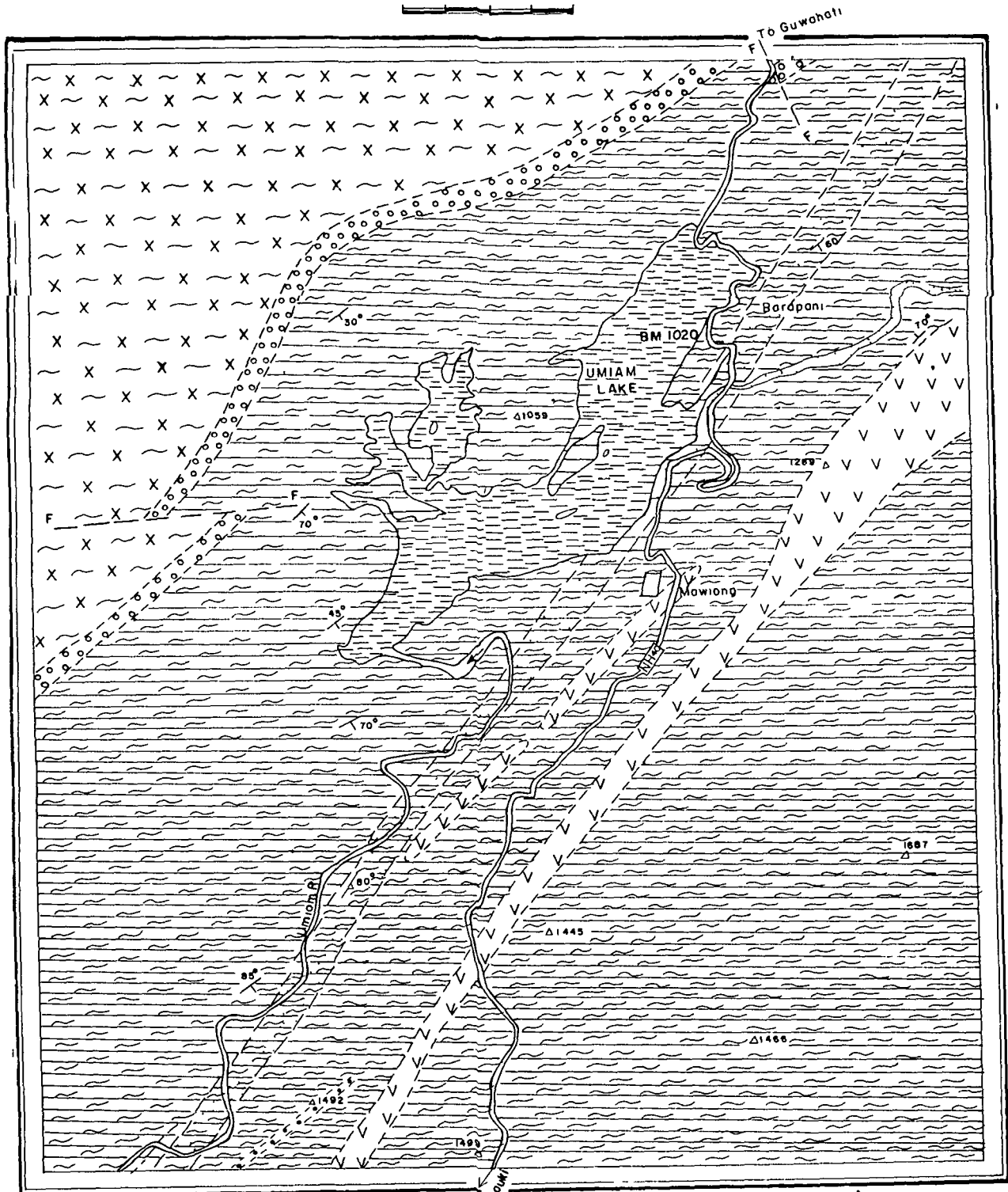


Fig (8)

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|--|--|--|----------------------------|
| | Gneissic Complex | | Khasi Green Stone |
| | Sand stone, Phyllite, Siltstone
Quartzite Association | | Barapani-Tyrsad Shear Zone |
| | Basal Conglomerate | | Inferred Fault |
| | Intraformational Conglomerate | | Umiyam Lake |
| | | | Dry Umiyam River Bed |

T_{30°} T_{70°} Bedding /
Foliation

Late Proterozoic to Archaean	G	C	Quartz biotite gneiss, Hornblende
	N	O	biotite gneiss, mica quartz schist,
	E	M	often migmatised
	I	P	
	S	L	
	S	E	
	I	X	
	C		

THE GNEISSIC COMPLEX

The gneissic complex forms the basement for the Shillong Group. The complex is represented by Quartz biotite gneiss, Hornblende biotite gneiss, mica quartz schist etc. and variants. The rocks are migmatised to varying extent as evidenced by the presence of leucosomes of different sizes mostly aligned concordant to the folia.)

The gneissic complex occurs in the NW corner of the area (Fig.8), confined to NW of Sumer ridge. The contact between the Gneissic Complex and the overlying Shillong Group runs mostly NE-SW with minor swings in N-S direction, locally.

The gneisses are mostly medium grained, greyish to pinkish rocks composed of pinkish to grey coloured felspar (K-felspar), quartz, biotite and magnetite as accessory. Gneissosity is by and large defined by alternation of granoblastic quartzofelspathic material and micaceous or prismatic mineral rich layers. With increase in micaceous mineral content the gneisses grade into schists.

West of G-S road near Barapani, immediately below the basal conglomerate of Shillong Group, occurs a biotite quartz schist. It shows crenulated foliation S_1 and axial plane cleavage S_2 . The schist is fine grained. Mineralogically comprising quartz biotite, magnetite, muscovite and apatite in varying proportions. The schist grades to gneiss towards north. According to Mazumdar (1986) the gneisses show upper amphibolite grade of metamorphism.

THE SHILLONG GROUP

The rocks of Shillong Group occupies a major portion of the area of study. It basically comprises a dominant arenaceous facies with subordinate pelitic facies which are weakly metamorphosed. These metasedimentary rocks occur as NE-SW trending linear bands represented by basal conglomerate, and an association of sandstone/quartzite/arkoses, siltstone-shale-slate-phyllite, locally carbonaceous and rarely mica schist. The rocks show heterogeneous nature and variation along as well across strike.

The contact between the Gneissic Complex and the overlying Shillong Group has variable nature in different places. South of Sumer ridge, a distinct unconformity demarcates the two Groups with commencement of basal conglomerate. But, south of Mairang plateau the contact between the two

Groups is rather sharp and the conglomerate is missing (De, 1981). However, in the area of study the Shillong Group has unconformable relation with the underlying Gneissic Complex, this is evident from the sharp difference of grade of metamorphism between the two Groups, variation in structural trends and fold styles. The presence of basal conglomerate marks the unconformity in the area. The different members of the Shillong Group are described below.

Basal Conglomerate Unit:

This is a thickly bedded unit and occurs as detached lensoid beds from near Barapani (Sumer ridge) in NE to Denghei peak 1851m. in SW. The width and length of these lenses is of the order of 50m and 500m respectively. The bedding is defined by pebble free layers. Compositionally the clasts are of vein quartz and rarely of quartzite. The pebbles lie with their long axes aligned parallel to bedding and short axes lying perpendicular to bedding. The size of clasts is under 10cms embedded in a matrix of sand silt and argillaceous components.

The Sandstone-Phyllitic quartzite Unit:

This is the dominant lithotype in the area. Basically this has two variations as per grain size viz. 1) coarse grained and (ii) Medium grained. The quartz grain components

of the sandstone is set in a matrix of clay and silt while the cementing material is mostly authigenic quartz. Where the quartz content is high and matrix low the sandstone appears as orthoquartzite. But, with increase in matrix components the sandstone passes to phyllite through an intermediate stage of phyllitic quartzite. However, the quartzite and its allied variants mostly occur in area south of Mawlai and, the phyllitic variants occur north of Mawlai.

The members of this association mostly the sandstone end members are buff to white and light grey or off white in colour. But, invariably the weathered outcrops show mottling due to feruginous stains of brown, maroon, orange-yellow colours. Where the cement and matrix is leached out the sandstones have become friable and soft, such material is being used as building materials.

The members show imprints of low grade metamorphism but they still retain the primary geopetal fabric in the form of current bedding, crude graded bedding and rarely ripple marks.

The Siltstone-shale-phyllite Unit:

These have been clubbed together for description purpose as they occur in association and represents the

argillaceous (pelitic) facies of the Shillong Group. Compositionally it is comparable to the sandstone unit, particularly the siltstone members and its allied variants. The quartz grains are set in a matrix of clayey minerals. compaction and recrystallisation has resulted in the formation of slates locally within this unit. This is the result of metamorphism.

At places where the argillaceous components in the rocks have increased and the grain size has decreased the rocks appear as shale and phyllite particularly north of Mawoing and before Barapani dam. The phyllite show various shades and colour viz. yellow grey and light green. The characteristic member of this association is carbonaceous slate/phyllite which is exposed along G-S road cutting before Barapani dam. It is a persistent and continues in SW upto Mawphlang (De, 1981).

A remarkable feature of this association is the presence of impersistent lenses of autoclastic conglomerate which is metamorphosed. The clast are by and large of vein quartz in a matrix of argillaceous components. The matrix appear as phyllite and the clasts are upto 6cms in long axes. Such conglomerate are seen locally. One such exposure can be seen on G-S road near Shillong 'Goo Shala' (Fig.P3).

THE KHASI GREEN STONE UNIT

It is a metamorphosed concordant basic intrusive, confined within the Shillong Group. Along the G-S road good sections are exposed near Mawlong and in Phud Umshing (Fig.P4). These are detached lenses occurring parallel to the metasedimentaries. The basic rocks are represented by epidiorite, metagabbro, metadolerite etc. Mineralogically it comprises hornblende, plagioclase, chlorite, biotite, epidote, zoisite, apatite, opaques and exhibit mostly relict ophitic to subophitic intersertal texture.

The rocks are generally massive with incipient schistosity. The rocks show following prominent set of joints.

1. NE-SW with dips of 80° - 85° due SE
2. NW-SE with dips of 75° due NE
3. $N80^{\circ}W$ - $S80^{\circ}E$ with dips of 70° - 75° due NE
4. $N65^{\circ}W$ - $S65^{\circ}E$ with dips of 80° due SW

The grade of metamorphism of Khasi Green Stone is same as that of the enclosing Shillong Group of rocks, i.e. Lower Greenschist facies. The weathering of the Khasi Greenstone has formed lateritic soil (Fig.P30) and has stained the adjacent rocks with ferugeneous stains.

STRUCTURES AND METAMORPHISM

The principal planar surface in the Gneissic Complex



Fig. (P3)

Autoclastic conglomerate within Shillong Group (near Shillong 'Goo Shala').



Fig. (P4)

Khasi Green stone exposure in Wah Umiam bed (about 200m downstream of dam).

is the foliation and Gneissosity. The trend of regional S-surface is NE-SW with moderate to steep dips on either side. On mesoscopic scale, S-shaped folds and reclined folds refolded on more open pattern dominate the structural styles (Mazumdar, 1986). As a result away from the nose of the folds the subsequent axial plane cleavages or acquired S-surfaces show transposed schistosity of the earlier phase of folds. According to Mazumdar (1986) the grade of metamorphism in the Gneissic Complex is of upper amphibolite.

The principal planar surface in the Shillong Group of rocks is the bedding, with NE-SW strike and moderate dips towards southeast. The foliation due to regional metamorphism is parallel to subparallel with bedding. The schistosity is prominent in pelitic members.

Broadly speaking, the fold pattern in Shillong Group is crestal type (Bellousov, 1962) with steep dips near the crestal parts and shallow dips in adjacent parts. De (1981) has recognised following types of folds.

- 1) Appressed intrafolial folds, trend of the folds is subparallel to bedding or foliation. The dominant trend is NE-SW with low to moderate plunge.

- 2) Asymmetrical to isoclinal folds, the trend of folds is also NE-SW, axial plane cleavage is subparallel

to bedding. The amplitude of the fold varies from a few cms to several meters.

3) Broad open to asymmetric folds plunging from NNE to ENE (Fig.P5).

TYRSAD-BARAPANI SHEAR ZONE

Tyrsad-Barapani shear zone is a prominent structural trend in the area. It is a zone of subvertical dips (Fig.P6) with local reversal, traced from Tyrsad in the southwest to Barapani in the northeast. This zone is accompanied by shearing of the rocks. The shear planes mostly follow the axial planes of the folds. The shear zone is exposed in the G-S road cutting between Mawlong and Barapani Dam. The sheared Quartz sericite schist and sericite quartzite show minor drag folds in the road cutting. The carbonaceous (Fig.P7) slate/phyllite members of the Shillong Group exposed near Barapani Dam shows small scale shears, crushing - fracturing and minor faults.

This shear zone is discernible on satellite imagery and continues in northeast upto the fringe of Karbi-Anglong district of Assam and in the southwest beyond Tyrsad. The shear zone is probably a manifestation of deepseated Basement controlled tectonic fracture.



Fig. (P5)

Open asymmetrical fold in Shillong Group phyllitic sandstone (south of Barapani).



Fig. (P6)

Sub vertical dips in Shillong Group (south of Barapani).

QUATERNARY AND RECENT TERRACES

These are confined along stream courses and have minor development. By and large, the Quaternary terraces are seen preserved along right bank of Umiam Lake (Fig.P8) below the colluvial fans. The terraces comprise assorted sand and minor pebbles. These are oxidised sediments as indicated by 'red' colouration and are compact. The average thickness of the terraces is more than 10m(Fig.P9) with bottoms concealed below water of Umiam Lake.

•

The recent terraces are seen at comparatively lower levels along the left bank of Umiam Lake (Fig.P10) and also along Wah Umiam course downstream of Dam (Fig.P11). At the confluence of Wah Umiam and Phud Umshing, three detached but paired terraces are seen. The high level terrace(T_3), at present, about 15m above river bed, is the oldest in timescale. The thickness of this terrace indicate moderate to calm energy regime but the younger terraces (T_2 & T_1) indicate higher energy conditions of deposition. These terraces have abundant influx of Khasi Green stone. This high influx is explained in Chapter-III.

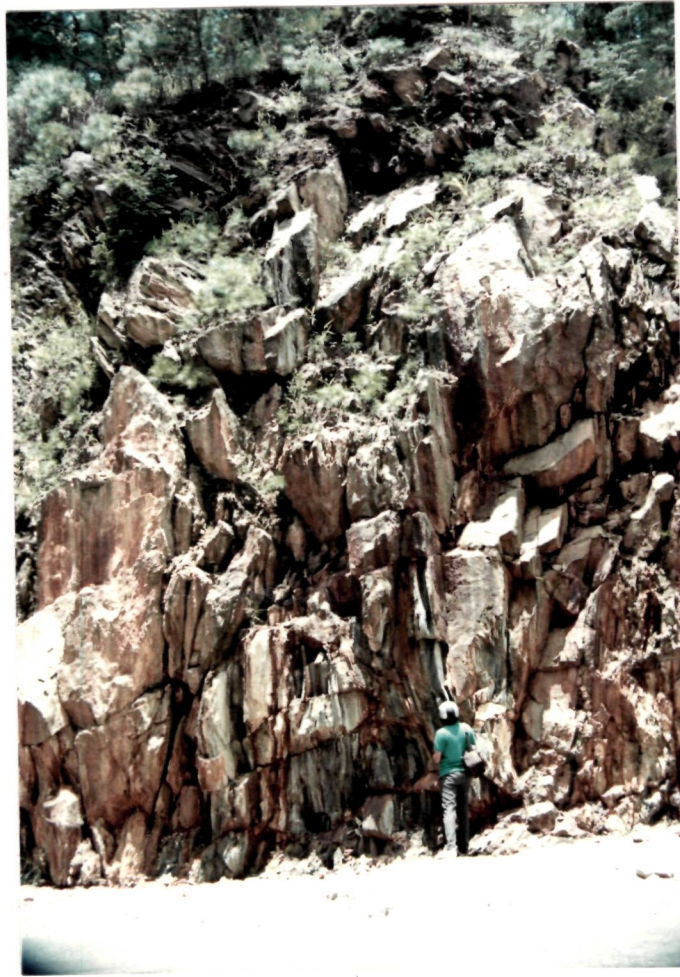


Fig. (P7)

Carbon phyllite (near 67 km post, G.S. Road) with pegmatite leucosomes).



Fig. (P8)

Quaternary terrace with 'creek inlets' along southern fringe of Umiam Lake.

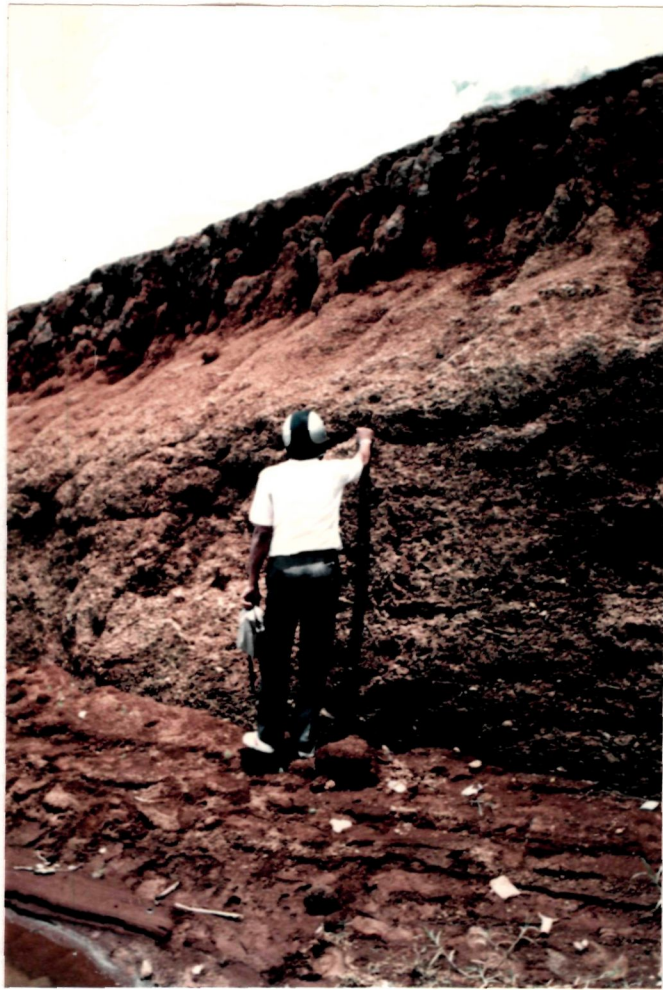


Fig. (P9)

Close up of Quaternary terrace showing grading of size.



Fig. (P10)

Recent terraces at lower levels along northern fringe of Lake. Terraces under paddy cultivation at present.



Fig. (P11)

Recent terraces
and channel lag
deposits downstream
of dam, consisting
of Khasi Green Stone.

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CHAPTER - III

GEOMORPHIC CHARACTERS

INTRODUCTION

A geomorphic unit also termed as physiographic unit is the product of various geomorphic processes acting in an area. The study of various large as well as small geomorphic units of an area helps in developing geological and geomorphological history. The present area forms part of a spectacular landscape consisting of plateau and hill components with associated valleys.

On a gross scale, the study area forms part of Meghalaya plateau which is a '3rd-ORDER' modulation of the earth's surface (Fairbridge, 1968).

A landform is a distinctive geometric configuration of the earth's landsurfaces. It exerts far reaching influences on the patterns of human activities. So, indirectly landforms control developmental planning and cultural activities in an area.

Landforms can be described qualitatively as well as genetically. A genetic description is useful in understanding the development of landforms because landforms are always 'sequential in nature'. Any landscape is nothing more than an existing stage in a great struggle to resist

the denudation, the ultimate fate of which is a peneplain.

LANDFORM EVALUATION

To evaluate the geological and geomorphological history of the area, detailed photogeological and field studies of the area were made. The different landforms were deciphered, classified and a geomorphic map prepared (Fig.9). Broadly the landforms of the area could be classified into following two Geomorphic domains and are described below.

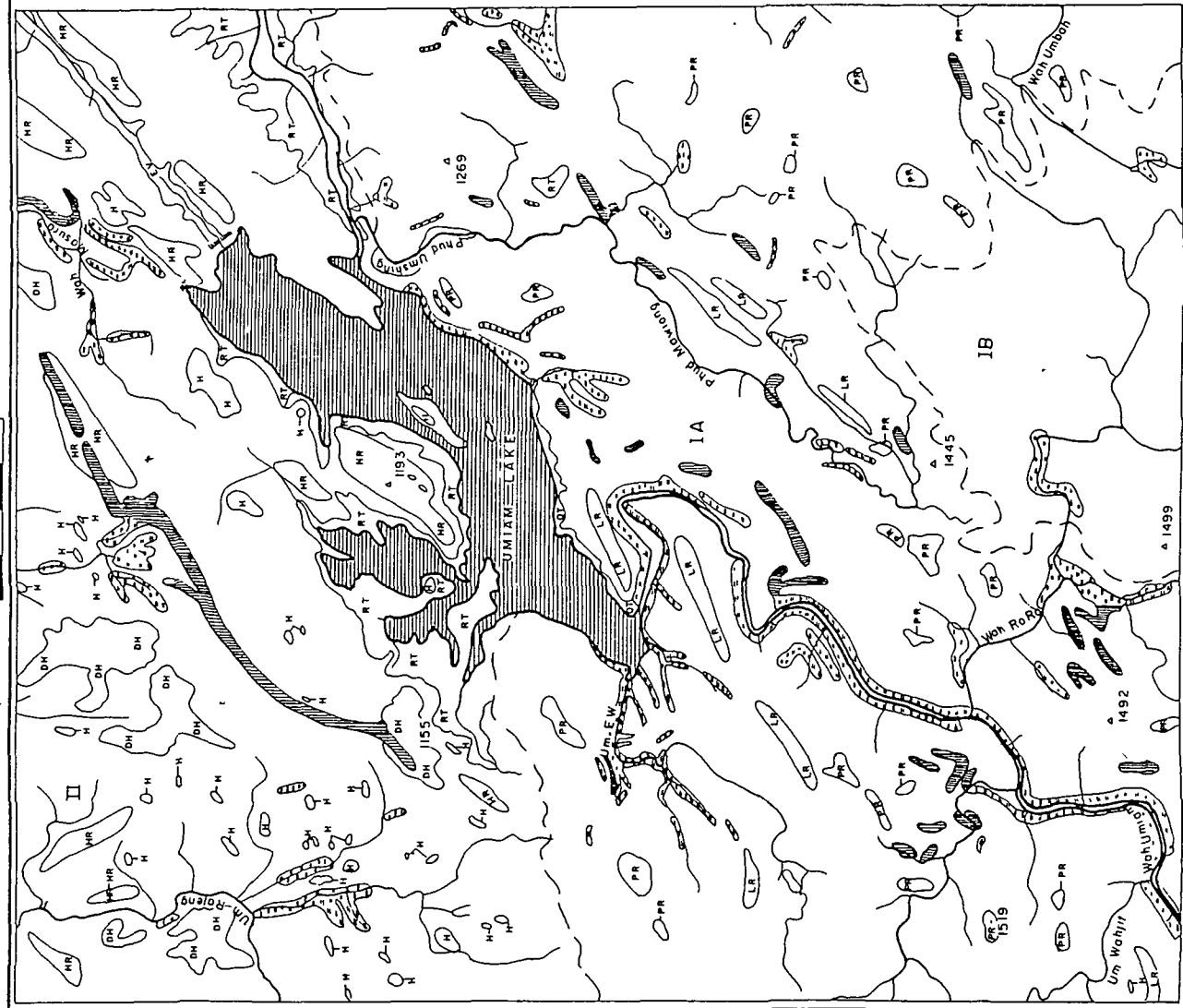
- 1) The Plateau
- 2) The Hills.

CLASSIFICATION OF LANDFORMS:

<u>Geomorphic Domain</u>	<u>Sub Domain</u>	<u>Landform Unit Types</u>	<u>Map Index</u>
A. PLATEAU-I	Dissected Plateau-IA & Plateau Plain-IB	1. Erosional Plateau Relicts Linear Ridges Escarpments Gorges Stream valleys	PR LR   
		2. Depositional Quaternary Terraces	QT
B. DENUDATIONAL HILLS-II		1. Erosional Hummocks Dissected Hills Hummocky Ridge Escarpments Gorges Elongated Vallyes Lake	H DH HR   EV 
		2. Depositional Recent Terraces	RT

GEOMORPHIC MAP

1km 0.5 0 0.5 1km



LEGEND

GEOMORPHIC DOMAIN A PLATEAU-I

LANDFORM UNIT TYPES I EROSIONAL

- IA Dissected Plateau
- IB Plateau Plain
- PR Plateau Relict
- LR Linear Ridges
- Escarpment
- Gorge
- Stream Valley

2 DEPOSITIONAL

- QT Quaternary Terraces

B DENUDATIONAL I EROSIONAL HILLS II

- H Hummocks
- DH Dissected Hills
- HR Hummocky Ridges
- Escarpment
- Gorge
- EV Elongated Valley
- Lake
- Stream Valley

2 DEPOSITIONAL

- RT Recent Terraces
- Geomorphic Domain Boundary
- Geomorphic Sub Domain Boundary

(I) The Plateau Domain-I:

The southern half of the area comprises Plateau representing 60.0% of the area. Overall it is confined to Shillong Group of rocks. It is divisible into two sub domains - (1) The dissected plateau-IA and (2) The Plateau Plain-IB. The dissected plateau forms about 85% of the plateau domain and the rest 15% represents the plateau plain. The general elevation of the plateau rises from 1100m in the north to 1500m in the south. The plateau plain sub-domain by and large has elevation between 1400m to 1500m and is confined in the southeastern part of the area. As it is with minimum undulation and dissection, it is the most thickly populated segment of the area. The township of Shillong has primarily developed on this sub-domain.

The dissected plateau as the name implies has straight skyline (Fig.P12). It is rugged in nature and has high dissection. As a result, this plateau segment supports lesser urbanisation. The limits of Shillong urban agglomeration are thus checked or retarded from expansion into the dissected plateau regime.

The important landform unit within the plateau domain are described below:

Plateau Relicts: These occur as small irregular remnants, confined in the Dissected plateau sub domain. It represents



Fig. (P12)

Plateau domain characterised by straight sky line.

the relicts of proterozoic erosional surface, an uplifted peneplain. The post jurassic uplift of the penplain rejuvenated the terrain and a new set of terrain characters developed on it. The base level of streams changed, resulting in vigorous down cutting and headward erosion. With progress of headward erosion and spurts of subsequent block uplifts, the initial peneplain (plateau) underwent extensive dissection (Fig.P13). The resultant scenario is a dissected plateau with relicts of plateau surface. These relicts would disappear in course of time with advancement of headward erosion. Such relicts are seen at different levels or with differing absolute relief (fig.P14). It is possibly because of reactivation of some subsurface structures (fractures) along which differential uplift has taken place. Such a possibility can not be ruled out, as some of the lineaments in Meghalaya do have history of reactivation (fig.7). This fact is clearly evident by the adaptation of channel network to lineaments (Fig.22) in the area of study.

Linear Ridges: These are narrow elongated ridges, aligned NE-SW in conformity to trend of Shillong Group of rocks. The ridges are confined in the southeastern corner of the area in the vicinity of Khasi Green stone. It appears that the emplacement of Khasi Green stone into the Shillong Group of rocks have indurated the latter in its vicinity. This resultant competency has made the rocks relatively



Dissected nature of plateau domain. Note slide prone areas along steep slopes and Jhum patches.

Fig.(P.13)

resistant, and the differential erosion produced the linear ridges. However, the main denudational agency in the area are the fluvial processes. The attendant drainage system with its rapid downcutting and headward erosion has a tendency to subdue the topography. This explains the linearity, narrowness and paucity of the ridges in the area.

Escarpments: It occurs scattered throughout the dissected plateau sub-domain but, rare incidences are also seen in plateau plain sub-domain. The escarpments show varying lengths (500m to 1200m approx.) These escarpments are of two types - one is associated with steep slopes giving rise to cuesta, and, the other type is structurally controlled possibly related to local hidden faults.

The escarpments aligned parallel to Shillong Group of rocks are usually associated with cuesta but the escarpments oblique to the strike of Shillong Group could represent surface manifestation of hidden faults.

Gorges: The gorge sections are associated with steep slopes along channel segments (Fig.P15). The gorge sections have alignment conformable as well as oblique with trends of Shillong Group of rocks. The oblique alignments are structurally controlled. The dissected plateau by far, has the maximum development of gorges. The gorges are more prominent in the southwestern corner of the area. The Wah Umiam depict-



Fig. (P14)

Plateau relicts at different levels.



Fig. (P15)

Gorge section associated with channel segments (Phud Umshing).

ing spectacular gorge section all along its course upto the Umiam Lake.

The plateau plain show minor development of gorge sections particularly in its western flank only. The plateau plain is conspicuous by low development of drainage network. The existing drainage in this sub-domain are sluggish and have low gradient. This is the direct result of human interferences with the environment as Shillong had always been the nucleus of cultural development. The resultant developmental activities around Shillong has almost deforested the complete Plateau plain of the primary forest.

This human interference with the environment and gentle topography has impeded drainage development. The structural control of drainage (Chapter-VII) causes a higher rate of infiltration through the concealed fractures and/or faults resulting in lesser 'flow'. Consequently, the gorge development is slow.

Stream Valleys: The Fig.(9) depicts the nature of stream valleys carved out in the terrain. This is the most easily discernible erosional feature controlling the development of landforms in the area.

The stream valleys usually show steep slopes, narrow cross-sections and high gradient except in plateau plain

sub-domain. It indicates rapid downcutting and headward erosion. The accompanied continuous recession of slopes has subdued the topography. The spasmodic rejuvenation of the terrain as evidenced by reactivated lineaments has produced cascading channel segments. The structural adaptation of streams is discussed in Chapter-VII. Such periodic rejuvenation have altered the micro watershed geometry resulting in valley cross-sections of 1st and 2nd order streams disproportionate to their run off and discharge. Such sites are at present being utilized for semi-permanent paddy cultivation by local inhabitants (Frontispiece) (Fig.P.16)

The stream valleys by virtue of steep gradients and slope, do not show much depositional landforms. But the high order streams wherever have wider cross-sections, loose their bedload carrying capacity and forms channel fill deposits. This feature is magnificiently depicted by Wah Umiam before reaching the Umiam lake (Fig.P17).

Quaternary Terraces: These are confined mostly along the northern fringe of the dissected plateau adjoining the Umiam Lake. These occur as high level terraces along 980m contour level (fig.P8). The average thickness of these terraces is approximately 10m (Fig.P9). This terrace is composed of assorted sand with minor pebbles. It is reddish to brown coloured (oxidised), compact and hard. Towards the dissected plateau end, these terraces are overlain



Fig.(P.16)

1st order stream valley disproportionate to discharge indicating change in watershed geometry. (Frontispiece).



Fig.(P.17)

Wah Umiam bend before Lake showing 'channel fill' deposit along concave side.

by 'debris slides' and colluvial fans. At present, the terraces are undergoing gully erosion (Fig.P18) resulting in dissection of the former due to which the lake forms 'creek' like inlets into the terraces.

II. The Hill Domain

It represents the northern half of the area comprising about 40% of the area. The northwestern part of this domain is underlain by gneissic complex while the southern fringe consists of Shillong Group of rocks. The general altitude of this domain decreases from 1100m in the south to below 900m in the north.

The domain is conspicuous by shallower dissection, subdued topography (Fig.P19) and erosional landforms. The hills within the gneissic complex show random alignments while the hills in the Shillong Group of rocks show alignments conformable with the trend of the latter. The important landforms within this domain are described below.

Hummocks: The Hill domain has scattered hummocks of varying shapes and sizes. By far, the Gneissic terrain has best development of hummocks in comparison to Shillong Group terrain. The hummocks are the ultimate product of hills due to dissection, a stage before peneplanation.



Fig.(P.18)

Gully erosion in Quaternary terrace (west of dam). Note gentle slopes.



Fig.(P.19)

Subdued topography showing hummocks in Hill Domain. Note extensive deforestation.

Dissected Hills: By and large, the dissected hills are confined within the Gneissic terrain. It occurs in irregular shapes due to headward and lateral erosion by streams. The dissection of the hills has proceeded along the zones of structural weakness. Such zones coincide with reactivated lineaments as previously discussed.

Hummocky Ridges: These are linear ridges comprising small hummocks showing linear dispositions. The ridges within the Shillong Group terrain have linearity parallel to the regional disposition of the rock types i.e. NE-SW direction. The profiles of these ridges are smooth and gentle. The ridges in the Gneissic terrain show orientation in NE-SW and NNW-SSE direction related to the regional trend of the complex.

Escarps: The escarpments are confined within Shillong Group of rocks forming cuesta. It is aligned in conformity with the trends of the rock types. The northern slopes of the escarpment are steeper than the southern slopes. The linear escarpment along Sumer ridge indicates surface expression of a concealed fault, the complementary northern fault' of the horst block discussed in chapter-IV.

Gorges: The active channel segments under the influence of reactivated lineaments show minor gorge sections particularly

in the northeastern corner of the Hill domain. Such gorge sections have NE-SW orientations.

Similarly, the active channel valleys within the Gneissic country have carved out locally minor gorges. These gorges within the stream valleys indicate rapid lateral erosion under the influence of localised structural adjustment in vicinity of the suspected 'northern fault'.

Elongated Valley: This is a narrow longitudinal valley confined within the Shillong Group of rocks in the northeastern corner of the Hill domain. It has alignment parallel to the regional trend of the Shillong Group of rocks. The cross-section of the valley is disproportionate to the discharge and gradient of its streams. This suggests modification in the watershed geometry. Such modifications have already been discussed in the plateau domain.

The active channel network in the Shillong Group of rocks have usually carved out small linear valley segments. These segments have valley cross-sections commensurate to their discharge and gradient.

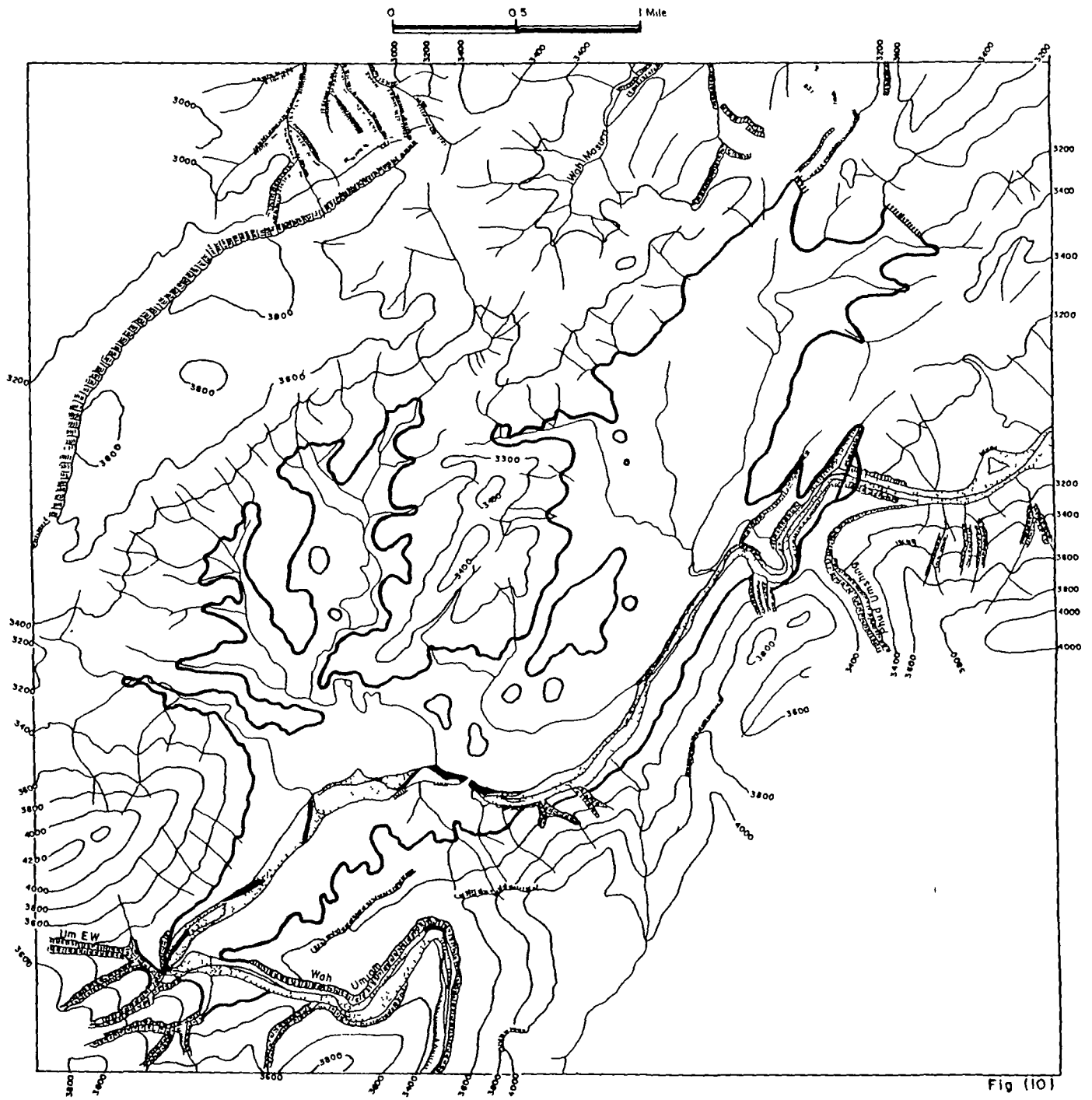
Lake: It is the most spectacular geomorphic feature in the area. The lake is spread over an area of about 10 sq.km. submerging an area southwest of Barapani upto 980m contour.

The lake is aligned in NE-SW direction occupying the low land. It has irregular boundary depending upon 980m contour configuration. The bottom profile of the lake is also highly irregular due to the rolling nature of the pre-lake topography (Fig.10). The lake has been formed by the construction of about 72m high concrete dam across Wah Umiam near Barapani. The northeastern limits of the lake has been restricted by the construction of two dikes. The main dike, located north of the dam, is an earthdam of 454m long and 28m high. The NH 40 passes over it. The second dike which is also an earth dam, is 168m long and 15m high over which the UCC college road passes. The lake shows wide fluctuations in water level during the year. Over a span of 12 years (1977 to 1988), the highest and lowest water level recorded are 981.70m in October, 1983 and 961.91m in April, 1986 respectively. The variation in waterlevel causes emergence and subemergence of islands in the lake which represent the top of submerged hummocks (Fig.P19A).

The lake occupies the downfaulted block or the graben block. It is bounded on the southern flank by Barapani-Tyrsad shear zone and by the suspected northern fault in the northern flank. This suspected graben structure has been discussed in chapter-IV.

In comparison to the southern flank of the lake,

PRE DAM TOPOGRAPHY IN THE LAKE AREA



LEGEND

-  RESERVOIR LEVEL AT 3200' CONTOUR
-  ESCARPMENT/GORGE
-  DAM
-  DYKE



Emergence of islands in Lake due to fluctuation in water level.

Fig.(P.19A)

the northern flank is highly irregular due to numerous upstream inlets along wide stream valleys.

The downstream impounding of Wah Umiam at Barapani by the dam has changed the whole hydrodynamic conditions of the river upstream. The Wah Umiam inlet segments into the lake has become sluggish because of backwaters due to the formation of lake. The result is formation of channel fill deposits at the inlet site (fig.P17). The normal load carrying capacity of the stream has decreased in the lake section of the stream. Moreover the outlet of the Wah Umiam, downstream of the dam, has almost no flowing water except when the lake water is discharged for regulating water level. Thus practically no bed load is transported out of the lake. The total effect of this situation is large accumulation of bed load in the reservoir area.

Recent Terrace: Recent terraces are confined by and large along the northern fringe of the lake (Fig.P10) and along the valley of the Wah Umiam downstream of the dam. The terraces fringing the lake are mostly of sand, and gravels. The bottom of the terraces are not seen due to the submergence of lake water but the exposed thickness varies from 15m to 20m. The top of these terraces show gully erosion.

The Wah Umiam valley, downstream of the dam from

near its confluence with Phud Umshing show three paired terraces on both the banks. The oldest terrace (T_3) is about 15m above the present river bed (Fig.P20). It is about 7m to 8m thick, comprising coarse sands with minor pebbles. The second terrace (T_2) is about 10m above the river bed and is about 5m thick (Fig.P21). It comprises very coarse sand, gravels and pebbles of mostly Khasi Greenstone and subordinate carbon phyllite-phyllitic sandstone etc. The general size of the pebbles vary from 2cm to 10cm. However, boulders of Khasi Greenstone, upto 20cm across are rarely seen in the terrace. The pebbles and boulders show very well roundness. The last terrace (T_1) is about 5m above the present river bed having a thickness of 5m (Fig.P22). It is highly assorted aggregate of Khasi Greenstone boulders with negligible sands. However, this terrace has patches rich in sand, gravel and show crude layering locally indicating fluctuating hydrodynamic conditions.

The present river bed shows large accumulations of boulders forming channel fill deposits near the confluence of Phud Umshing and Wah Umiam (Fig.P11). After the construction of dam, the Wah Umiam does not bring any more bedload into this part of the valley. The present channel fill deposits represent prelake accretion with little accumulation from Phud Umshing and terrace wash from terrace T_1 .



Fig.(P.20)

High level recent terrace (T₃), downstream of dam.



Fig.(P.21)

High level Recent Terrace(T₂) downstream of dam.

The nature of the three terraces indicate wide fluctuations in the hydrodynamic conditions of the Wah Umiam and Phud Umshing. The oldest terrace reveals moderate energy environment, representing quite stabilised terrain conditions. Subsequent terraces indicate higher energy environment and high influx of larger size boulders. This is perhaps due to sudden changes in watershed geometry due to reactivation along lineaments and corresponding Block movements up and down.

MINOR LANDFORMS AND MICRO RELIEF

Minor landforms are less conspicuous than the major landforms which are not observed in the topographic maps on 1:50,000 scale as well as small scale aerial photographs. These are best observed in the field. Micro relief refers to the small scale differences in relief, consisting of minor undulations on the surface of the land.

Most micro relief features have a height range between 10cm and 5m, and have horizontal dimensions of 20cm to 20m. Surface form features, smaller than these, are termed as nano relief (Young, 1975).

Most minor and micro relief features are developed entirely in regolith and some on bedrock while others at the junction of bedrock and regolith. These features are commonly

controlled by lithology, structure, weathering, mass wasting, erosion and deposition.

Minor Landform:

In the present area, the minor landforms identified are: -

1) Subdued Ridge and Elongated Depression:

These are commonly seen in the Plateau Plain sub domain chiefly and to some extent the Hill domain. The general trend of these forms is in NE-SW direction parallel to the general strike of the rocks. The elongated depressions are occupied by the 1st order streams which have advanced from the stage of gullies. Occasionally, the terraces along the fringe of the lake as well as Wah Umiam show flat 'ledges' due to dissection by subsequent streams.

2) Colluvial Fan:

These are wide spread throughout the area confined mostly below steep slopes. Invariably the colluvial fans form gentle to moderate slopes and coalesce to form blankets. They mark the termination of gentle to moderate slope and initiation of steeper slopes at its upslope ends. At lower levels these fans override the bedrock or terraces. Conspicuously, some of the road cutting sections expose these fans which slide down along the cut faces due to instability of slopes.

3) Gully and Spur:

These are very common features along the slopes of the hills of the area. They vary from macro to micro in dimensions and are formed by the 1st order streams. They cause dissection of the general slopes of hills. Generally the gullies are V-shaped in profile (Fig.P23) while, spurs have pointed to rounded apex as inverted 'V' or 'U'. The gullies are more prominent over the terraces and often have rock debris at its bottom (Fig.P24).

Micro Relief:

In the present area, micro relief features can be grouped on the basis of their morphology as:

1) Terracette:

On moderate to steep slopes, there are often found varieties of relatively narrow terraces which are discontinuous flat boulders or anastomosing lines of steps that collectively are known as terracettes. These are sometimes called 'pseudo terraces' or 'false terraces' and also known as 'sheep tracks'. They can be explained in a number of ways such as - lithological, structural or tectonical, ablation product, fluvial terraces, landslip effects, solifluction, antiplanation product etc. The following types of terracettes have been observed in the area.

- a) Lithological terracettes - Produced due to differential erosion.



Fig.(P.22)

Recent terrace (T_1),
downstream of dam.



Fig.(P.23)

Gully erosion with
'V' shape section and
rills along slope-Minor
land forms. Fore ground
showing slope elements.

- b) Structural terracettes - These are mainly due to cross and longitudinal joints. The jointed blocks slip down under gravity.
- c) Erosional and Depositional Terracettes - Stream course terracettes.

3) Micro scarp:

These are found all along the free-face slopes of the hills in various dimensions, ranging from tens of meter to few meters. These are more common in terrain lain by Shillong Group particularly competent strata.

3) Gully and Stream Channels:

These are very well developed over recent and Quaternary terraces, as well as over soils (fig.P25) and old slide materials. Such gully formation and attendant erosion commences mostly where human interferes with environment or over exploits land resources. More often than not gully initiation takes place with modification of slopes along foot tracks, cattle tracks, or timber haulage tracks. Minor rills flowing along these artificial indentations, during rains, convert them into gullies in course of time with increasing runoff and down cutting.



Fig.(P.24)

Development of gullies on terrace. Foreground showing colluvial fans overlying terraces.



Fig.(P.25)

Advance stage of rills. Gully formation along slopes - Minor relief.

- | | | |
|------------------------|------|---|
| Fairbridge, R.W.,(ed.) | 1968 | The Encyclopedia of Geomorphology. Encyclopedia of earth science series, Vol.III, Reinhold Book Corp., New York, 1295p. |
| Young, A., | 1975 | slopes - Geomorphology text, Univ. of East Anglia. |

CHAPTER - IV

RELIEF ANALYSIS

INTRODUCTION

To study the geomorphological features of any area, the first step is the analysis of its relief features. Relief and other geomorphic elements are based on differences in elevation. The important geomorphic elements are absolute relief, relative relief, altitudinal distribution etc.

The process of evolution of the relief of an area depends upon geological structures, lithotypes, climatological conditions and the nature of the original topographic surfaces of the area.

The present relief features of the study area show manifestation of fragmental or remnental shapes arising due to diverse denudational agencies. The elements of relief are discussed in this chapter.

ABSOLUTE RELIEF

Absolute relief of the area has been analysed with the help of toposheet on 1:50,000 scale. The area has been divided into one x one km. grids. Absolute height in each grid has been recorded from spotheights, traingulation points wherever available and from the maximum contour

value passing through the grid (with contour interval 20m.). These absolute heights are plotted at the centre of the grids and the area contoured with contour interval of 100m. (Fig.11). Contouring reveals 9 categories of absolute relief in the area ranging from below 900m. to above 1600m. Table (7) shows category wise area distribution. The area has been calculated by planimeter, .

DISTRIBUTION PATTERN OF ABSOLUTE RELIEF

The maximum elevation of 1687m. is on the Mawpat ridge located in the southeast corner of the study area. The height category of above 1600m. covers only 3.02% (4.32 sq.km.) of the total area. It occurs in patches at three places (Fig.11) viz., in south eastern corner of the area on Mawpat ridge and around Rynjah, and as a small patch northwest of Lyngkhatraian and, in the south western fringe of the area. Table (7) reveals that the area has three major height categories viz., 1000m-1100m covering 20.1% (28.75 sq.km.), 1100m-1300m covering 19.83% (28.35 sq.km.) and 1300m-1600m covering 45.26% (64.72 sq.km.) of the total area respectively. The terrain between 1000m-1100m and above 1600m categories is represented by Shillong Group of rocks and the height categories by and large show spatial distribution in conformity to the regional disposition of the Shillong Group. Significantly the Umiam lake is

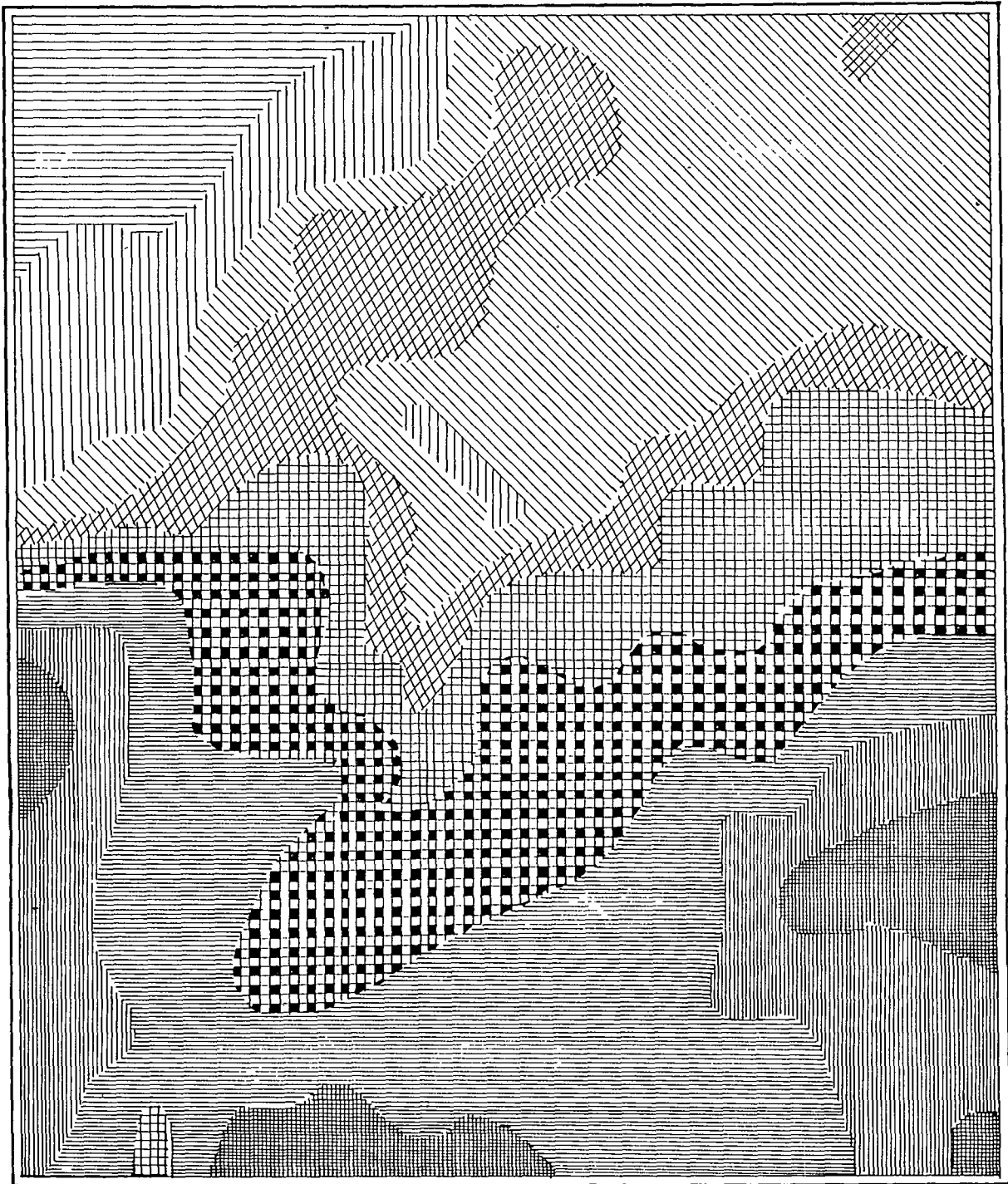
TABLE - 7

Category wise distribution of absolute relief

Absolute Relief category in m .	Area in sq. km.	Area in Per cent	Cumulative area in per cent	Major Category
Above 1600	4.32	3.02	3.02	1300m-1600m 64.72 sq.km. (45.26%) I
1500-1600	17.15	11.99	15.01	
1400-1500	29.23	20.44	33.45	
1300-1400	18.34	12.83	48.28	
1200-1300	13.28	9.29	57.57	1100m-1300m 28.35 sq.km. (19.83m) II
1100-1200	15.07	10.54	68.11	
1000-1100	28.75	20.10	88.21	1000m-1100m 28.75 sq.km. (20.10%) III
900-1000	9.71	6.79	95.0	
Below 900	7.15	5.0	100.0	
Total	143.00	100.00		

ABSOLUTE RELIEF

km 1 0.5 0 0.5 1 km



INDEX

METRES

	> 1600
	1500-1600
	1400-1500
	1300-1400
	1200-1300
	1100-1200
	1000-1100
	900-1000
	< 900

Fig (11)

confined in the 1000m-1100m height category, with lowest exposed contour of 980m (water level).

The lowest elevation of 880m occurs in the north western corner of the area. This topographic low land forms the lower catchment of Um Raleng and its tributaries. Lithologically the low land area below 1000m-1100m height category is represented by Migmatite-Gneissic Complex.

RELATIVE RELIEF

Relative relief in general, denotes the actual variation of height in an unit area with respect to its local base level. According to Glock (1932), relative relief is not strictly a function of elevation above sea level. Relative relief is also known as **relative altitude, topographic relief, amplitude of available relief, drainage relief, and local relief** etc. Importance of relative relief study in understanding landforms has been highlighted by Johnson (1933) and Smith (1935), Dov Nir (1957) used ratio between relative relief and absolute relief as a measure of "dynamic potential" of an area.

for the purpose of relative relief analysis, the area has been divided into one x one km. grids as done in the case of absolute relief analysis. The height difference between the highest and lowest elevation within each

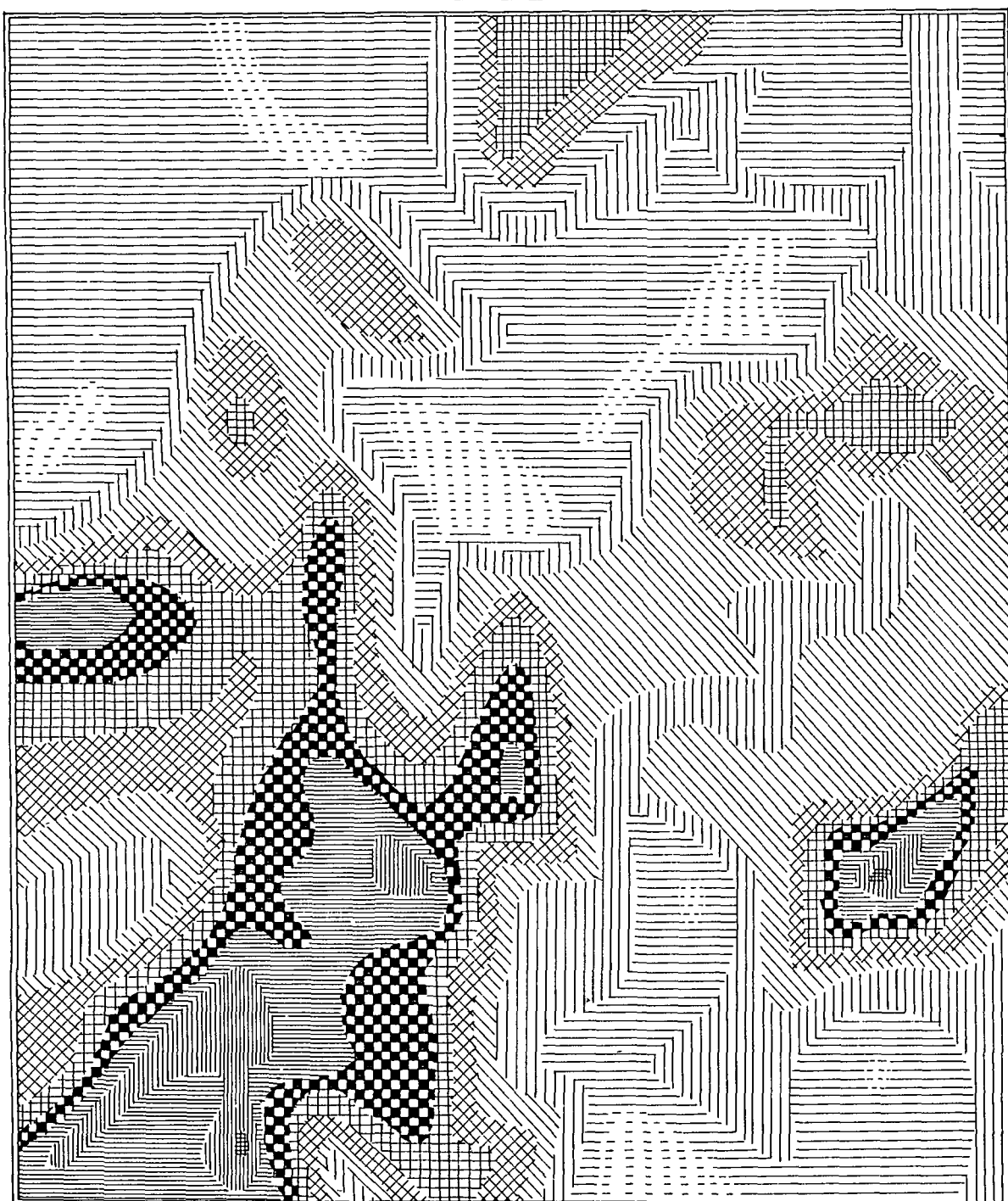
TABLE - 8

Category wise distribution of relative relief

Relative relief category in m.	Area in sq. km.	Area in per cent	Cumulative area sq. in per cent	Major category
Above 450	0.06	0.04	0.04	
400-450	2.85	1.99	2.03	
350-400	7.25	5.07	7.1	I
300-350	10.15	7.1	14.2	
250-300	14.09	9.85	24.05	II
200-250	16.41	11.48	35.53	
150-200	27.97	19.57	55.10	
100-150	24.57	17.18	72.28	III
50-100	33.28	23.27	95.55	
Below 50	6.37	4.45	100.00	
Total	143.00	100.00		

RELATIVE RELIEF

1km 0.5 0 0.5 1km



INDEX

METRES

	> 450
	400 - 450
	350 - 400
	300 - 350
	250 - 300
	200 - 250
	150 - 200
	100 - 150
	50 - 100
	< 50

Fig (12)

grid is computed and recorded at the centre of the grid (with contour interval 20m). The area is contoured with contour interval of 50m (Fig.12). The figure reveals 10 categories of relative relief ranging from less than 50m to above 450m. The category wise area distribution is shown in the Table-8. The area of each category is calculated by planimeter.

DISTRIBUTION PATTERN OF RELATIVE RELIEF

Perusal of Table(8) indicates that the area with high relative relief, 400m-450m and above forms just 2.03% (2.91 sq.km.) of the total area. It occurs as insignificant and isolated patches in the southwestern and northeastern corners of the area (Fig.12). Three major relative relief categories viz. 300m-400m covering 12.17% (17.40 sq.km.), 200m-300m covering 21.33% (30.50 sq.km.) and 50m-200m covering 60.95% (87.16 sq.km.) of the total area respectively are revealed from the Table (8).

Interestingly, the Umiam lake occurring in the central part of the area shows low relative relief between 50m-150m. The contour configuration around the Umiam lake area shows an elongated 'bowl' like depression. By and large the terrain with relative relief categories between 50m-100m and more than 450m is represented by Shillong Group of rocks. These

categories show linear distribution in conformity to the regional disposition of the Shillong Group of rocks.

The lowest relative relief of less than 50m is seen as isolated patches in the northwestern corner, the central part in Umiam Lake area and in the southeastern corner of the area. Except for the northwestern part, where the lowest relief area is in the migmatite gneissic complex, the other occurrence of the lowest relative relief category is in Shillong Group of rocks.

CORRELATION OF ABSOLUTE AND RELATIVE RELIEF

The relationship between absolute and relative relief is seen from the distribution pattern of frequencies of relative relief in different categories of absolute relief (Table-9). It is evident from this table that frequencies of moderate relative relief are distributed throughout the area. The frequencies of moderately high relative relief are occupied between 1000m-1100m and above 1600m categories. Frequencies of high relative relief are found between 1100m-1200m and above 1600m categories of absolute relief. The category of very high relative relief is confined in areas with the highest absolute relief i.e., 1500m-1600m category and above.

It is clearly seen that in the area, the relative

TABLE - 9

Distribution of frequencies in categories of absolute and Relative Relief
(A two way classification of the units of one sq.km.)

Absolute Relief in m.	Relative Relief in m.										Total Grid frequency	Total % frequency
	Moderate Relief		Moderately high		High Relief				Very high			
	Below 50	50 to 100	100 to 150	150 to 200	200 to 250	250 to 300	300 to 350	350 to 400	400 to 450	450 and above		
Above 1600	-	-	2	-	1	2	-	-	-	1	6	4.2
1500 - 1600	1	1	2	6	2	-	2	-	1	1	16	11.18
1400 - 1500	3	2	8	3	2	4	4	2	5	-	33	23.08
1300 - 1400	-	-	4	1	1	2	3	3	-	-	14	9.79
1200 - 1300	-	-	3	1	4	4	3	-	-	-	15	10.49
1100 - 1200	-	-	3	4	3	5	-	-	-	-	15	10.49
1000 - 1100	4	6	8	4	3	-	-	-	-	-	25	17.48
900 - 1000	4	9	1	-	-	-	-	-	-	-	14	9.79
Below 900	1	3	1	-	-	-	-	-	-	-	5	3.5
Total	13	21	32	19	16	17	12	5	6	2	143	
Total in %	9.09	14.68	22.38	13.29	11.19	11.89	8.39	3.49	4.2	1.4		100.0

relief increases with rise in absolute relief to some extent. The statement of Dov Nir (1957) that "There is a definite relationship between absolute relief and relative relief in each landscape type" holds good in the area.

A quantitative analysis of the absolute relief and relative relief data is done and the correlation table (Table-10) is prepared. The co-efficient of correlation has been computed using Carl Pearson formulae. The co-efficient of correlation between absolute relief and relative relief is +0.47.* The regression lines for the two variables

*(A) Computation of co-efficient of correlation is done by using Carl Pearson correlation co-efficient formulae which is given below:

$$\frac{\sum U_i V_j f(X_i Y_j)}{n}$$

$$r_{XY} = r_{UV} = \frac{\sigma_U \sigma_V}{\sigma_X \sigma_Y}$$

Where, r_{XY} = correlation co-efficient of variables X and Y

r_{UV} = correlation co-efficient of variables U and V

$$\bar{U} = \frac{\sum U_i f(X_i)}{n} \quad (\text{Arithmetic mean of new variable } U_i)$$

$$U_i = \frac{X_i - a_1}{C_1} \quad (\text{New set of variable corresponding to } X_i \text{ series})$$

Where, a_1 = assumed mean of class marks of X_i series.

C_1 = class interval of X_i series.

$$\bar{V} = \frac{\sum V_j f(Y_j)}{n} \quad (\text{Arithmetic mean of new variable } V_j)$$

$$V_j = \frac{Y_j - a_2}{C_2} \quad (\text{New set of variable corresponding to } Y_j \text{ series})$$

where, a_2 = assumed mean of class marks of Y_j series

C_2 = class interval of Y_j series.

TABLE - 10

Correlation table for absolute and relative relief variables (Data in m.)

Relative Relief		Moderate			Moderately high			High			Very high	Total Grid Frequency f(x)	Total Frequency in %	$(x) \sum_{j=1}^n$	$(x^2) \sum_{j=1}^n$	$(x, y) \sum_{j=1}^n$
		0 to 50	50 to 100	100 to 150	150 to 200	200 to 250	250 to 300	300 to 350	350 to 400	400 to 450						
Absolute Relief	X_1	25	75	125	175	225	275	325	375	425	475					
	$\begin{matrix} Y_1 \\ V_1 \\ U_1 \end{matrix}$	-5	-4	-3	-2	-1	0	+1	+2	+3	+4					
	1600-1700	-	-	2	-	1	2	-	-	-	1	6	4.2	+24	+96	-12
	1500-1600	1	1	2	6	2	-	2	-	1	1	16	11.18	+48	+144	-60
	1400-1500	3	2	8	3	2	4	4	2	5	-	33	23.08	+66	+132	-64
	1300-1400	-	-	4	1	1	2	3	3	-	-	14	9.79	+14	+14	-06
	1200-1300	-	-	3	1	4	4	3	-	-	-	15	10.49	0	0	0
	1100-1200	-	-	3	4	3	5	-	-	-	-	15	10.49	-15	+15	+20
	1000-1100	4	6	8	4	3	-	-	-	-	-	25	17.48	-50	+100	+158
	900-1000	4	9	1	-	-	-	-	-	-	-	14	9.79	-42	+126	+177
	800-900	1	3	1	-	-	-	-	-	-	-	5	3.5	-20	+80	+80
Total Grid Frequency f(y)		13	21	32	19	16	17	12	5	6	2	143		+25	+707	+293
Total frequency in %		9.09	14.68	22.38	13.29	11.19	11.89	8.39	3.49	4.2	1.4		100.0			
$V_j f(y)$		-65	-84	-96	-38	-16	0	+12	+10	+18	+8	-251				
$V_j^2 f(y)$		325	336	288	76	16	0	12	20	54	32	1159				
$V_j U_j f(x, y)$		+75	+176	-24	-26	-06	0	+17	+14	+39	+28	+293				

Notation: X_1 = Class mark (mid value) of absolute relative categories. Y_j = Class mark (mid value) of relative relief categories. U_1 and V_j = New set of variables corresponding to X_1 and Y_j respectively and defined as below:

$$U_1 = X_1 - a_1 / C_1, a_1 = \text{assumed mean of class marks of } X_1 \text{ series, } C_1 = \text{class interval of } X_1 \text{ series.}$$

$$V_j = Y_j - a_2 / C_2, a_2 = \text{assumed mean of class marks of } Y_j \text{ series, } C_2 = \text{class interval of } Y_j \text{ series.}$$

are shown in Fig.13. The relationship between the absolute and relative relief is expressed by the following equations:

$$1) \dot{Y} = 0.24X - 113.87$$

$$2) X = 0.93Y - 1093.40.$$

The co-efficient of correlation value of 0.47 indicates

Contd....

$$\sigma_u = \sqrt{\frac{\sum f(X_i)U_i^2}{n} - U^2} \text{ (Standard deviation of new variable } U_i)$$

$$\sigma_v = \sqrt{\frac{\sum f(Y_j)V_j^2}{n} - V^2} \text{ (Standard deviation of new variable } V_j)$$

(B) Computation of Regression co-efficient has been done using following formulae:

$$(1) \quad r_{XY} \frac{\sigma_x}{\sigma_y} = \text{Regression co-efficient of variables X on Y.}$$

$$(2) \quad r_{XY} \frac{\sigma_y}{\sigma_x} = \text{Regression co-efficient of variables Y on X.}$$

$$(3) \quad Y - \bar{Y} = r_{XY} \frac{\sigma_y}{\sigma_x} (X - \bar{X}) - \text{(for Y unknown and X known)}$$

$$(4) \quad X - \bar{X} = r_{YX} \frac{\sigma_x}{\sigma_y} (Y - \bar{Y}) - \text{(for X unknown and Y known)}$$

where, r_{XY} = Correlation co-efficient of variable X on Y.

$$\bar{X} = a_1 + C_1 U \text{ (Arithmetic mean of } X_i \text{ series)}$$

$$\bar{Y} = a_2 + C_2 V \text{ (Arithmetic mean of } Y_j \text{ series)}$$

$$s_x = C_1 \sigma_u \text{ (Standard deviation of } X_i \text{ series)}$$

$$s_y = C_2 \sigma_v \text{ (Standard deviation of } Y_j \text{ series)}$$

Computation

$$r_{XY} = r_{UV} = 0.47425 = 0.47$$

$$\bar{X} = 1267.5$$

$$\bar{Y} = 187.2$$

$$s_x = 221.7$$

$$s_y = 112.05$$

Equation of Regression lines are:

$$(1) \quad Y = 0.24X - 113.87$$

$$(2) \quad X = 0.93Y - 1093.40$$

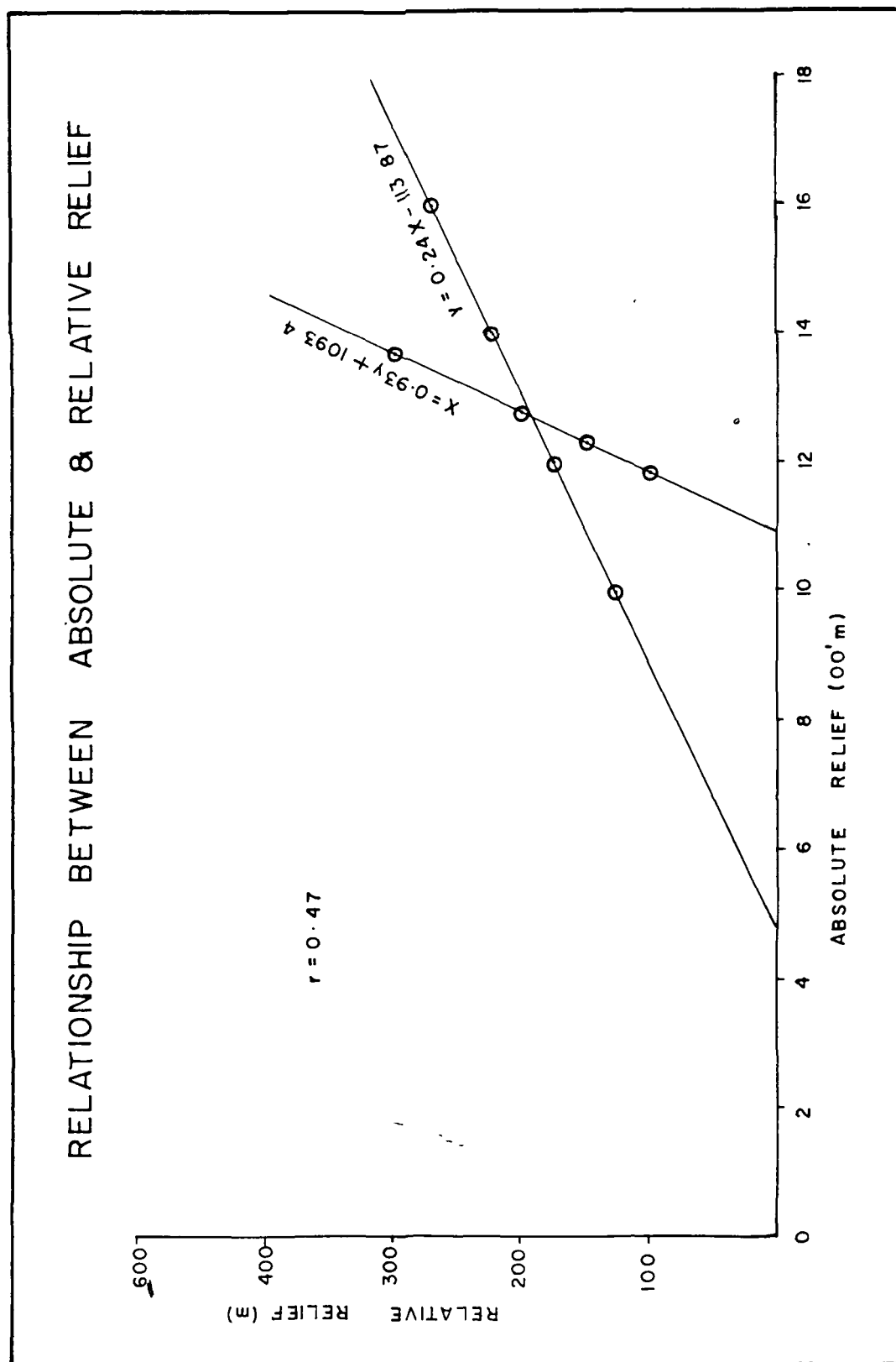


Fig.(13)

moderate correlation between the two variables. The correlation is significant at 1% level of significance. Considering the plateau nature of the terrain and its being part of the Peninsular Shield, good to very good values of co-efficient of correlation (0.5 to 1.0) are anticipated in this segments of shield area with mature topography. However, the computed co-efficient of correlation has only moderate value of 0.47. It is due to the fact that this segment of shield area, after acquiring mature topography, suffered periodic uplift since Mesozoic.

The topography subsequently rejuvenated and developed a superimposed denudational history. The topography is yet to stabilize again and attain maturity to have higher co-efficient of correlation value.

The presence of deep incised river valleys and gorges in the Meghalaya Plateau are the evidence of superimposed denudational imprints in an otherwise stable and mature topography.

It is postulated that these nala sections, gorges and steep sided deep incised valleys are manifestations of deep subsurface fractures. Vertical to subvertical block uplifts along these fracture have fragmented the Meghalaya

Plateau into graben like blocks of varying dimensions. Evidently, the rolling dips in Shillong group of rocks seen locally, are a pointer towards the differential vertical movement along such fractures. The amplitude and wave lengths of these warps depends on the scale of movement. Where movement is low, the amplitude is of the order of a few metres and the beds have sub horizontal disposition. But, where the movement is moderate to high, the amplitude of warps also increase correspondingly and the beds show moderate to steep disposition. The 'Step Like' or 'Cascading' or 'bench topography' encountered from south (Upper Shillong) to north (Barapani) is the result of differential vertical movement in these graben blocks.

AREA HEIGHT DISTRIBUTION

The technique of area-height analysis helps in understanding the altitudinal distribution in an area. It is useful for evaluating erosional morphology with the help of curves showing relationship between area and height. This analysis includes study of hypsometric curve, area-height curve and altimetric-frequency curve. Such an analysis reveals the nature and types of various landforms existing in an area.

Hypsometric and Area - Height Curve:

These are one of the best quantitative techniques

to analyse the terrain characteristics. These curves have been used to indicate the proportion of the area lying at various elevations. A contour map of the area (Fig.2) with 100m contour interval was prepared from toposheet on 1:50,000 scale. Nine categories of heights have been classified in map ranging from below 900m to above 1600m. The area of each category has been calculated with the help of planimeter and is expressed in percentages. The area altitude relationship is shown in Table-11.

The hypsometric curve for the area is drawn by using two variables i.e. height and cumulative percentage area while, the area-height curve is drawn by using height versus area percent (Fig.14a & 14b).

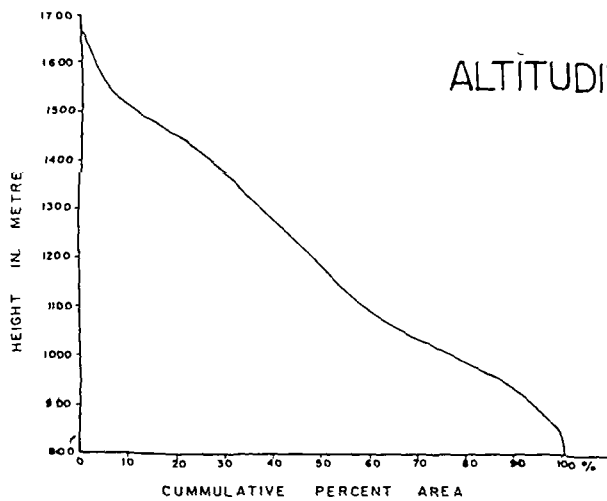
A perusal of Table(11) and Fig.14a & 14b reveals that the maximum area 21.72% (31.06 sq.km.) of the total area falls in 900m-1000m category. This occurs mainly in the central and northern portion of the area. The Umiam Lake is confined within this category. Next in area, comes the height category 1400m-1500m, 16.02% (22.901 sq.km.) of the total area. This occurs in the southern, south-eastern and south-western portion of the area.

It is also seen that height categories of 1500m-1600m

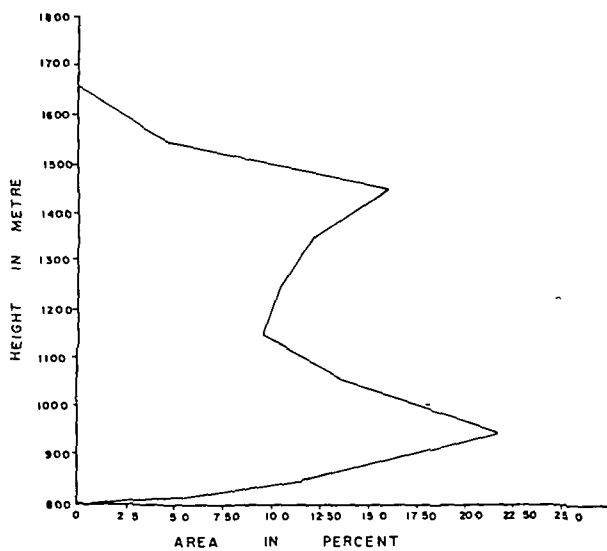
TABLE - 11
Area altitude relation

Height in mts. (class interval)	Height in mts. (mid point)	Area in sq. km.	Area in per cent	Cumulative area in sq. km.	Cumulative area in per cent
Above 1600	1650.0	0.59375	0.41520	0.59375	0.42
1500-1600	1550.0	6.44750	4.50874	7.04125	4.92
1400-1500	1450.0	22.91250	16.02272	29.95375	20.95
1300-1400	1350.0	17.19375	12.02360	47.1475	32.97
1200-1300	1250.0	15.02500	10.50699	62.1725	43.48
1100-1200	1150.0	13.86000	9.69230	76.0325	53.17
1000-1100	1050.0	19.56625	13.68269	95.59875	66.85
900-1000	950.0	31.05875	21.71940	126.6575	88.57
Below 900	850.0	16.34375	11.42919	143.00125	100.00
Total		143.00	100.00		

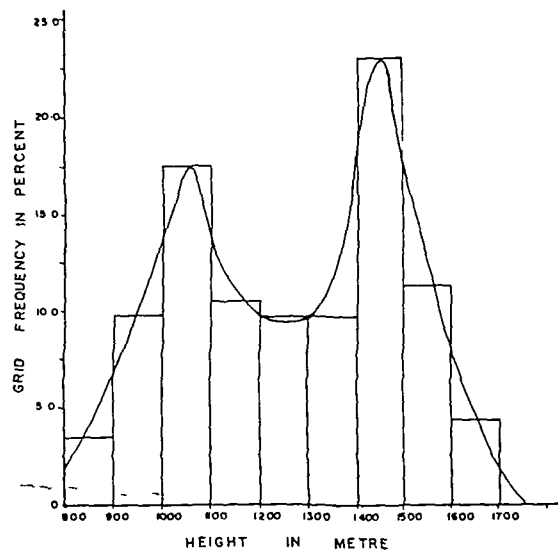
ALTITUDINAL DISTRIBUTION CURVES



(a) HYPSONOMETRIC CURVE



(b) AREA-HEIGHT CURVE



(c) ALTIMETRIC FREQUENCY CURVE

and above 1600m occupy insignificant area. These categories have only 4.5% (6.45 sq.km.) and 0.42% (0.59 sq.km.) of the total area and occur as patches in the southeastern, southwestern and southern corner of the area.

Conspicuously, the hypsometric curve shows break in slope after 1500m-1600m category, indicating sudden change in topography. The fall in areal extent of higher altitude category is due to the occurrence of high hills and ridges with high to very high relief.

Interestingly the lowest altitude category, i.e. below 900m is confined in northwestern corner of the area. It represent undulating and rolling topography with low relative relief in migmatite gneissic terrain. In contrast to this the terrain above 900m altitude category shows dissected plateau with moderate to very high relative relief over Shillong Group of rocks.

Altimetric Frequency Curve:

The data for altimetric frequency curve have been obtained by recording the highest elevation within each grid and computing the category wise elevation frequencies as shown in Table-12.

TABLE - 12
Altitudinal frequency distribution

Absolute relief Category in m.	Frequency of grids	Percentage grid frequency	Area in sq. km.	Area in per cent
Above 1600	6	4.20	4.32	3.02
1500-1600	16	11.19	17.15	11.99
1400-1500	33	23.08	29.23	20.44
1300-1400	14	9.80	18.34	12.83
1200-1300	15	10.49	13.28	9.29
1100-1200	15	10.49	15.07	10.54
1000-1100	25	17.48	28.75	20.10
900-1000	14	9.80	9.71	6.79
Below 900	5	3.50	7.15	5.00
Total	143	100.0	143.0	100.0

The altimetric frequency curve is made by plotting elevation categories versus percent grid frequencies (Fig.14C). The curve indicates uneven distribution of frequencies. The maximum grid frequencies i.e. 92.3% lie between 900m-1000m and 1500m-1600m categories representing 91.98% (13.53 sq. km) of the total area. However, two frequency maxima, 17.48% and 23.08% are conspicuous at 1000m-1100m and 1400m-1500m categories respectively. These represent areal extent of 20.10% (28.75 sq.km.) and 20.44% (29.23 sq.km.) of the total area. The low frequencies, 3.5% and 4.2% occur in below 900m and above 1600m categories respectively.

The frequency maxima (Fig.14C) denotes two summit regions in the area with a low land in between. These summits signify two erosion surfaces occurring at different levels. The nature of altimetric curve prominently shows step or terraces like two redige regions broadly aligned in NE-SW direction. These topographic terraces appear to be structurally controlled. A strong possibility of a hidden graben structure in the area is not ruled out. This feature is distinctly discernible in the contour map of the area (Fig.2). The Tyrsad-Barapani shear zone probably marks the "Southern Fault" of the 'Graben Structure'. The complimentary "Northern Fault" is suspected to be passing through crest of Sumer ridge. The NE-SW trending Umiam river flows in the

trough part of the graben and the 1000m-1100m category summit region marks the northwestern flank of the graben while the southeastern flank is marked by the 1400-1500m category summit region. The low land in the central part is the result of fluvial erosion by Umiām and its tributary networks.

CHAPTER - V

SLOPE ANALYSIS

INTRODUCTION

Slopes are fundamental elements of the landscape (King, 1962). In its broadest sense, it is an element of the interface between lithosphere and either hydrosphere or atmosphere (Fairbridge, 1968). The slope elements of an area reflect the evolutionary history of the existing landscape. Thus, study of slopes of an area is of paramount interest in geomorphology.

In general, slope is often used to refer to the angle which any element of the landscape makes with the horizontal. In other words, slope is a function of relief inclination shown in degrees. Thus, slopes are upward or downward inclination of the surfaces of landscape measured in degrees with respect to horizontal. Often, slope is also measured in grade or gradient.

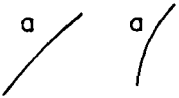
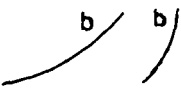
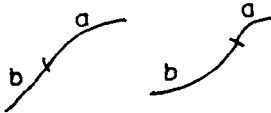
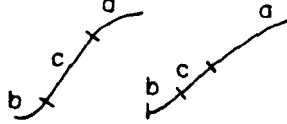
In the present study we are concerned with the slopes of fluvial denudation. Such slopes comprise head water of streams and are adjusted to the geometry of stream network systems.

ELEMENTS OF SLOPE

Slope are perceptible inclination visible on mountain ranges, ridges, scarps, plateau section, flanks of valley etc. Commonly, slopes are classified in terms of slope profile which is a slope belt of unit width extending from drainage divide at the upper extrimity, down to a lower terminus which is commonly a stream channel or a natural discontinuity such as terrace, pediment or cliff. A slope profile is best drawn along the down gradient line orthogonal to topographic contours.

A slope profile may have a variety of forms (Fig.15a) Geometrically, slopes may consist segments which are concave upward, convex upward, straight or rectilinear and complex (Savigear, 1956 & Young, 1964 in Fairbridge, 1968). The inflexion points or the point where the slope changes its profile is termed as 'break-in-slope'. The different elements of slope are shown in Fig.15a&b. King (1957) has given a different slope profile for stratified rocks depicting the different elements (Fig.15b). According to Frye (1959) and Fairbridge (1968), King's profile is usually not applicable in areas with non-stratified rock. However, King's profile is useful in qualitative analysis of slope profiles. The four elements of King's profile are described below:

i) Crest (Waxing slope): Crest slope or waxing slope is the

ELEMENTS OF SLOPES (AFTER YOUNG 1964)	
a Convex	
b Concave	
c Straight or Rectilinear	
Convex-Concave Slopes without Straight Element	
Convex-Concave Slopes with Straight Element	
Complex Slopes (Polycyclic and/or structural control)	

Fig(15a)

ELEMENTS OF FULLY DEVELOPED HILLSLOPE(AFTER KING 1957)

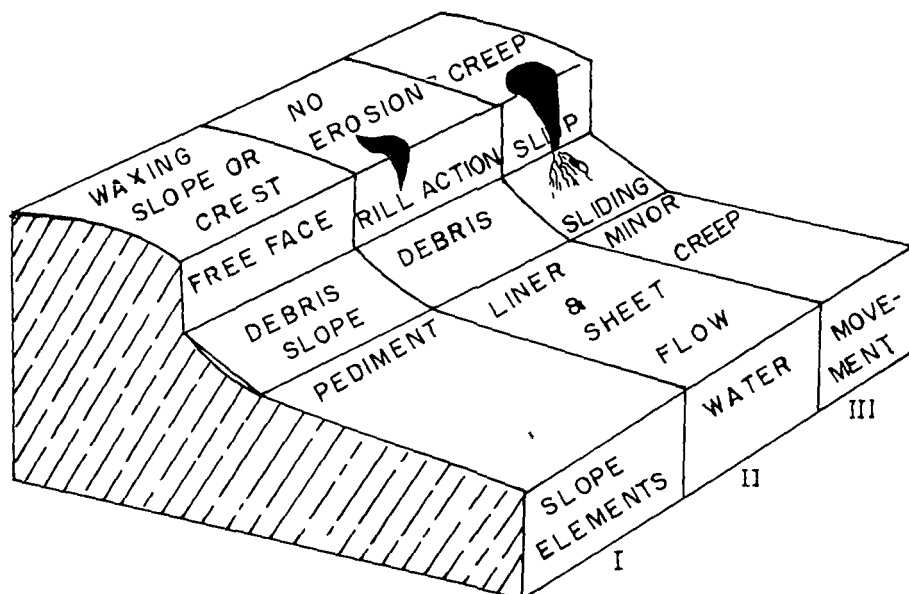


Fig (15b)

upper part of the slope profile. the profile is usually convex. Weathering and soil creep are the main processes forming this convexity.

ii) Scarp (Free Face): The scarp or free face is usually present immediately below the crest slope. It is the most active element in back wearing caused by rillwash and landslides.

iii) Debris Slope (Constant Slope): This part of slope forms just below the free face. It is mostly developed on scree or talus fallen from the scarp above and hence, termed as debris slope. The angle is determined by the angle of repose of the coarse material. Weathering reduces it to finer particles, which are then removed by wash, flowing as rills, or turbulent sheet flow.

iv) Pediment (Wanning Slope): Wanning slope is generally formed by the accumulation of debris from higher slopes. The pediment is a broad concavity extending from the base of the other elements to the stream or alluvial plains. It is produced by surface wash and its profile may approximate to an hydraulic curve.

Young (1972) has classified slopes into ten classes based on their inclination, as given below:

A:	0°-2°	Level to very gentle
B:	2°-5°	Gentle
C:	5°-10°	Moderate
D:	10°-18°	Moderately steep
E:	18°-30°	Steep
F:	30°-45°	Very steep
G:	45°-70°	Precipitous
H:	70°-90°	Almost vertical
I:	Over 90°	Over hanging

SIGNIFICANCE OF SLOPE ANALYSIS

The primary aim of slope analysis is to identify slope elements in an area. Since slope elements are the product of certain processes operating on the earth surface, their study helps in understanding the landform evolution in that particular area.

The manner in which contemporary processes and changes can influence slope form is of general interest in applied geomorphology. At the same time, there is increasing awareness of the practical value of slope studies with regard to proposed and existing developments in hilly areas (Anon, 1978). The aims of slope study can be summarized as follows:

- (a) To assess the stability of different types of slopes under given conditions.
- (b) To assess the possibility of landslides involving natural or existing man made slope.

- (c) To analyse slips and landslides that have already occurred and to assist in the understanding of failure mechanisms and the influence of environmental factors.
- (d) To enable the redesign of failed slopes, and the planning and design of preventive and remedial measures where necessary.
- (e) To enable a study of the effect of exceptional loadings such as earthquakes on slopes and embankments.
- (f) To understand the development and form of natural slopes and the processes that have been responsible for the different natural features.

Slopes are ubiquitous elements of the land surface. They exert their influence on development of soil, loss of soil by soil erosion, mining operations, agricultural practices and development of communication network.

Since all these aspects are related to slope, a detailed analysis of slope of an area becomes essential for charting out a developmental plan for the area.

METHODOLOGY

An exact way of representing slope is to give gradient along a line which can be done as follows:

- (a) Drawing profiles on the basis of contours from maps.

- (b) Measuring gradient directly in the field of hill-sides by Abney Level.
- (c) Channel gradient on the basis of contour and drainage maps.

However, such linear expression though exact, do not provide a spatial distribution of gradient in an area. The earth surface slopes in different directions with different values, so a linear expression does not give the true picture of slope in an area. Thus a spatial distribution of slope variation giving average slope is preferred over linear expressions though at the cost of exact slope values. Different methods are suggested by Finster Walder (1890), Wentworth (1930), Smith (1935), Riasz and Henry (1937), Miller (1949), Strahler (1956), Miller and Summerson (1960) etc. Some methods are much laborious over others and have complicated calculations and the results obtained are not proportionately satisfactory to the labour involved. However, the method devised by Wentworth (1930) for 'general and random' determination of average slope over an area from a contour map is quite satisfactory, and has been adopted for the slope analysis in the area.

The formula devised by Wentworth is given below:

$$\text{Average Slope} = \tan \theta = N \times CI/3361$$

Where, N = Average no. of contour crossing in an area per sq. mile.

CI = Contour interval in feet.

3361 = A constant figure.

Zakrzewska (1967) modified Wentworth's above formula as given below:

Slope in degree = $\tan \theta = V \times N / 0.6366K^*$

Where, V = Vertical contour interval in metre or in feet.

N = No. of contour crossing per sq. km. or per sq. mile and,

K = Constant, 1000 for metric units and 5280 for feet and miles i.e. British units.

The area has been divided into one x one km grids and the number of contours crossing per sq.km. i.e. per grid is counted (contour crossing per side of the grid divided by four = contour crossings per grid). With the above modified Wentworth's formula, average slope per grid is computed (the value obtained by the formula is converted into degree). These average slope values obtained have been classified into 7 categories with an interval of 5°. These 7 categories were further classified into five qualitative groups as per Young's classification (cf. P.83).

*0.6366K becomes 636.6 for metric system (0.6366x1000) because 1 km=1000m. 0.6366 is the mean of all possible values of $\sin \theta$ (where θ is the horizontal angle between the contour and the grid line 0.6366K becomes 3361 in f.p.s. (0.6366x5280) because 1 mile = 5280 feet.

The spatial distribution of the 7 categories of slopes are shown in Fig.(16). The frequency distribution of slope in the area is given in Table(13).

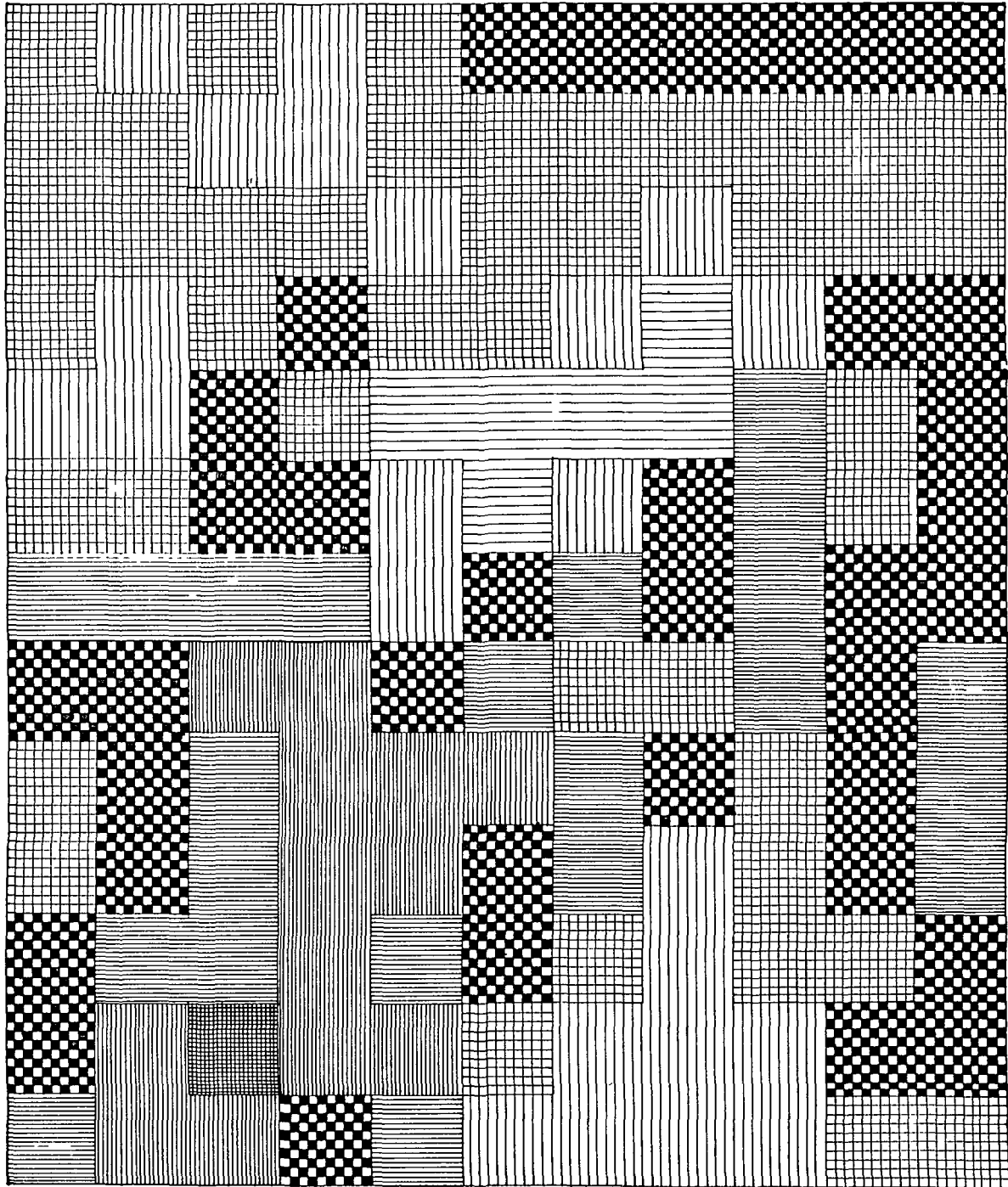
TABLE - 13
Frequency distribution of slope values

Slope(°)	Frequency of Grid	% of total frequency	Cummulative % of frequency	Slope Category
Above 30	1	0.70	0.70	Very steep
25-30	13	9.09	9.79	Steep
20-25	22	15.38	25.18	
15-20	36	25.18	50.36	Moderately steep
10-15	42	29.37	79.73	
5-10	23	16.08	95.80	Moderate
Below 5	6	4.20	100.0	Level to gentle
Total	143	100		

The Table-(13) reveals the distribution pattern of frequencies as per various slope categories in the area. It is seen that the category of very steep slope has the minimum slope frequency (0.70%). Similarly, the level to gentle slope category has insignificant frequency distribution (4.20%). However, the contribution of moderate slope frequencies is 16.07%. Remarkably, the category of moderately steep to steep slope (10°-30°) category constitute

AVERAGE SLOPE

1 km 0.5 0 0.5 1 km



INDEX

SLOPE IN DEG PER Sq Km

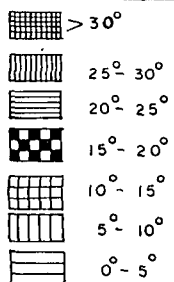


Fig (16)

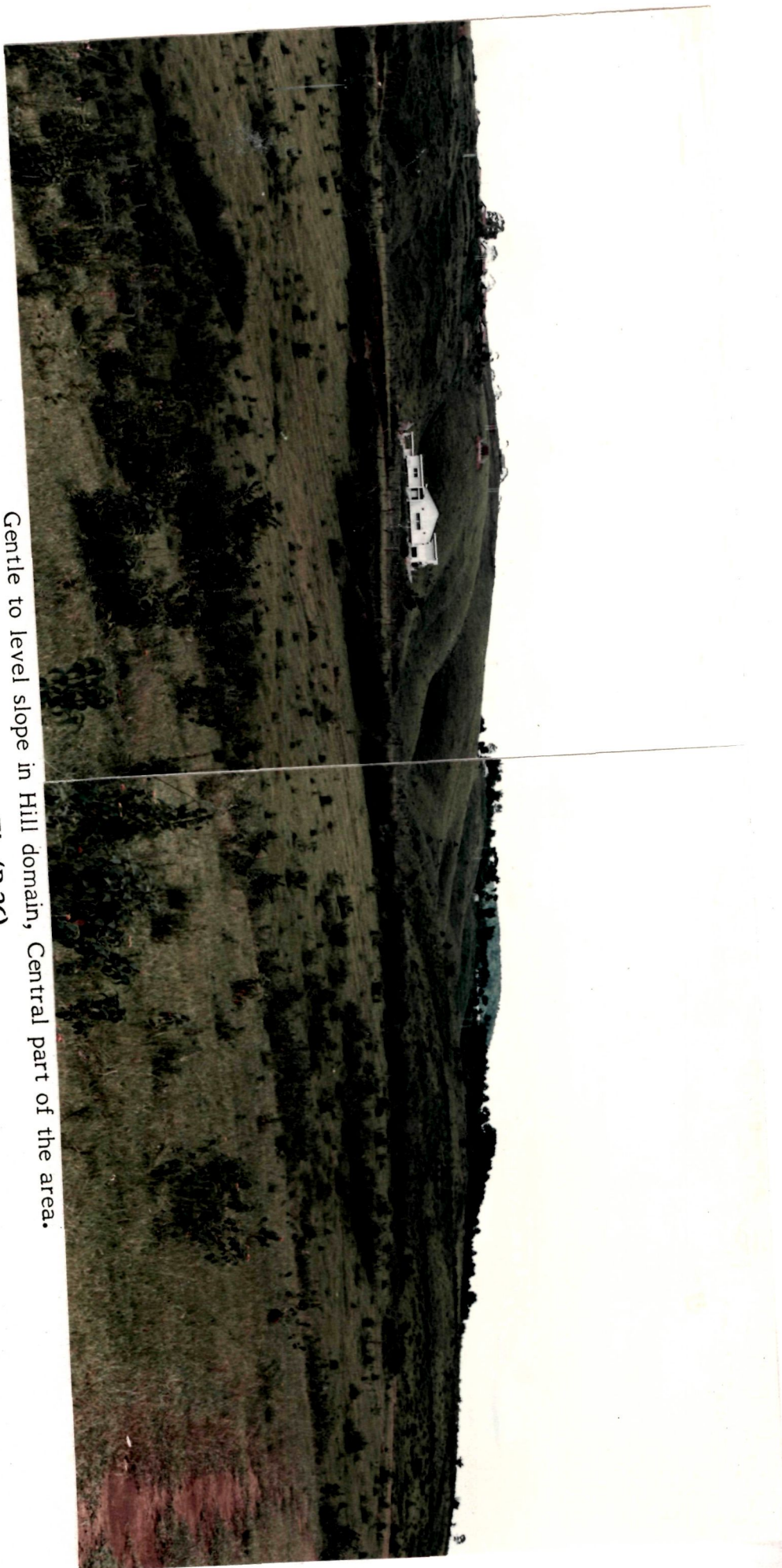
maximum slope frequencies (79.03%). The area-wise slope distribution is given in Table-(14).

TABLE-14
Area-Slope distribution

Slope(°)	Area in sq. km.	Cummulative area in sq.km.	Area in %	Cummula- tive % area	Slope category
Above 30	1	1	0.70	0.70	Very Steep
25-30	13	14	9.09	9.70	Steep
20-25	20	36	15.39	25.18	
15-20	36	72	25.18	50.36	Moderately Steep
10-15	42	114	29.37	79.73	
5-10	23	137	16.07	95.80	Moderate
Below 5	6	143	4.20	100.0	Level to Gentle
Total	143		100.0		

The Figure-(16) reveals that the slope frequencies have uneven distribution. The category wise area slope distribution is discussed below.

Level to Gentle Slope: This group (below 5°) has relatively small coverage (4.20%) mainly confined in the central part of the area (Fig.P26). Significantly, this is the sector where the Umiam Lake is located and the river Umiam debouches into the lake.



Gentle to level slope in Hill domain, Central part of the area.

Fig.(P.26)

The area exposes mostly alluvial terraces, debris slopes and colluvial fans over Shillong Group of rocks. The conspicuous landforms in the sector are the high level terraces.

Moderate Slope: This group (5° - 10°) have areal coverage of (16.07%) and occurs in patches in the northwestern corner, central part and southeastern corner of the area. It shows uneven distribution. However, part of Shillong Township and Mawlai Township are located in this grade of slope.

The part of slope category located in the northwestern corner is by and large confined in the Gneissic Complex while the remaining part of this category that is occurring in the central and southeastern corner of the area is over Shillong Group of rocks.

Moderately Steep Slope: Over 50% of the area (54.55%) is occupied by moderately steep slope category (10° - 20°). It shows patchy distribution. Fig.(16) reveals a conspicuous pattern broadly an inverted 'L' shaped distribution. The horizontal arm of 'L' aligned in E-W direction, north of Umiam lake and the vertical arm is aligned in N-S direction, east of Shillong Township. This category of slope distribution shows a pattern oblique to the regional trend of

lithotypes. Possibly this indicates the development of slopes independent of structural trends.

Steep Slope: This group (20° - 30°) has a spatial coverage of (24.48%). It shows clustering in the southwestern corner and eastern flank of the area. Broadly this clustering shows a NE-SW trend in the southwestern corner, more or less coinciding with the Wah Umiam trend. The eastern flank shows N-S trend parallel to Phud Umshing. By and large this category forms the Umiam gorge section in the area.

Very Steep Slope: This group of slope (above 30°) covers a very insignificant coverage (0.70%) in the southwestern corner of the area. It is confined in the southern proximity of the Mawlynti ridge occurring west of the confluence of Wah Ro Ro and Wah Umiam.

The Mawlynti ridge forms a steep sided promontory at its southernmost tip, into Wah Umiam Valley. Possibly this is the reason for the occurrence of very steep slope in this sector of the area.

The relation between area slope distribution is further been shown by drawing area-slope curve and slope give (Fig.17a & 17b). It is conspicuous seen that the sudden

rise of the curve after 5° of slope has large coverage of the area.

Correlation of Absolute Relief and Slope:

The relationship between absolute relief and slope is seen from the distribution pattern of frequencies of slope in different categories of absolute relief (Table-15). It is evident that the level to gentle slope category (0° - 5°) have low frequency distribution (4.2%) and occupies areas with 900m to 1100m height groups.

The moderate slope category (5° - 10°) has fairly good frequency distribution (16.08%) and is distributed throughout the area except in height groups of 1200m-1400m and above 1600m.

Moderately steep slopes (10° - 20°) has the dominant frequency distribution (54.55%). The maximum slope frequency (37.2%) of this class is seen in 1100m-1200m height category. This is followed by 26.9% and 11.5% frequency distribution in 1400m-1600m and 1200m-1300m height categories.

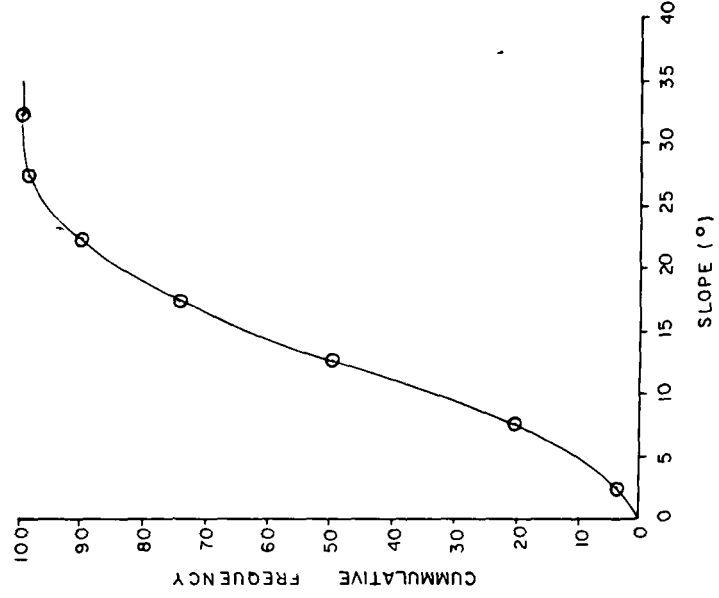
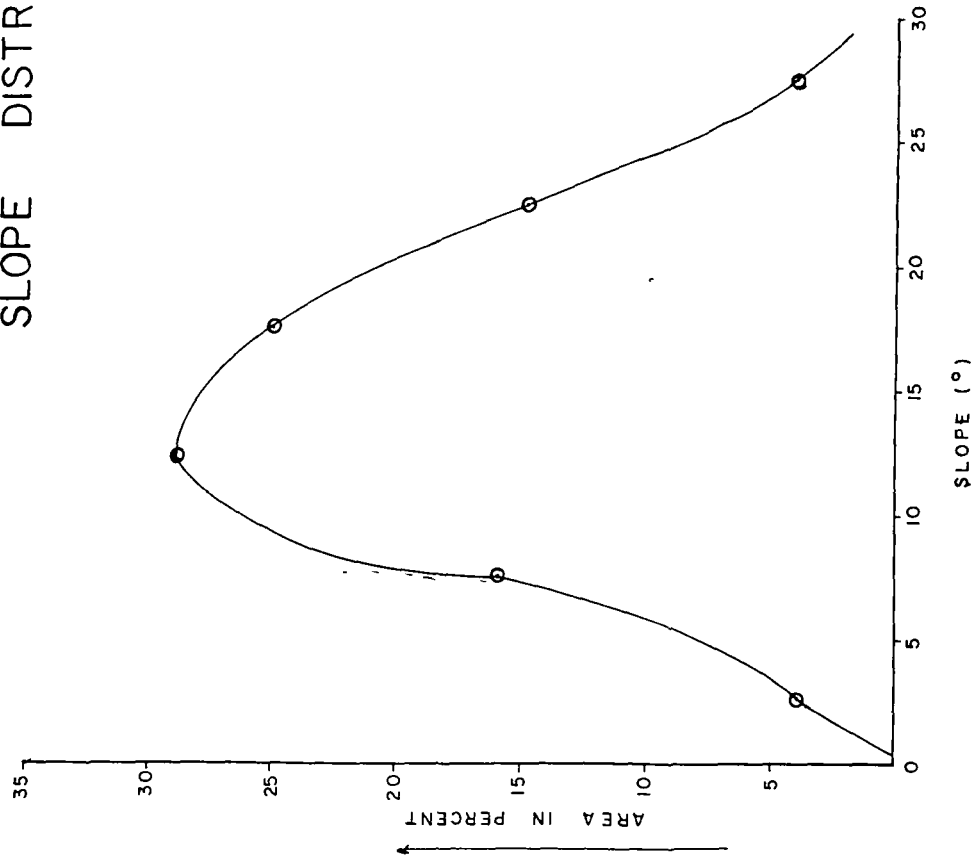
The steep slope category of 20° - 25° subclass is distributed (15.38%) from 1200m to above 1600m height categories. However, its subclass (25° - 30°) is distributed

TABLE - 15

Distribution of frequencies in categories of Absolute Relief and Slope
(A two way classification of the units of one sq.km.)

Absolute Relief in m.	Slope in degree							Total Grid fre- qu- ency	Total % fre- qu- ency
	Level to Gentle 0° to 5°	Moderate 5° to 10°	Moderately Steep		Steep		Very Steep 30° to 35°		
			10° to 15°	15° to 20°	20° to 25°	25° to 30°			
Above 1600	-	-	2	3	1	-	-	6	4.20
1500 - 1600	-	1	5	6	3	1	-	16	10.49
1400 - 1500	-	8	3	7	9	5	1	33	23.78
1300 - 1400	-	-	2	2	5	5	-	14	9.09
1200 - 1300	-	-	2	7	4	2	-	15	11.19
1100 - 1200	-	1	7	7	-	-	-	15	11.19
1000 - 1100	4	6	11	4	-	-	-	25	16.78
900 - 1000	2	6	6	-	-	-	-	14	9.79
Below 900	-	1	4	-	-	-	-	5	3.49
Total	6	23	42	36	22	13	1	143	
Total in %	4.2	16.08	29.37	25.18	15.38	9.09	0.7	4	100.0

SLOPE DISTRIBUTION



(a) AREA SLOPE CURVE

(b) SLOPE OGIVE

in 1200m to 1600m height categories only (9.09%).

Remarkably very steep class of slope (30° - 35°) has very limited frequency distribution (0.7%), only confined in 1400m-1500m height category.

To evaluate correlation between slope and absolute relief, a quantitative analysis is attempted and correlation table prepared (Table-16). The coefficient of co-relation is computed between the two variables using Carl-Pearson formulae.

The coefficient of co-relation value between absolute relief and slope is 0.46. The regression lines for the two variables are shown in (Fig.18a). The relationship between the absolute relief and slope is expressed by the following equations:

$$1) \quad Y = 0.04148X - 37.0$$

$$2) \quad X = 11.674Y + 1085.68$$

The co-efficient of correlation value of +0.46 indicate moderate correlation between absolute relief and slope. The correlation is significant at 1% level of significance. It implies that the slope does rise to some extent with rise in absolute height in the area. A general pattern

TABLE - 16
Correlation table of absolute relief and slope variables

Slope(°) Absolute Relief(m)		Level to Gentle	Moderate	Moderately Steep		Steep		Very steep	Total frequency in %	$\sum f(x)$	$\sum f(y)$	$\sum f(x,y)$
		0° to 5°	5° to 10°	10° to 15°	15° to 20°	20° to 25°	25° to 30°	30° to 35°				
	Y_j	2.5	7.5	12.5	17.5	22.5	27.5	32.5				
	V_j	-3	-2	-1	0	+1	+2	+3				
	U_j											
	X_i											
1600-1700	+4	-	-	2	3	1	-	-	4.20	+24	+96	-4
1500-1600	+3	-	1	5	6	3	1	-	11.19	+48	+144	-6
1400-1500	+2	-	8	3	7	9	5	1	23.08	+66	+132	+6
1300-1400	+1	-	-	2	2	5	5	-	9.79	+14	+14	+13
1200-1300	0	-	-	2	7	4	2	-	10.49	0	0	0
1100-1200	-1	-	1	7	7	-	-	-	10.49	-15	+15	+9
1000-1100	-2	4	6	11	4	-	-	-	17.48	-50	+100	+70
900-1000	-3	2	6	6	-	-	-	-	9.79	-42	+126	+72
800-900	-4	-	1	4	-	-	-	-	3.49	-20	+80	+24
Total grid frequency $f(y)$		6	23	42	36	22	13	1	100.0	+25	+707	+184
Total frequency in %		4.2	16.08	29.37	25.18	15.38	9.09	0.7				
$\sum f(x)$		-18	-46	-42	0	+22	+26	+3				
$\sum f(y)$												
$\sum f(x,y)$		+54	+92	+42	0	+22	+52	+9				
$\sum f(x,y)$		+42	+32	+32	0	+36	+36	+6				

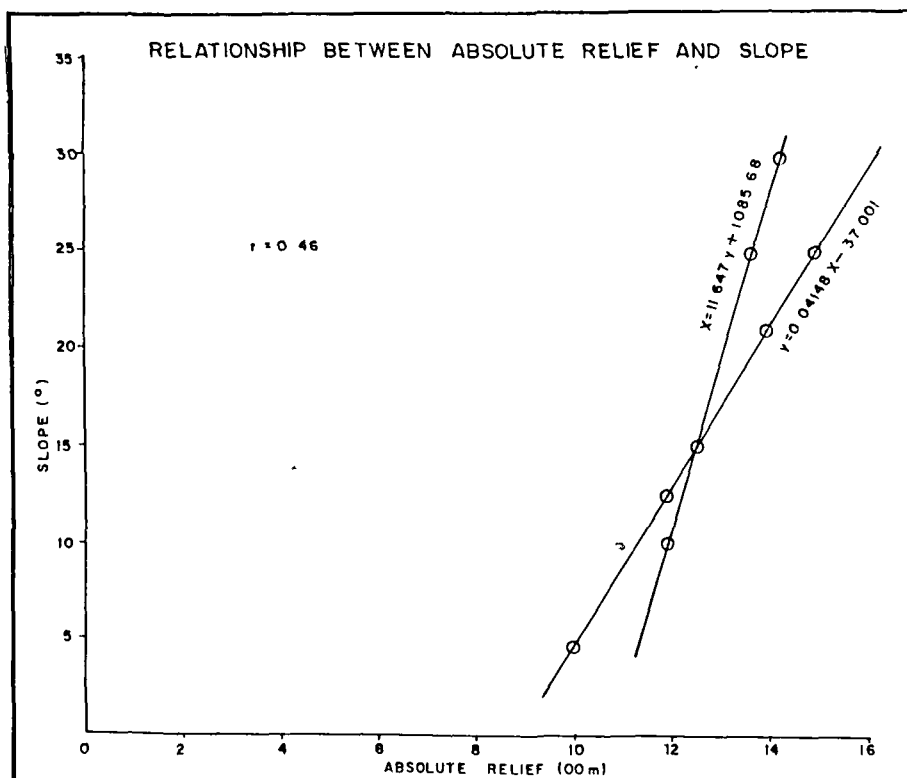


Fig (18a)

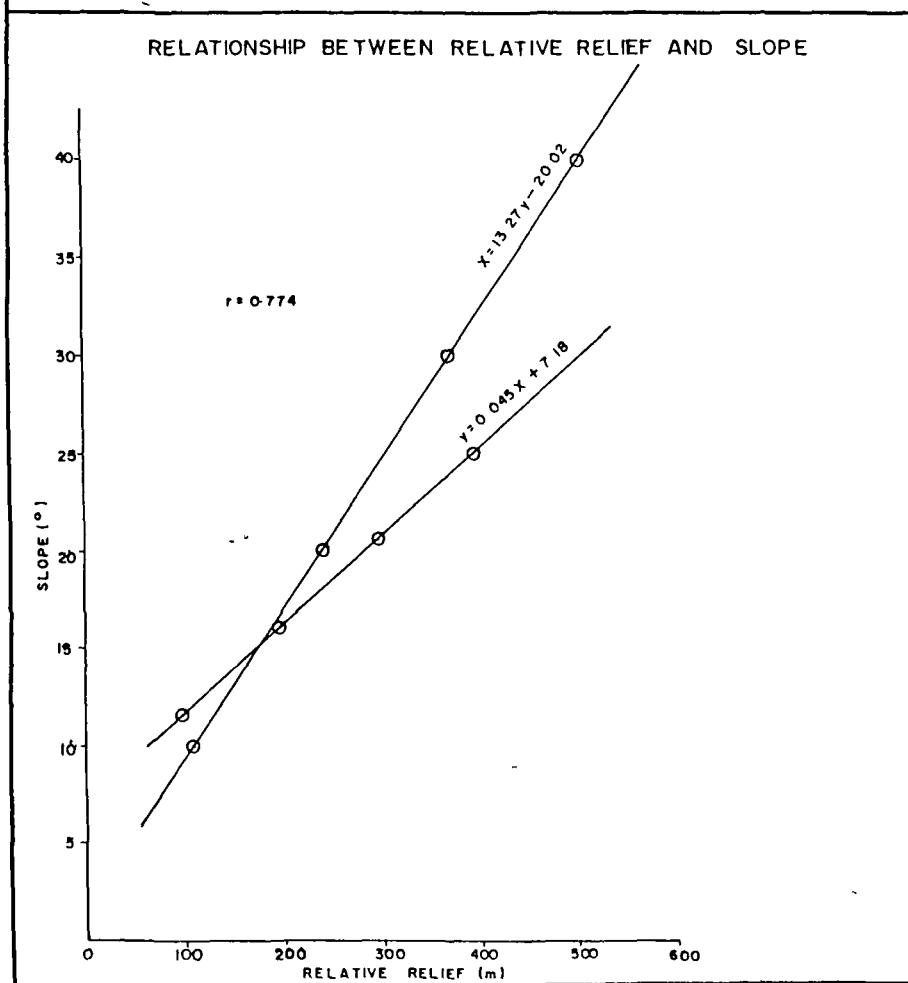


Fig (18b)

of slope rise is exhibited (moderate to steep slopes). However, elevation above 1600m do not have steep slopes but, have only moderate slope. This is typical of plateau regions where the ridge tops have smooth skyline or profiles (Fig.P12). Subsequent dissection of Plateau has resulted in uneven distribution of slope frequencies in the area

Correlation of Relative Relief and Slope:

A correlation between relative relief and slope is attempted, the distribution pattern of slope category frequencies in different relative relief categories is evident in Table-(17). It is seen that the level to gentle slope category (0° - 5°) have low frequency distribution (3.49%) and occupies relative relief categories below 50m and 150m-200m category only. This indicates that areas where incision is low necessarily have gentler slopes and vice versa. A comparison of relative relief map (Fig.12) and average slope map (Fig.16) makes it abundantly clear. This implies that the area represents a dissected plateau, showing gentler slopes in area with low relief i.e. Plateau ridge tops.

The moderate to moderately steep slopes (5° - 20°) have high frequency distribution (71.33%) in below 50m to 350m and above 450m relative relief categories. By far the maximum frequency distribution (34.2%) of this slope

TABLE - 17

Distribution of frequencies in categories of relative relief and slope
(A two way classification of the units of one sq. km.)

Relative Relief in m.	Slope in degree							Total Grid frequency	Total % frequency	
	Level to Gentle	Moderate	Moderately steep		Steep		Very steep			
			0° to 5°	5° to 10°	10° to 15°	15° to 20°				20° to 25°
Above 450	-	-	-	1	-	1	-	1	2	1.4
400 - 450	-	-	-	-	3	2	1	2	6	4.2
350 - 400	-	-	-	-	-	5	-	5	5	3.5
300 - 350	-	-	1	1	7	3	-	3	12	8.39
250 - 300	-	-	3	7	7	1	-	1	18	12.58
200 - 250	-	1	3	9	1	1	-	1	15	10.5
150 - 200	1	-	7	11	-	-	-	-	19	13.28
100 - 150	-	7	14	7	4	-	-	-	32	22.38
50 - 100	-	10	11	-	-	-	-	-	21	14.68
Below 50	4	6	2	1	-	-	-	-	13	9.09
Total	5	24	41	37	22	13	1	1	143	
Total in %	3.49	16.78	28.67	25.88	15.39	9.09	0.7	0.7		100.0

TABLE - 18

Correlation table of relative relief and slope variables

Slope(°) Relative Relief(m)		Level to Gentle	Moderate		Moderately Steep		Steep		Very steep	Total freq- uency f(x)	Total freq- uency in %	$\sum_1^1 f(x)$	$\sum_1^1 f_2(x)$	$\sum_1^1 V_1 f(x,y)$
			5° to 10°	7.5	10° to 15°	15° to 20°	20° to 25°	25° to 30°						
	Y_1	0° to 5°							30° to 35°					
	Y_1	2.5			12.5	17.5	22.5	27.5	32.5					
	X_1	V_1 U_1												
450-500	475	+4	-	-	-	1	-	1	-	2	1.4	+8	+32	+8
400-450	425	+3	-	-	-	-	3	2	1	6	4.2	+18	+54	+30
350-400	375	+2	-	-	-	-	-	5	-	5	3.5	+10	+20	+20
300-350	325	+1	-	-	1	1	7	3	-	12	8.39	+12	+12	+12
250-300	275	0	-	-	3	7	7	1	-	18	12.58	0	0	0
200-250	225	-1	-	1	3	9	1	1	-	15	10.5	-15	+15	+2
150-200	175	-2	-	-	7	11	-	-	-	19	13.28	-38	+76	+20
100-150	125	-3	7	7	14	7	4	-	-	32	22.38	-96	+288	+72
50-100	75	-4	10	11	11	-	-	-	-	21	14.68	-84	+336	+124
0-50	25	-5	6	2	2	1	-	-	-	13	9.09	-65	+325	+130
Total Grid frequency f(y)	5	24	24	41	37	37	22	13	1	143	-250	+1158	+418	
Total frequency in %	3.49	16.78	16.78	28.67	25.88	25.88	15.39	9.09	0.7	100.0				
$V_1 f(y)$	-15	-48	-48	-41	0	0	+22	+26	+3	-53				
$V_1^2 f(y)$	+45	+96	+96	+41	0	0	+22	+52	+9	+265				
$V_1 U_1 f(x,y)$	+66	+184	+184	+112	0	0	+3	+44	+9	+418				

category is in 100m-150m relative relief areas, followed by 25.61% in 50m-100m relative relief category.

Steep to very steep slopes (20° - 35°) have moderate frequency distribution (25.18%); 25° - 30° slope category occupies 200m to above 400m relative relief categories. However, very steep slope category (30° - 35°) has lowest frequency distribution (0.7%) occupying only 400m-450m relative relief category.

Quantitative analysis of relative relief and slope category frequency distribution is attempted and correlation table prepared (Table-18). The coefficient of correlation value between the two variables is 0.774. The correlation is significant at 1% level of significance. The regression lines for the two variables are shown in Fig.(18b). The relationship between the relative relief and Slope categories is expressed by the following equations:

$$1) \quad Y = 0.45X + 7.18$$

$$2) \quad X = 13.27Y - 20.02$$

The coefficient of correlation value of 0.774 indicates fairly good correlation between the above two variables. This value of coefficient of correlation is due to the fact that the area forms part of a dissected plateau with low incision i.e. low relief.

Slope Development: _

Slope of an area is a function of climate, lithology, tectonics, structural elements and biotic activities. A slope form can have a concave, convex, straight or a complex morphology showing all the three forms.

The slopes in the area depicts all the three 'forms' discretely as well as in combination (Fig.P1 & P23). The top of ridges usually have convex profiles but the ridge flanks show combination of all the three forms. By and large the convex and straight segment of the slope profiles in the area are erosional in nature while the concave slopes are depositional in nature. The natural slope profile is seen at places modified due to the interference of 'man'. The sections in the vicinity of developmental schemes show modified slope profile particularly in the areas which have been denuded of vegetation and where there are unsystematic slope cuttings. Such sites often becomes prone to landslides (Fig.P27) as the stability of slopes get jeopardised. The slope frequently fails due to rapid change in equilibrium conditions This is the common feature seen along highway slope cuttings (Fig.P28 & P29).

The slope profiles over Gneissic country in the northwestern corner of the areas are mostly concavo-convex.



Fig.(P.27)

Modified slope profile
segment prone to slope
failure.



Fig.(P.28)

Slope instability in
Khasi Green stone
due to steep cutting.
Note deforestation
on slope.

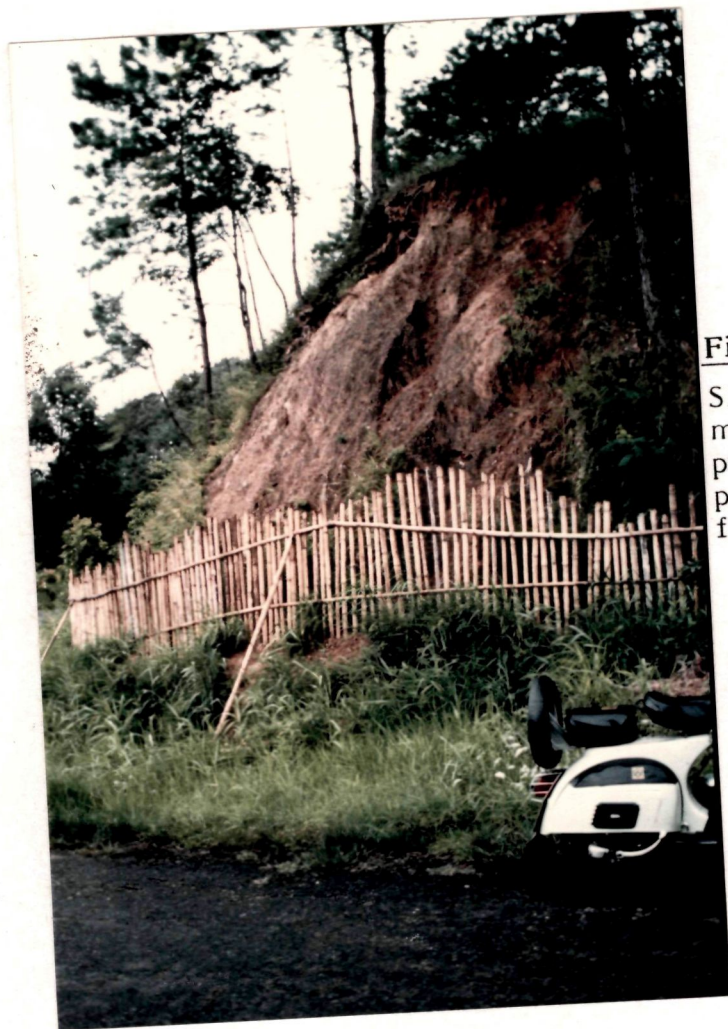


Fig.(P.29)

Slope failure due to modification of slope profile. Note temporary protection by bamboo fence.

Slopes over Shillong Group show all the three slope elements, however, the bottom slopes are remarkably 'concave with low curvature, merging with pediments.

It is evident from the correlation of different variables that the slopes in the area are by and large controlled by lithology, tectonics and structural characteristics in the area. The climate more or less can be taken uniform over the area.

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CHAPTER - VI

WEATHERING, SOIL AND MASS WASTING

INTRODUCTION

These three phenomena occur in nature in a sequence as part of 'Circulation of Matter'. Weathering is the initial phase in the denudational history of any landscape, as rocks must be weathered before the debris can be transported and erosion is very limited unless the agents of transport are carrying a load of debris.

Soil is the phase through which much of the rock waste of the lands must pass before it is ultimately removed. The movement of rock debris and soil on slopes is subjected to a large variety of processes, some of which act slowly but continuously like soil creep. However, process of mass wasting cause sudden movements of large masses of material followed by long period of quiescence.

WEATHERING

The inherent contrast in the underlying bedrock are brought into relief by process of weathering and erosion. Both weathering and erosion are strongly influenced by climate. A given set of climate and geological conditions

causes the development of certain complex weathering and erosional processes.

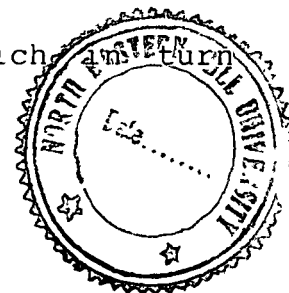
Weathering may be defined as the disintegration or decomposition of rocks in situ at or near the ground surface. It is primarily concerned with reduction of a rock mass to a form and size susceptible to erosion, which is accompanied by such agencies as mass movement, running water etc.

FACTORS CONTROLLING WEATHERING

The factors influencing weathering in an area are mainly climate, temperature, rainfall, humidity, geology etc. The geologic factors, more or less remain constant in an area over long period of time but the other factors are time dependent. As a result, climate, temperature, humidity and rainfall exert greater influence in the weathering processes.

The climate of the area falls under "Selva" (Fig.5). The high rainfall and plateau nature of the area is conducive to deep chemical weathering. Due to the climate and altitude, the area has luxuriant pine forests. The "litter" of the pine forest turns the soil acidic which increases leaching i.e., chemical weathering.

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Similarly, the area shows wide variations in temperature (Table-2). The high variation in temperature increases mechanical disintegration of rocks.

The area experiences high rainfall (Table-1). The rainfall over the acidic soils yields large amount of acidic waters which increases removal of huge quantities of leached ions and precipitate part of them when changed Eh-pH conditions are encountered. Similarly, higher rainfall in the catchment of Wah Umiam increases run-off along slopes. Consequently, large quantities of material are constantly removed downslope. As a result, new bedrock is frequently exposed to physical and chemical weathering.

Humidity is related to rainfall and temperature. Because of higher rainfall in the area, the humidity normally remains moderate to high (Table-3). As a result evaporation is slow. This indirectly helps in retaining the soil moisture for prolonged period. The overall effect is faster and prolonged chemical weathering.

Rock weathering has two general processes, operating in the area i.e. 1) physical weathering, involving rock disintegration, without any change in mineralogical constitution, and (2) chemical weathering, involving complete

or partial mineralogical reconstitution (alteration).

In the study area, the lithological variations can be grouped into following divisions, as per their spatial distribution.

- 1) The Gneissic association
- 2) The Khasi Green Stone
- 3) The Shillong Group.

These three litho groups exhibit different weathering characteristics, due to the intrinsic variation in mineralogy and structural attributes. The difference in physical weathering is more pronounced than the differences in chemical weathering.

Gneisses: The gneisses, by and large are the most competent rocks, occupying the northwestern part of the area. These rocks tend to break down into two stages, firstly the rocks break into blocks along joints and gneissosity surfaces and detach from the main mass. Under the influence of gravity these blocks move down as per the profile of slopes. These blocks show spheroidal weathering. The hummocky topography in the Gneissic terrain is due to accumulation of such boulders or remnants of it.

Reduction in size and opening of joints and other surfaces of fissility like gneissosity causes the gneisses to be attacked faster chemically. It alters into a granular debris, comprising kaolinised felspar and quartz. Much of the Fe, Mg ions have leached out of the weathered rock. The chemical alteration advances as a front along joints and other fissile surfaces, from outward to inward. As a result, the slope profiles show at many a place 'Core boulders', which is an unaltered gneiss core with an envelope of weathered mass of sand like gritty material.

The Khasi Green Stone: In contrast to gneisses, the Khasi Green Stone due to its massive nature produces bouldry outcrops. The size of boulders vary mostly between 10cms to 30cms, rarely upto 1-2m across. The boulders are detached mostly along the orthogonal fractures and have suffered rounding of corners due to chemical weathering. Such features are very commonly seen in area around Mawiong.

The Khasi Green Stone, due to its basic/ultrabasic nature is more prone to chemical alteration and has weathered out fast producing a reddish-brown regolith (Fig.P30) and soil mantle (lateritic). Due to steeper slopes and extensive deforestation, the red soil-mantle has moved outwardly and mushroomed over the underlying rocks. As a result this



Fig.(P.30)

Soil profile over Khasi
Green Stone.

lateritic soil is seen disproportionately to the areal distribution of the parent rock.

The pine forest in the area makes the soil acidic in nature and due to high precipitation the leaching of Fe-Mg is fast. As a result the staining and pigmentation of adjoining rocks along joints and fractures has become pronounced.

Whereever the rock is sheared it has suffered brittle failure and occurs as a pulverised mass. Due to this the Khasi Green Stone has become more permeable to the chemical solution or more prone to chemical attack. In such areas the rock has completely altered into an undifferentiated soil profile.

The Shillong Group: By far it is the predominant rock type in the area. The rocks are very well bedded and due to alternation of quartzite, phyllite and siltstone show differential weathering. The quartzites and phyllitic sandstone being more resistant stand out in relief, while the siltstone and phyllites form subdued topography like 'benches', valley flats.

In areas where the beds have horizontal to subhorizontal

disposition the physical weathering of rocks is much impeded except where the slopes have been destabilized by excavations. However, in areas where rocks have steeper or vertical dips the physical weathering is more pronounced (Fig.P31), particularly in vicinity of Barapani-Tyrsad shear zone and other structural lineaments. Such area show large accumulation of rubble as the rocks disintegrate along bedding, foliation and joint surfaces. The rocks are pulverised along 'shears' and weathers out faster (Fig.P32) as slides on different scales and modes.

Chemically the rocks are not as receptive as Khasi Green Stone but being well bedded and foliated are more permeable. The permeability is further enhanced due to the presence of joints and fractures. The permeability induced subsurface water circulation is conspicuously evident by numerous fresh water springs in and around Shillong Township, Mawlai and Barapani ICAR research farm. Water seepage is a very common phenomenon visible along sharp cuttings or topographic breaks in Shillong Group of rocks.

This subsurface water circulation net work has altered the Shillong Group of rocks extensively. The intergranular cementing material has been leached out many a places. As a result the sandstone, phyllitic sandstone have lost

Fig.(P.31)

Physical weathering
in subvertical phyllitic
sandstone (south of
dam).



Fig.(P.32)

Sheared phyllitic sandstone
exposed north of dam,
depicts 'faster' physical
weathering.

their intergranular bonding strength and have become like sands and silts. This is being used as building material as a substitute for river sands and silts.

Another conspicuous feature of the subsurface water circulation is the movement of Fe-Mg ions and their precipitation along fractures and open space cavities. A very common feature seen in Shillong Group of rocks is the presence of thin encrustations of goethite as laminae and dripstones. This is due to precipitation of Fe ions under evaporation. These goethite encrustations are commonly seen where the rock cutting remain unmodified for prolonged periods. Such feature is commonly seen in Mawlai, Barapani and Nongbir areas. Where the rock cutting is modified frequently, the Shillong Group of rocks show variegated colouration (brown-maroon-orange).

SOILS

The study area shows little variation in respect of climatic-factors (rainfall, temperature and humidity). Geologically also the different rock types show gross homogeneous characters and more or less similar uniform weathering phenomena. Consequently the resultant soil profiles are the result of local relief differences and high degree of denudation by 'Jhum' activity.

The dominant litho types in the area belong to the low grade metamorphosed Shillong Group represented by quartzite, phyllitic sandstone, phyllite and siltstone, intruded locally by minor lenses of Khasi Green Stone. The northwestern part of the area has a small patch of gneisses.

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The soil has predominantly formed by the in situ weathering of these rocks. They have variable colours both at surface and subsurface depending upon the degree of oxidation of Fe-Mg-Mn bearing mineral phases. The soils are strongly acidic throughout the solum. The low pH and low base saturation indicate heavy leaching of bases under high rainfall conditions. However, the limited area occupied by river valleys show transported soil profiles.

By and large the in situ soil profile is thick with argillic horizon and a thick weathered mantle below. The salient characteristics are given below.

Soils over Gneissic Terrain: The Gneissic Complex is confined in the northwestern part of the area. The soil derived from the gneisses is mostly medium to fine textured. The soil profile is mostly thick. The colour varies from dark tan to dark reddish brown. Texturally it is lo^aamy to clayey, non sticky and non plastic.

It is gravelly at places due to the presence of abundant fragments of quartz. Due to the presence of ever green forest, the top soil is rich in humus because of leaf litter. However, on steep slopes and on areas of 'Jhum' activity the top soil has relatively lesser humus. It is constantly being eroded and deposited at lower levels and valley flats. As a result the soil profile does not show well differentiated A- and B- horizons. In areas of low relief where the soil is developed on ledge/spur tops, having gentle and rolling topography, the soil profile does have differentiated A- and B- horizons.

Soils over Shillong Group: Soils derived from rocks of Shillong Group are medium to fine textured. The depth of soil horizon varies between 20cm to 200cm, with gravelly horizon locally. Due to continuous leaching the bases are leached out. In general the soil is homogenous, granular, loomy to clayey, non sticky and non plastic. The colour of soil varies from very dark grayish brown to yellow through brownish yellow. Due to the presence of evergreen forest, the top soil is rich in humus. Jhumming activity in the area has eroded much of the top soil to lower levels and at some areas the fertility of the soil has been reduced. The soil shows differentiated profile on gentler slopes only.

Soils over Khasi Green Stone: Soils over Khasi Green Stone is typically lateritic (Fig.P30) giving a reddish brown hue to the landscape around. Due to the basic nature of the rock, it is more susceptible to alteration and has produced extensive soil horizon. The soil is clayey to loamy, moderately fine and granular. It is non plastic and non sticky. Its colour varies from yellow red to red. The in situ soil profile varies in depth from 20cm to 200cm and shows homogenous nature.

According to Prasad et al (1980,1981), steep slopes accelerate removal of soil separates, exchangeable cation through the various agencies like high intensity of rainfall, movement of animals and human beings. Soil properties as modified by topography in East Khasi Hills is given in Table(19).

A perusal of Table(19) indicates significant removal of organic carbon, exchangeable calcium, magnesium and sodium from slopy lands and these have been accumulated in the Valleys. Clay content in the valleys is low, this is mainly because the runoff with fine sediments get less time for settling due to heavy flow. This is the characteristic feature of soils throughout the entire Meghalaya plateau. When the flow of the runoff sediment is slow, clay

TABLE - 19

Altitudinal variation in physico-chemical properties of soils
(after Prasad et al 1980, 1981)

Soil Properties	Altitudes (above m.s.l.)		
	Above 1000m		100 - 1000m
	Upland	Lowland	Upland
Sand %	50.4 - 57.60(54.4)	49.6 - 57.8(53.8)	50.4 - 68.8(56.9)
Silt %	27.4 - 34.8(30.5)	31.4 - 34.8(33.4)	16.4 - 24.4(21.3)
Clay %	12.4 - 20.8(15.1)	10.8 - 16.4(12.8)	12.8 - 27.8(20.8)
pH	4.70 - 5.40(5.09)	4.70 - 5.35(5.05)	4.35 - 5.45(5.09)
Org. C. %	1.14 - 3.06(2.12)	0.96 - 5.53(3.24)	1.14 - 2.40(1.81)
Exch. Ca+Mg(me/100g)	3.99 - 5.15(4.62)	3.57 - 5.36(4.54)	3.27 - 7.04(5.04)
C.E.C. (me/100g)	6.25 - 9.25(8.35)	8.00 - 14.50(10.70)	7.00 - 10.00(8.55)
Exch. Acidity (me/100g)	0.35 - 3.70(1.83)	0.88 - 3.12(1.62)	0.20 - 5.75(1.87)
			0.35 - 3.03(1.31)

and organic fractions get accumulated in the valleys. Such a situation is not found in the area of study. But, Prasad et al (op.cit) have reported accumulation of clay and organic carbon in Manipur valley.

MASS WASTING

Mass wasting is an important gravity controlled movement of materials over the earth's surface. It is a slow to sudden downward and outward movement of materials and perhaps is the most important agency that sculpture and reduce the earth's surface. Sharpe (1938) made one of the first attempts to classify the various types of mass wasting.

There are four major classes of mass wasting which are designated as slow flowage, rapid flowage, landslides and subsidence. Among these, landslides are by far the most important mass wasting phenomenon. ?

LANDSLIDES

Landslides are of profound interest to the earth scientists, environmentalists and engineers. Landslide phenomenon is one of the most widespread and effective agent in sculpturing the earth's surface. A landslide unforeseen or improperly provided for, may destroy settlements, or engineering structures like road, bridges, buildings,

etc. or impair their usefulness. It may also bring sudden deaths to people who have trusted these structures.

Landslides denote downward and outward movement of slope forming materials, primarily composed of natural rocks, soil, artificial fills or combination of these materials. The moving mass may proceed by anyone of the three following types of movements, or their combinations.

(a) Falling

(b) Sliding

(c) Flowing

Normally surficial creep, solifluction and avalanches are not considered as landslides (Varnes, 1958). Various classifications of landslide have been suggested. According to ward (1945), "classification of landslides should help an engineer to identify the different phenomena associated with the slides for appropriate remedial measures." Earth scientists, environmentalists or engineers need a classification to interpret the past and present trends of topography as revealed by their observations". The most acceptable classification of landslides in vogue is given by Varnes (1958). The same is reproduced in Table(20) and nomenclature shown in fig.(19). The nomenclature of different parts of a slide are shown in Fig.(20).

TABLE - 20

Classification of Landslides (after Varnes, 1958)

TYPE OF MOVEMENT	TYPE OF MATERIAL			
	BEDROCK		SOILS	
FALLS	ROCKFALL		SOILFALL	
FEW UNITS SLIDES MANY UNITS	ROTATIONAL SLUMP	PLANAR BLOCK GLIDE	PLANAR BLOCK GLIDE DEBRIS SLIDE	ROTATIONAL BLOCK SLUMP FAILURE BY LATERAL SPREADING
DRY FLOWS WET	ALL UNCONSOLIDATED			
	ROCK FRAGMENTS	SAND OR SILT	MIXED	MOSTLY PLASTIC
	ROCK FRAGMENT FLOW	SAND RUN FLOW RAPID EARTHFLOW	LOESS FLOW DEBRIS AVALANCHE	SLOW EARTHFLOW MUDFLOW
COMPLEX	COMBINATION OF MATERIALS OR TYPE OF MOVEMENT			

CLASSIFICATION OF LANDSLIDES (after varnes 1958)

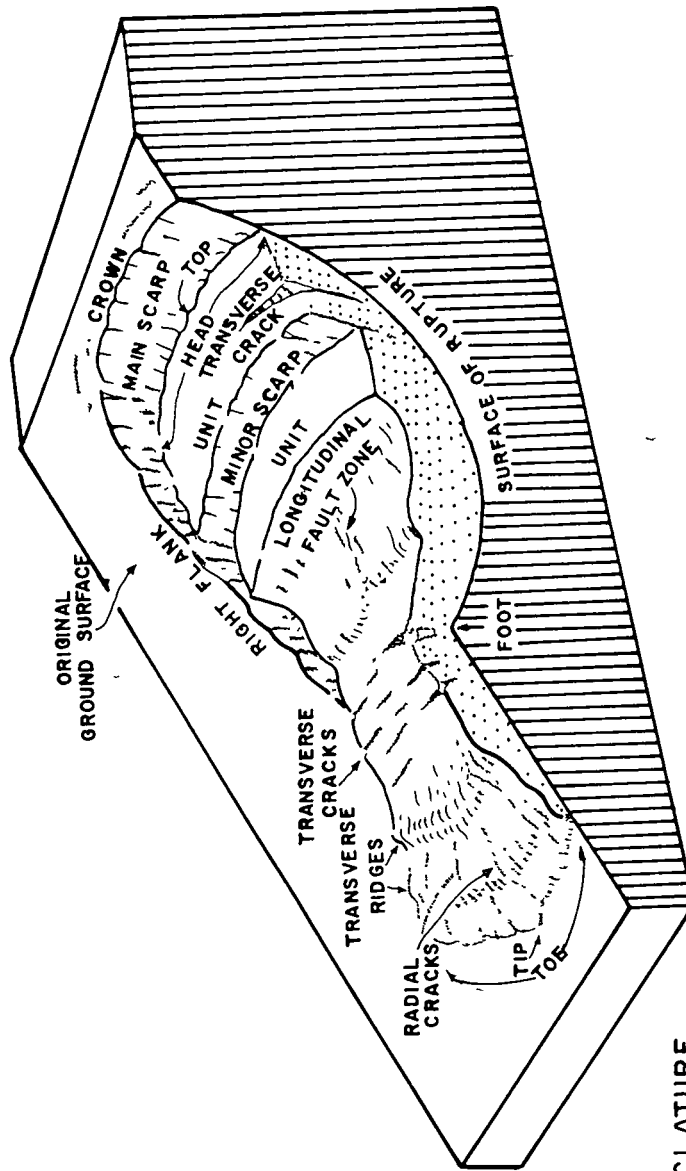
TYPE OF MATERIAL
 SOILS
 BEDROCK
 MIXED ROCKS, SOIL, CLAY, ETC.
 MOSTLY PLASTIC

TYPE OF MOVEMENT
 ROTATIONAL
 PLANAR
 BLOCK SLIDE
 DEBRIS SLIDE
 DEBRIS FLOW
 DEBRIS AVALANCHE
 DEBRIS FLOW (SILT)
 SAND FLOW
 LOESS FLOW (SILT)
 SAND FLOW (SILT)
 SAND FLOW (SILT)
 SAND FLOW (SILT)
 SAND FLOW (SILT)

SCALE
 0 100 200 300 400 500 600 700 800 900 1000 METERS

LEGEND
 TYPE OF MATERIAL
 TYPE OF MOVEMENT

NOMENCLATURE OF THE PARTS OF A LANDSLIDE



NOMENCLATURE

MAIN SCARP- A steep surface on the undisturbed ground around the periphery of the slide, caused by movement of slide material away from the disturbed ground. The projection of the scarp surface under the disturbed material becomes the surface of rupture.

MINOR SCARP- A steep surface on the disturbed material produced by differential movements within the sliding mass.

HEAD- The upper parts of the slide material along the contact between the disturbed material and the main scarp.

TOP- The highest point of contact between the disturbed material and the main scarp.

FOOT- The line of intersection (Sometimes buried) between the lower part of the surface of rupture and the original ground surface.

TOE- The margin of disturbed material most distant from the main scarp.

TIP- The point on the toe most distant from the top of the slide.

FLANK- The side of the landslide.

CROWN- The material that is still in place, practically undisturbed, and adjacent to the highest parts of the main scarp.

ORIGINAL GROUND SURFACE- The slope that existed before the movement which is being considered took place. If this is the surface of an older landslide that fact should be stated.

LEFT AND RIGHT- Compass directions are preferable in describing a slide, but if right and left are used they refer to the slide as viewed from the crown.

LANDSLIDES IN THE AREA:

In the study area, the landslide prone zones are confined within the Shillong Group of rocks. Landslides are more frequent where the developmental (constructional) activities have modified slope profiles, particularly making the profile segments steeper in sections (Fig.P33). This makes the slopes unstable with a tendency to fall as and when the equilibrium is disturbed.

The part of area falling within the Shillong agglomeration seldom shows landslides which is mainly because of the horizontal to subhorizontal disposition of Shillong Group of rocks and associated gentler slopes. However, along steeper slope segments particularly in vicinity of nalas, rare landslide incidences do occur. These nala sections are surface manifestation of structural weakness (cf. Relief analysis), rendering weak but the otherwise competent strata. During rains when the pore water pressure increases these weathered rocks easily fail along fissile surfaces like bedding/foliation or joints, under the load pressure of civil structures like residences or 'load release' due to cutting of slopes.

Conspicuously the part of area falling in Bhoi C-D block, Myllem C-D block and Mawphlang C-D block shows

frequent incidences of land slides, particularly between Mawlai and Sumer. Incidentally all the active landslides of the area are encountered along National Highway No.40. The important landslides of the area are described below.

SLIDE NO. I: SLUMP

Location: Between km post 74-73, left side* of road (Shillong-Guwahati) between electric pole No.15 and 17.

The slide is in weathered and altered Shillong Group of rocks. The rocks are completely altered to soil of maroon to brown colour. The soil is homogenous in nature, coarse to medium grained, loamy without any differentiated soil profile. The slide has a width of 60m, height of crown is 10m, and the slumped material showing slope of 70°-75°.

SLIDE NO. II: SLUMP

Location: Between km post 74-73, left side of Highway, in between electric pole No.46-48.

It is a debris slide on a old stabilised slide in highly weathered Khasi Green Stone. The profile section of the slide exposes the debris of an old slide - assorted boulders and pebbles of highly weathered Khasi Green Stone

*Herein side refers to in direction Shillong to Guwahati.

in a red-maroon matrix of loamy soil. The width of the slide is 50m and height is 10m. The top of crown shows evidences of deforestation as revealed by the presence of only 2-4 years old pine trees. The slumped material has slope of 75° - 80° and shows transverse tensional cracks, the trace of slip surface is visible.

SLIDE NO. III: SLUMP

Location: Between km post 73 and 72, left side of road in between electric pole 61 and 62.

The longitudinal profile of slide is gently convex, about 50m long running parallel to the highway. The slide is on soil after weathered Khasi Green Stone. The Crown height is 10m and the crown top has a slope of 10° - 15° , is deforested with a few remanent of old pine trees, 25-30 years old. The slumped material has very steep slope (80°) and is prone to frequent failures. The trace of slip surface is intermittently visible.

SLIDE NO.IV: DEBRIS SLIDE

Location: After Mawiong village, between 72-71 km post on left side of the highway.

The rocks are sheared and highly weathered Khasi Green Stone with red soil on top. The slide is 45m long with

a crown height of 10m. The top of crown has slope of about 20° , it is deforested and has few pines of 6-8 years old.

SLIDE NO.V: SLUMP

Location: At 71km post, left side of the highway.

The slide is on soil after sheared Khasi Green Stone. The width of slide is 90m and crown height is 10m. The top of crown has gentle slope of 15° - 20° and is deforested. It shows evidences of afforestation with pines of 3-5 years old. The slumped material has steep slope of 75° - 80° .

SLIDE NO.VI: SLUMP

Location: Between km post 71-70, left side of highway.

The slide is on soil after weathered Khasi Green Stone. The width of slide is 40m and height of crown is 10m, while the height of free face is 3m. At crown an old pebble line is seen indicating relict of an old slide now exposed in road cutting. The top of crown show pine afforestation of 3-5 years old, it has 15° - 20° slope and the slope of slumped material varies from vertical to 70° . Intermittently the trace of slip surface is visible.

SLIDE NO.VII: SLUMP

Location: Near Mawlong toll barrier,. between km post 71-70, left side of the highway.

The slide is over highly weathered Khasi Green stone and its soil profile expose homogeneous red coloured loamy to clayey soil. The width of slide is 25m with crown height of 15m. The hight of free face is about 3m. The top of crown has a slope of 15° and show evidences of Jhuming activity. The top has now afforested pine 'trees of 6-8 years old. The slumped material has steep slopes of 70° - 90° .

SLIDE NO.VIII: SLUMP

Location: Between 71-70 km post, about 300m away from slide VII, left side of highway.

This is a zone of four slides in a row spread over a cummulative length of 200m. The slides vary width from 15m to 20m, with crown heights varying from 10m to 15m. The slides are over soil after Khasi Green Stone. The soil is loamy to clayey and of reddish brown colour. The top of crown has slope of 15° - 20° and the pine afforestation of 3-5 years old. The slumped material has slope of 70° to 90° .

SLIDE NO.IX: SLUMP

Location: Between 70-69 km post, left side of the highway.

The slides is on soil after weathered Khasi Green Stone. The colour of soil is reddish brown. The slide has a width of 120m, crown height of 10m and height of free face 2m. The top of crown is deforested and has only a few shrubs. The top of crown slope is about 20° and slope of slumped material is steep (75° - 80°).

SLIDE NO.X: ROCK FALL & ROCK SLIDE

Location: Between km post 68-67, left side of highway.

The slide is in phyllitic sandstone and phyllites of Shillong Group. The beds have vertical dips and have prominent joint parallel to bedding/foliation surface. The rock is sheared and has a zone of pulverised material at the central part of the slide. The width of slide is about 10m and height of free ^{face} is 20m. The top of free face has slope of 35° - 40° and is deforested rarely showing pines of 2-3 years old.

SLIDE NO.XI: ROCK SLIDE

Location: Between 68-67 km post, right side of highway.

The slide is on sheared phyllitic sandstone, quartzite and phyllite of Shillong Group (Fig.P34). The width of



Fig.(P.33)

Steeper profile section due to road cutting. Note bending of tree trunks.



Fig.(P.34)

Rock slide in Shillong Group. Steep cutting (Right corner) initiates instability (between 67-68km post, G.S.Road).

slide is about 85m, crown height about 20m and height of free face is 3m. The slide appears to be quite active all along its width but during different times. The top of crown has pine about 20-25 years old while the dormant portion of the slide does not show pines older than 8-10 years indicating the dormancy period of the same order. The top of crown slope is about 45° and the slumped material also has slope of 45° .

SLIDE NO.XII: SLUMP

Location: About 30m away from slide XI, towards Barapani, on right side of road.

This appears to be a frequent slide spot and the slide has been provided with breast wall. The slide is in soil after Shillong Group of rocks, and has a width of 10m and crown height of 6m. The top of crown is afforested with pines of 6-8 years old. The trace of slip is not visible.

SLIDE NO.XIII: SLUMP

Location: Between km post 68-67, right side of the highway.

The slide is on soil after Shillong Group of rocks. The slide is active and has breached the breast wall. The width of slide is about 20m and crown height of 3m. The

top of crown slope is 20° - 25° with pines of 25-30 years old. However, the flanks of slide has only 6-8 years old pine, indicating the dormancy period of flanks. The slumped material has slope of 75° (fig.P35).

SLIDE NO.XIV: DEBRIS SLIDE

Location: Between 68-67 km post, right side of the highway.

The slide is on Shillong Group of rocks and appears to be quite active as its breast wall is broken at flanks. The width of slide is 45m and height of crown is 15m. The top of crown has gentle slope of 40° and the slope of slumped material is 75° . The height of free face is 1m.

SLIDE NO.XV: DEBRIS SLIDE

Location: Near km post 67, right side of highway.

The slide is in carbon phyllite of Shillong Group. The width of slide is 4m and height of crown is 10m. The top of crown has slope of 30° and has pine trees 30-35 years old and the flnaks have pine trees about 8-10 years old, indicating the order of dormancy of slide in flanks. The slumped material has slope of 75° - 80°

SLIDE NO.XVI: DEBRIS SLIDE

Location: Between km post 67-66, right side of highway.



Fig.(P.35)

Rock slide showing dormant patches. Note age difference in pine trees.

The slide is in carbon phyllite of Shillong Group. The width is 25m, height of crown is 10m and height of free face is 1m. The top of crown has slope of 25° - 30° and is forested with pines of 25-30 years old. The flanks have pine about 8-10 years old and the slumped material has slope of 75° .

SLIDE NO.XVII: ROCK GLIDE-ROCK FALL

Location: The slide is located between 67-66 km post, right side of road.

The slide is on sheared phyllitic sandstone of Shillong Group. The beds are thinly bedded with vertical dips showing minor folding. The width of slide is 20m and height of crown is 20m. The top of crown has slope of 30° - 35° and is forested with pines of 15-20 years old, while the flanks have pines of 6-8 years old. The slumped material at the toe has 70° - 75° slope.

SLIDE NO.XVIII: SLUMP

Location: It is located between 67-66 km post, left side of highway.

The slide is on phyllitic sandstone, which is highly sheared. The slide is on a pre-existing slumped material. The width of slide is 20m, height of crown 10m and height of free face 3m. The top of slide has slope of 30° with

pinus 25-30 years old. The slumped material at toe has slope of 70° .

SLIDE NO.XIX: DEBRIS SLIDE

Location: Opposite 66 km post.

The slide is on phyllitic sandstone and appears to be quite active with a breast wall. The width of slide is 15m and height of crown is also about 15m. The top of crown has sparse pine trees of 25-30 years old, and its slope is 45° . The slumped material has slope of 75° - 80° .

SLIDE NO.XX: DEBRIS SLIDE

Location: Between km post 66-65, left side of the highway.

The slide is on sheared phyllitic sandstone and is provided with a breast wall. The width of the slide is 20m the height of crown 10m, and the height of free face is 3m. The crown top has slope of 45° with pines of 20-25 years old and the slumped material has slope of 75° .

SLIDE NO.XXI: DEBRIS SLIDE

Location: Between km post 64-63, left side of highway.

The slide is in weathered quartzite. Its width is 10m and height of crown is 8m, the height of free face is 2.5m. The top of crown is deforested and has slope of

30°, while the slope of slumped material is 75°-80°.

The aforesaid description of various slides reveal the following facts:

- 1) The common landslides are slump type.
- 2) The slides are mainly caused due to slope failure.
- 3) The two important factors contributing to land slide initiation are deforestation and steep slope cut along the highway.

These landslides can not be prevented but, can be avoided if suitable measures as given below, are taken before a developmental scheme is implemented.

- 1) Proper grade maintenance of slope.
- 2) The slope cut faces should be rounded rather than making them sharp.
- 3) Breast wall and retaining walls to be made.
- 4) Benching and terracing of slopes.
- 5) Proper drainage galleries and drains to be provided.
- 6) Wire mesh or cribs to be provided in rock fall areas.
- 7) Slope profiles to be suitably modified in slide prone areas.
- 8) Vegetation cover along the highway areas not to be disturbed.
- 9) Total ban on agriculture, grazing and additional residential constructional activities along both sides of the highway.

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CHAPTER - VII

FLUVIAL MORPHOLOGY

INTRODUCTION

Fluvial processes concern with the development of the features of an individual valley and the development of a system of drainage, composed of many individual valleys.

Run off rain water in the form of sheetwash or in concentrated channels forming streams, is the most dominant geomorphic agent in sculpturing the landscape of an area. The activities of streams or running water could be either erosional or depositional. Progressive dissection and degradation of the higher lands is caused by fluvial processes. Due to erosion, different types of valleys interfluvial ridges are formed depending on the stage of development of the river and on the lithology and structure of the area.

DRAINAGE SYSTEM

The drainage map (Fig.21) of the area indicates that the area by and large, forms part of Wah Umiam (River Umiam) basin. However, the northwestern corner of the area forms part of Um Trew basin, drained by Raleng river (Um Raleng), a tributary of Um Trew. The southeastern fringe of the area is being drainage^{ed} by Umbah and Wah Tamdong form-

DRAINAGE MAP OF BARAPANI AREA

1 km 0.5 0 0.5 1 1.5 2 Km

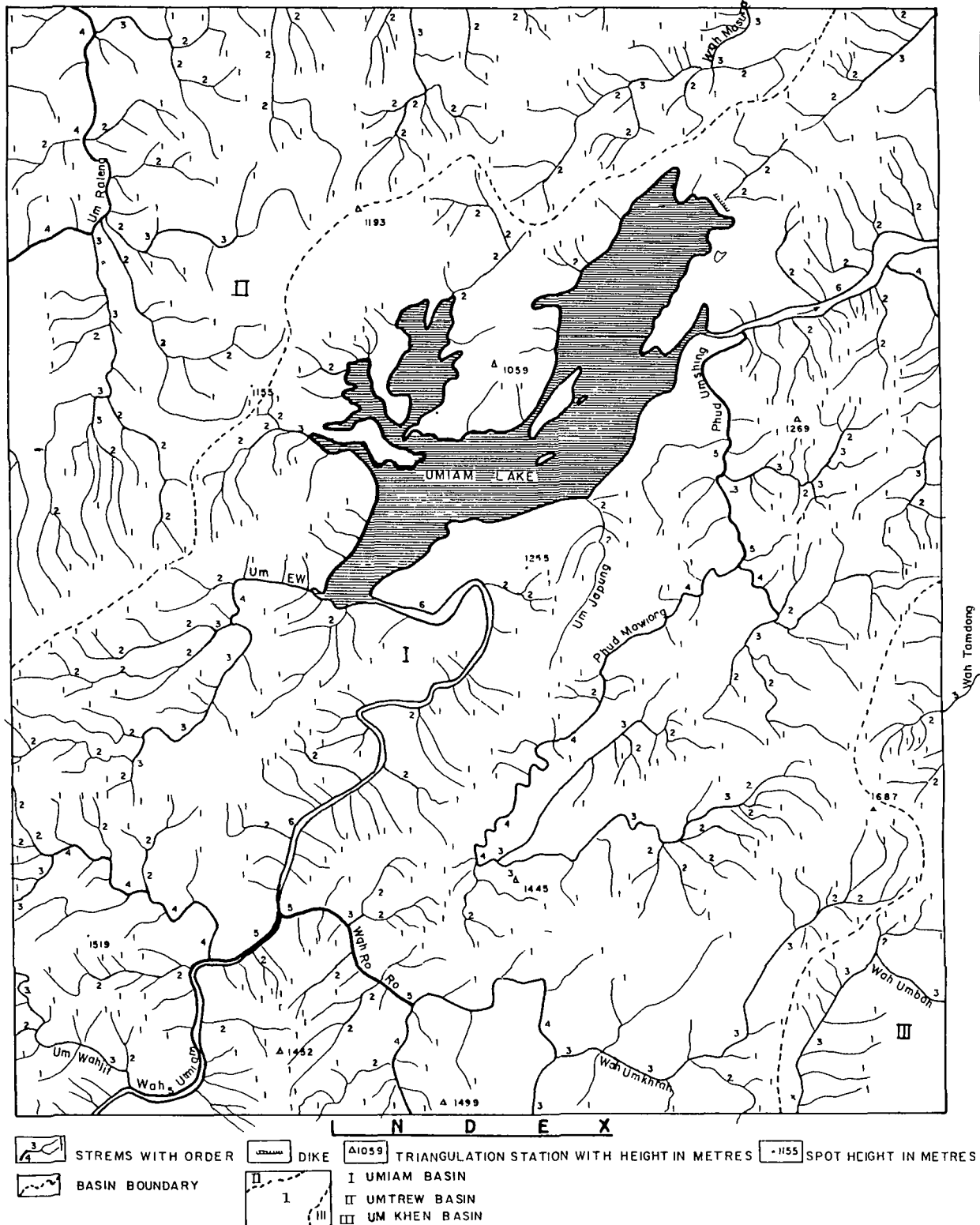


Fig (21)

ing part of Umkhen basin, to the east of Umiam basin. Only the headwater channel network of Um Tamdong falls in the area, between Mawpat and Mawtawar. To understand the Drainage system in the area Drainage analysis has been done.

Drainage Analysis:

Drainage analysis is a way to understand evolution of landforms. Analysis of drainage patterns are being studied by more and more elaborate methods. The increasing accurate methods of measuring landforms and geomorphological processes are producing a vast amount of quantitative data. This has to be analysed by numerical methods so that an orderly behaviour may be described from amongst the accumulated data.

System of landforms evolving from same geological processes and material process a high degree of geometrical similarity and helps in recognition and classification of landforms, Drainage analysis helps in evaluating landforms.

The description of channel network was changed from a qualitative and deductive study to a rigorous quantitative science by Horton (1945) and developed by Strahler (1952, 1957, 1958, 1964). Other workers who developed it further are Schumm (1956), Morisawa (1958), Chorley (1966), King (1966), Doornkamp and King (1971) etc.

A particular geometric property of channel net work is sampled and measured from maps or aerial photographs or by direct field study.

Methods of Analysis:

The drainage analysis has been applied to the area drained by given streams and their tributaries. For this purpose, 1:50,000 scale toposheet was used. The major river draining the area is the 6th order stream, Wah Umiam flowing in northeasterly direction. However, the area of study, as already stated, comprises parts of Umiam basin, Um Trew basin and Umkhen basin (Fig.21).

A particular feature of channel network which can be measured directly from the toposheet is termed as an "element". Similarly the quantitative expression relating two or more element is termed a "parameter". The important "elements" and "parameters" computed are given in Table(21).

TABLE - 21
Morphometric variables for the area

Sl. No.	Element/Variable	Symbol	Units	Dimensions
1.	Stream order	U	Enumerative	0
2.	Number of stream of order U	Nu	"	0
3.	Total number of stream within the area	$(\sum N)_u$		0
4.	Bifurcation ratio	$R_b = N_u / N_{u+1}$	"	0
5.	Total length of streams of order U	L_u	Km	L
6.	Total length of streams in the area	$(\sum L)_u$	Km	L
7.	Mean length of streams of order u	$\bar{L}_u = L_u / N_u$	Km	L
8.	Stream length ratio of order u	$R_l = L_u / L_{u-1}$	Enumerative	0
9.	Drainage density	$D_u = (\sum L)_u / A_u$	Km/Km^2	L^{-1}
10.	Stream frequency	$F_u = (\sum N)_u / A_u$	Numbers/Km^2	L^{-2}
11.	Texture ratio	$T_u = (\sum N)_u / P_u$	Number/Km	L^{-1}

TABLE - 22

Determination of the morphometric parameters

[illegible]

The morphometric variables are measured from toposheet supported by field observations and calculated after Horton (1945), Strahler (1964), Doornkamp & King (1971) and Strahler (1975). A sample quantitative study has been made in the area to know the salient morphometric characteristics. The important determination of morphometric parameters are given in Table(22). The significance of each parameter is discussed below.

Channel Segment Ordering:

The relative magnitude of a segment of a stream channel is a hierarchy determined by arrangement of tributaries with respect to the main trunk. The system of ordering channel segments proposed by Horton (1945) and modified by Strahler (1952), is followed here. The smallest fingertip tributaries or stream which have no tributary are known as first order streams. When two of these first order channel meet, they make a channel segment of second order. When two streams of second order merge, a segment of third order is formed and so on and so forth. If a first order stream enters a second order stream, then there is no change in the order of second order stream.

An increase in stream order only occurs when two streams of like order join each other. The area drained

by a channel of order 'U' and all its tributaries, down to its junction with another channel of order equal to or greater than 'U' is designated as the basin of the order 'U'. It is worth mentioning that the hierarchy or ordering of stream network is a function of scale of map or toposheet used.

Stream Number:

For the present study, toposheet on 1:50,000 scale has been used. After, all the streams have been assigned their respective orders, all the segments of order 'U' are connected to yield the Number 'Nu' of the stream order 'U' in the area. The hierarchial order of prominent streams in the area is given in Table (23) and each stream discussed below.

TABLE - 23
Hierarchial order of streams

Sl. No	Name of stream	Nature of stream	Basin	Location	Order
1	2	3	4	5	6
1.	Wah Umiam	Trunk stream	Umiam	Central part	6
2.	Phud Umshing	Tributary of Wah Umiam	Umiam	Northeastern part	5
3.	Wah Ro Ro	Tributary of Wah Umiam	Umiam	Southeastern part	5
4.	Um Ew	Tributary of Wah Umiam	Umiam	West Central Part	4
5.	Um Wahjit	Tributary of Wah Umiam	Umiam	Southwestern part	3
6.	Um Japung	Tributary of Wah Umiam	Umiam	Central part	2

contd...

1	2	3	4	5	6
7.	Wah Tamdong	Tribituary of Umkhen	Umkhen	Southeastern part	3
8.	Wah Umbah	Tribituary of Umkhen	Umkhen	Southeastern part	3
9.	Um Raleng	Tribituary of Um Trew	Um Trew	Northwestern part	4
10.	Wah Masura	Tribituary of Um Trew	Um Trew	Northeastern part	3

Wah Umiam:

In the area, Wah Umiam is the highest order (6th order) stream. It is the trunk or master stream within the area. It has its headwaters in the northeastern corner of the toposheet 78 0/11, around Sohiong and flows in north-eastern direction. Since, Wah Umiam originates outside the area of study, its order is not fixed.

The Wah Umiam enters the study area as a 5th order stream, from the southwestern corner of the area. It changes into a sixth order stream after its confluence with Wah Ro Ro. The Wah Umiam leaves the study area from the north-eastern corner as a 6th order stream but with almost negligible discharge. This is because the river has been dammed at Barapani for a hydroelectric project. Thus, the low lying areas, upstream of the dam, around Barapani upto the R.L. of 981m (3220') have been converted into an artificial lake

or reservoir.

The Wah Umiam in the area of study drains the terrain comprising mainly Shillong Group of rocks with minor Khasi Greenstone. However, small sections of river course between the lake and Um Wahjit show alignments oblique to its normal course. These oblique alignments are parallel to the N-S, E-W, NW-SE lineaments, possibly structurally controlled.

The river, in general, has sinuous course (Fig.P17) and narrow valley with gorge section before it meets the lake.

2. Phud Umshing: It is a fifth order stream joining Wah Umiam, down stream of Barapani dam. It has a northsouth course upto its confluence with a fourth order stream coming from Mawtawar. Beyond this confluence point, upstream segment of phud Umshing is known as Phud Mawiong a fourth order stream. Phud Mawiong rises from west of Mawpat flowing in eastwest direction and takes a sharp hair pin bend west-southwest of Kytanmosar and flows in northeast direction. The channel segment trends oblique to regional trend of Shillong Group of rocks is very conspicuous. These oblique channel segments are the sections cutting large stratigraphic thickness of the rock types providing varied lithologies. The phud Umshing channel network drains Shillong Group country with Khasi Green Stone lenses. The area around its confluence

with Wah Umiam has large accretion of boulders and pebbles of Khasi Green Stone with subordinate Shillong Group boulders (Fig.P11). This accretion of Khasi green Stone boulders is disproportionate to its volumetric distribution within Shillong Group (cf. Fig.8). The Phud Umshing-Phud Mawiong channel segments have cut steep sided narrow valleys and gorges with steep channel gradient capable of carrying large bed load. The northeast flowing segments of phud Mawiong by and large drains parallel to Khasi Greenstone and contribute high flux of detritus. Where the phud Umshing joins the Wah Umiam, its narrow gorge opens up into a comparatively broad valley and its hydro dynamic regime changes. Its velocity decreases and gradient falls. As a result of this, its bed load suddenly drops out and accumulates as channel fills and forms terraces at different levels. The Khasi Greenstone boulders are massive and have higher relative density than the Shillong Group of rocks. As soon as load carrying capacity of the stream decreases the "heavier" boulders and pebbles 'lag' first than the "lighter" one which moves farther. The resultant accumulation thus shows disproportionate distribution of lithotypes as mentioned above.

3. Wah Ro Ro: It is a fifth order tributary of Wah Umiam, the confluence being west of Mawlai, below Umj Jew spur.

The general course of Wah Ro Ro upto its upstream confluence with the fourth orders Wah Umkhrach, is northwest with eastwest segment. These trends are oblique to the regional disposition of Shillong Group, indicating possibilities of structural control of streams, in segments.

The famous Beadon fall with a height of 107m is located on this stream, opening into a magnificent gorge section, down stream.

Wah Ro Ro has two fourth order tributaries joining together near Mawlai. The Wah Umkhrach, rises from area in between Nongthymmai and South of Mawpat, joins with another fourth order stream originating from area between Shillong peak and Laitkor protected forest. Both the tributaries are sluggish by and large draining terrain with moderate to gentle slopes except in headwater zones having steeper slopes. Their first and second order channel network have deep incised valleys.

Interestingly both of these fourth order tributaries have northwesterly courses with eastwest channel segments. These trends are oblique to regional strike of Shillong Group of rocks, suggesting structural control of channel courses.

4. Um Ew: This is a fourth order channel segment joining the Lake Umiam in the west central part of the area. The principal segment of the Um Ew has a east-southeasterly course before joining the Lake. In the upstream, it takes a southerly swing where it is joined by two north easterly flowing tributaries of third order. Its headwater rises from area east of Denghei ridge. Um Ew cuts a magnificent gorge section in Shillong Group of rocks which transcuts the regional trend of formations and is in alignment with the ESW-WNW Wah Umiam gorge section, before the later meets the Lake Umiam. This remarkable straight gorge section possibly is a manifestation of some hidden structural discontinuity.

5. Um Wahjit: It is a third order left bank tributary of Wah Umiam. The confluence is in the southwestern corner of the area. It rises from area in between Mawlum and Maw-laiteng. Its course is highly sinuous. The course has in general, two alignments. From Wah Umiam confluence upto near Nong Madan, it has northwesterly course and beyond Nong Madan it has southeasterly course. Um Wajit cuts a deep gorge in Shillong Group of rocks. It has a steep gradient and shows a fall in level of more than 600m in its channel length of about 6.5km.

6. Wah Japung: It is a second order stream rising from near

Mawiong in the central part of the area. Its upstream segments of first order has a northeasterly trend and before joining the lake it takes a northwesterly swing and debouches into the lake cutting steep-sided wide gorge into older (Pliocene) Wah Umiam terraces.

However, the headwater channel drains by and large Khasi Greenstone terrain.

7. Wah Tamdong: It is a principal third order tributary of Um Tung, draining into Umkhen basin. Its headwater channel network only is confined in the area, rising from southeast of Mawtarar. The general trend of Wah Tamdong is in conformity with regional strike of Shillong Group of rocks.

8. Wah Umbah: It is a third order tributary of Umkhen. Part of its segment is only confined in the southeastern corner of the area. It rises from near Nongthymmai-Happy Valley area flowing in a general northeasterly direction with local north-south segments. It takes a sharp bend near Mawpat and flows in southeasterly direction. The famous spread eagle falls (20m) is located on this channel segment near Umpling. The channel segment has low gradient and is a sluggish stream draining a rolling topography underlain by Shillong Group of rocks.

9. Um Raleng: It is a fourth order tributary of the Um Trew, confined in the northeastern corner of the area. The stream network by and large drains the Gneissic Complex. Conspicuously it has northsouth course with segments aligned in northeast direction. But the northsouth alignment is dominant. It is joined by two streams of third order and couple of streams of second order. Most of the second order stream segments have dominant eastwest courses. The principal segment of Um Raleng originates outside the area, rising from north of Denghei. However, one of its prominent third order stream originates within the area. Um Raleng channel network drains area with moderate to low relief, cutting deep valleys locally.

10. Wah Masura: It is a third order tributary of Um Trew. It has a northeasterly course, by and large draining terrain of Shillong Group. Its headwater rises around Umsawlum. Its northeasterly course changes to north northwest at the northern margin of the area and cuts into gneissic country.

DRAINAGE PATTERN

The overall drainage pattern in the area is dendritic. However, the drainage network over Shillong Group of rocks show dendritic to rectilinear pattern. But, the gneissic terrain has only dendritic pattern.

A very remarkable feature seen in the right portion of the area is the reclined 'V' shaped drainage network. The convexity points towards southwest. The tip of the 'V' represents the confluence of Wah Ro Ro with Wah Umiam.

STRUCTURAL ADAPTATION OF STREAMS

The structural control of the channel segments in the area is amply evident from the Fig.(22). In general four trends are very remarkable.

- 1) NE-SW trend: This is the dominant trend and conforms with the regional disposition of formation.
- 2) NW-SE trend: This is oblique to the structural grain of the country.
- 3) N-S trend: This is oblique to the structural grain of the country.
- 4) E-W trend: This is oblique to the structural grain of the country.

The persistent northeasterly channel segment courses which are basically lithologically controlled, have modified segments locally, due to the secondary structural elements. These elements are surface manifestations like linear joint system, fracture system and concealed faults. These modified oblique segments are correlatable with the lineament trends of Meghalaya (cf. Fig.7).

A very spectacular structural control of channel

ADAPTATION OF STREAMS TO STRUCTURE

1 km 0.5 0 0.5 1 km

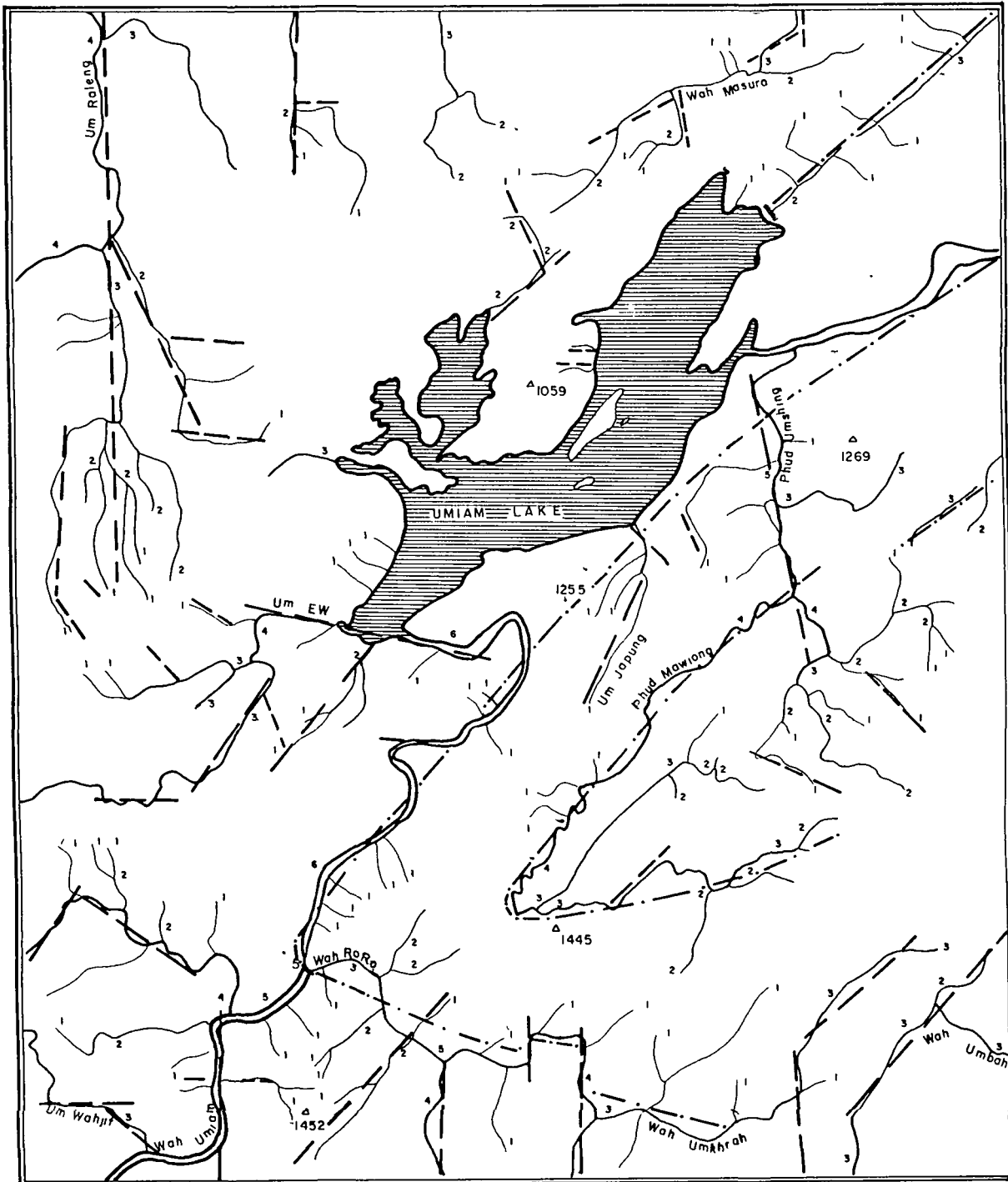


Fig (22)

INDEX

-  STRUCTURALLY CONTROLLED CHANNEL SEGMENTS
-  INFERRED FOLD TREND LINES
-  STREAMS WITH ORDER
-  TRIANGULATION STATION WITH HEIGHT IN METRES
-  DYKE

segments is reflected by the reclined 'V' shaped channel network in the right portion of the area. This pattern possibly reflects the tight folded configuration of the basement rocks — the Gneissic Complex. This indicate that the thickness of Shillong Groups of rocks in this part of the area is very thin. As a result, the structural fabric of the underlying basement appears to have overtaken the modification of the channel network. However, more work is required to draw firm conclusion.

STREAM LENGTH

The order wise channel segment lengths have been computed by rotometer. A perusal of Table(22) reveals that, the total length of 1st and 2nd order streams have highest ratio of 3.47 while that of between 2nd and 3rd order streams is 1.86, between 3rd and 4th order is 1.57, between 4th and 5th order is 2.17, between 5th and 6th order is 0.98.

It is seen that the mean length increases as the order of segment increases. The lowest mean length of 0.46 is shown by 1st order stream and the highest mean length of 10.75 is shown by the 6th order Wah Umiam. However, the stream length ratios do not show a regular pattern, the lowest ratio is shown by 2nd order while the highest ratio is shown by 6th order stream.

BIFURCATION RATIO

This ratio denoted by R_b , is the ratio between the number of channel segments of a particular order N_u to the number of channel segments of the next higher order N_{u+1} , i.e. $R_b = N_u/N_{u+1}$. The bifurcation ratio does not remain constant from one order to the next because of variations in the watershed geometry. It is related to the branching pattern of the drainage network. Normally, in homogeneous bedrock terrain the value ranges between 3 and 5. But where, structural elements have caused basin elongation, this value increases appreciably. The bifurcation values for the area is given in Table(22). According to Giusti and Schneider (1965), bifurcation ratios within an area decreases with the increase in order of stream. The bifurcation ratio determined (Table-22), in general, agree with the conclusion of Giusti & Schneider (op.cit.) but, a little departure is shown by 3rd/4th order channel segments which is due to the fact that the area has suffered rejuvenation and the channel segments have yet to stabilise. Moreover extensive deforestation in the area has interfered with the normal development of channel network.

DRAINAGE DENSITY

It is simply the ratio between cumulative channel lengths of channel segments of all orders and area of basin.

Numerically it is defined by the relation $Du = (\sum L)u / Au$ where
 where Du = Drainage density in Km/Km^2

$(\sum L)u$ = Sum of total lengths of streams of all orders in Km

Au = Total area of drainage basin in Km^2

The expression Du gives the average density of streams in an area, theoretically the value should always come more than 1. However, to know the variation of drainage density in the area, density has been computed per sq.km. and variation map prepared.

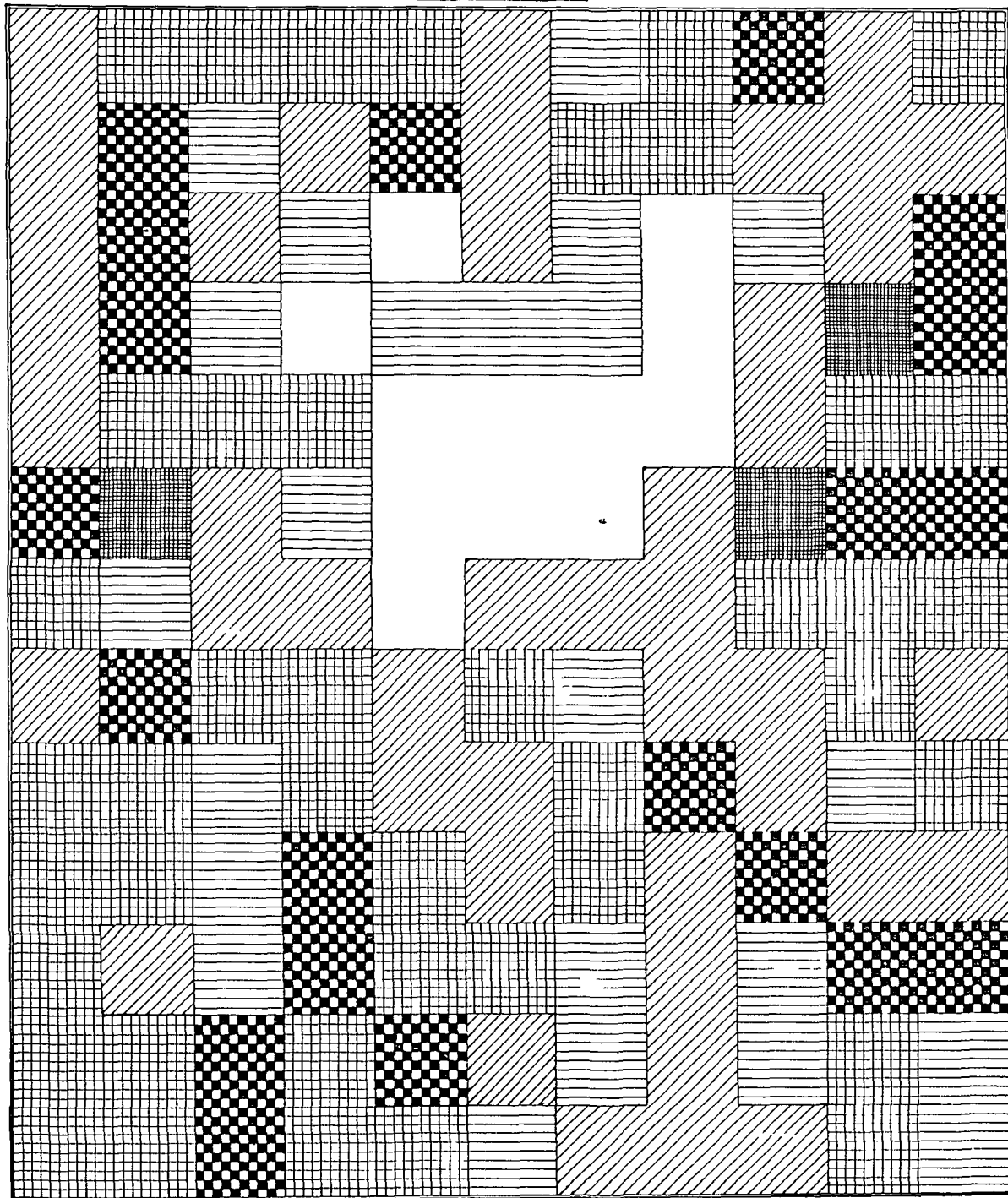
The area has been divided into one x one Km grids and drainage density per grid of 1 sq.km. has been computed. The lengths of channel segments have been recorded by roto meter. The drainage density has been classified into six groups (Table-24) ranging from below 1 to more than 5.

TABLE - 24
Frequency distribution of drainage density

Drainage Density (Km/Km ²)	Frequency of grids	% of total frequency	Cummulative % of frequency	Density Category
Above 5	3	2.10	2.10	Fine
4-5	20	13.99	16.09	Moderately fine
3-4	42	29.37	45.46	Moderate
2-3	43	30.07	75.53	Moderately coarse
1-2	23	16.08	91.61	Coarse
Below 1	12	8.39	100.00	Very Coarse

DRAINAGE DENSITY

1 km 0.5 0 0.5 1 km



INDEX

Km PER Sq.Km



> 5



4 - 5



3 - 4



2 - 3



1 - 2



< 1

Fig (23)

density is confined in the north central part of the area. Interestingly the Umiam Lake is located here. Though category wise distribution of drainage density is irregular but, in comparison to northern half, the southern half of the area has moderately coarse to moderately fine category of drainage density. It implies that the northern half of the area has relatively coarse texture. This is expected because the northwestern corner is a Gneissic terrain (which normally has poor drainage) and north central part of the area is submerged under lake, and the area fringing the Lake has poor development of drainage, because of smaller proportion of runoff.

CORRELATION OF ABSOLUTE RELIEF AND DRAINAGE DENSITY

The effect of Absolute relief on drainage density is seen from the distribution pattern of frequencies of drainage density and absolute relief categories (Table-25). It is evident that the lowest frequency distribution is shown by fine category (2.1%) which is confined to 1100m-1300m height groups only. Similarly very coarse drainage density frequency (8.39%) is distributed in 900m-1200m height groups. The moderately coarse to moderate drainage density contribute the largest proportion of frequency distribution (61.14%). It is distributed in all the categories of height groups.

However, the highest drainage density frequency

TABLE - 25

Distribution of frequencies in categories of absolute relief and drainage density
(A two way classification of the units of one sq. km.)

Absolute Relief in m.	Drainage Density in Km/Km ²						Total Grid frequency	Total % frequency
	V. Coarse 0 - 1	Coarse 1 - 2	Mod. Coarse 2 - 3	Moderate 3 - 4	Mod. Fine 4 - 5	Fine 5 - 6		
Above 1600	-	1	3	-	1	-	5	3.5
1500 - 1600	-	4	-	10	3	-	17	11.89
1400 - 1500	-	7	11	12	3	-	33	23.08
1300 - 1400	-	1	5	6	2	-	14	9.78
1200 - 1300	-	1	7	4	2	1	15	10.49
1100 - 1200	2	3	5	3	-	2	15	10.49
1000 - 1100	8	5	5	3	4	-	25	17.48
900 - 1000	2	1	5	3	3	-	14	9.79
Below 900	-	-	2	2	1	-	5	3.5
Total	12	23	43	43	19	3	143	
Total in %	8.39	16.08	30.07	30.07	13.29	2.1		100.0

distribution (23.08%) is seen in 1400m-1500m high group. While 1000m-1100m height group has second highest (17.48%) drainage density frequency distribution. But, the height groups of 1100m-1400m, together have the largest drainage density frequency distribution (30.76%).

The correlation Table for the two variables is prepared (Table-26). The coefficient correlation between the two variables is 0.143. The regression lines for the two variables are shown in Fig.(24a). The relationship between the absolute relief and drainage density is given by the following equations:

$$1) Y = 0.0026X - 0.539$$

$$2) X = 7.753Y + 1245.08$$

The coefficient of correlation value of 0.143 indicate very low correlation between absolute relief and drainage density, in the area of study. The correlation is significant at 10% level of significance. Superposition of absolute relief map (Fig.11) over drainage density map (Fig.23) makes discernible a feeble correlation between the two. Broadly the northern half of the area show absolute relief from less than 900m to 1300m and relatively lower drainage density.

CORRELATION OF RELATIVE RELIEF AND DRAINAGE DENSITY

A correlation between relative relief and drainage

TABLE - 26
Correlation table of absolute relief and drainage density variables

Correlation table of absolute relief and drainage density variables												
Drainage density Km/Km ²	Very	Coarse	Mod.Coarse	Moderate	Mod.Fine	Fine	Total Grid freq- uency f(x)	Total freq- uency in %	$\sum f(x)$	$\sum f(x)$	$\sum V_j f(x,y)$	$\sum U_i f(x,y)$
Absolute Relief(in m.)	0 - 1		1 - 2	2 - 3	3 - 4	4 - 5	5 - 6					
	0.5		1.5	2.5	3.5	4.5	5.5					
	X_1	Y_j	V_j	U_i	-2	-1	0	+1	+2	+3		
1600-1700	1650	+4	-	3	-	1	3	5	3.5	+20	+80	+4
1500-1600	1550	+3	-	-	10	3	3	17	11.89	+51	+153	+36
1400-1500	1450	+2	7	11	12	3	3	33	23.08	+66	+132	+22
1300-1400	1350	+1	1	5	6	2	2	14	9.78	+14	+14	+9
1200-1300	1250	0	1	7	4	2	1	15	10.49	0	0	0
1100-1200	1150	-1	3	5	3	-	2	15	-10.49	-15	+15	-2
1000-1100	1050	-2	5	5	3	4	-	25	17.48	-50	+100	+20
900-1000	950	-3	1	5	3	3	3	14	9.79	-42	+126	-12
800- 900	850	-4	-	2	2	1	-	5	3.5	-20	+80	-16
Total Grid frequency f(y)		12	23	43	43	19	3	143		+24	+700	+61
Total Frequency in %		8.39	16.08	30.07	30.07	13.29	2.1		100.0			
Total Frequency in %		-24	-23	0	+43	+38	+9	+43				
$V_j f(y)$		+48	+23	0	+43	+76	+27	+217				
$V_j^2 f(y)$		+48	-15	0	+34	0	-6	+61				
$V_j U_i f(x,y)$												

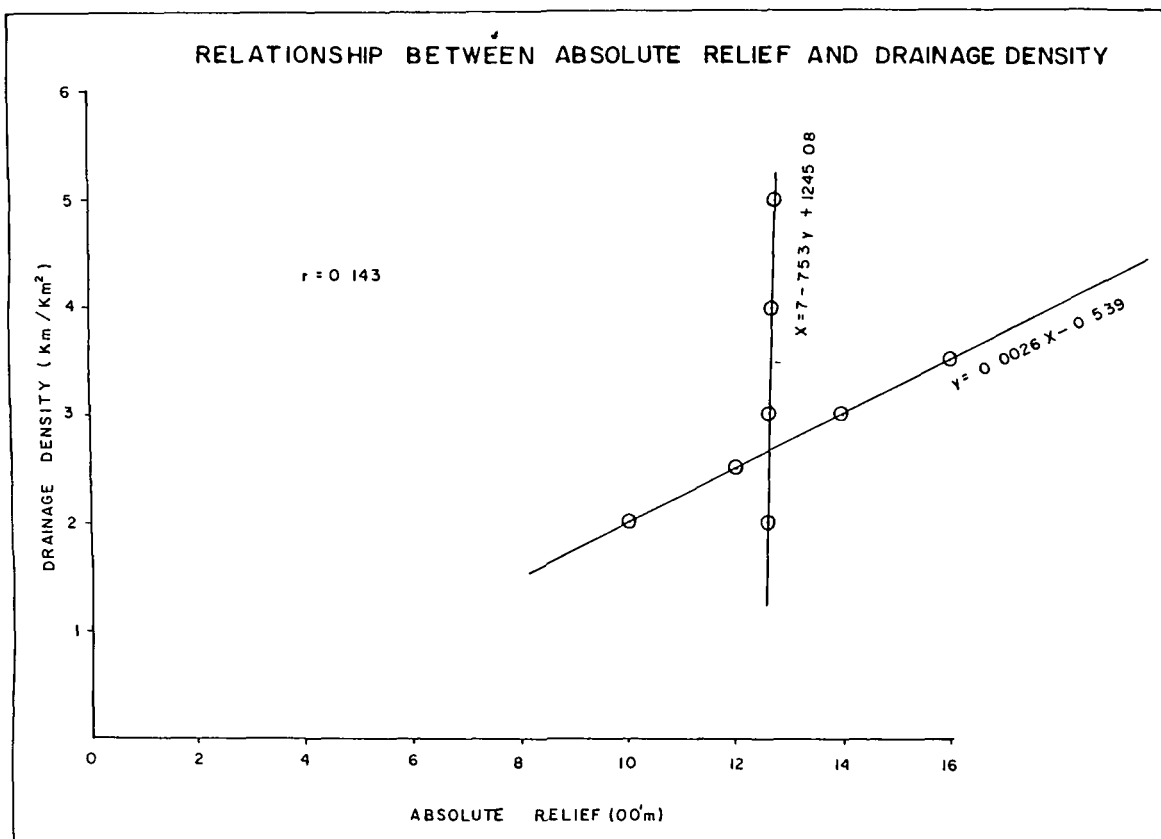


Fig (24a)

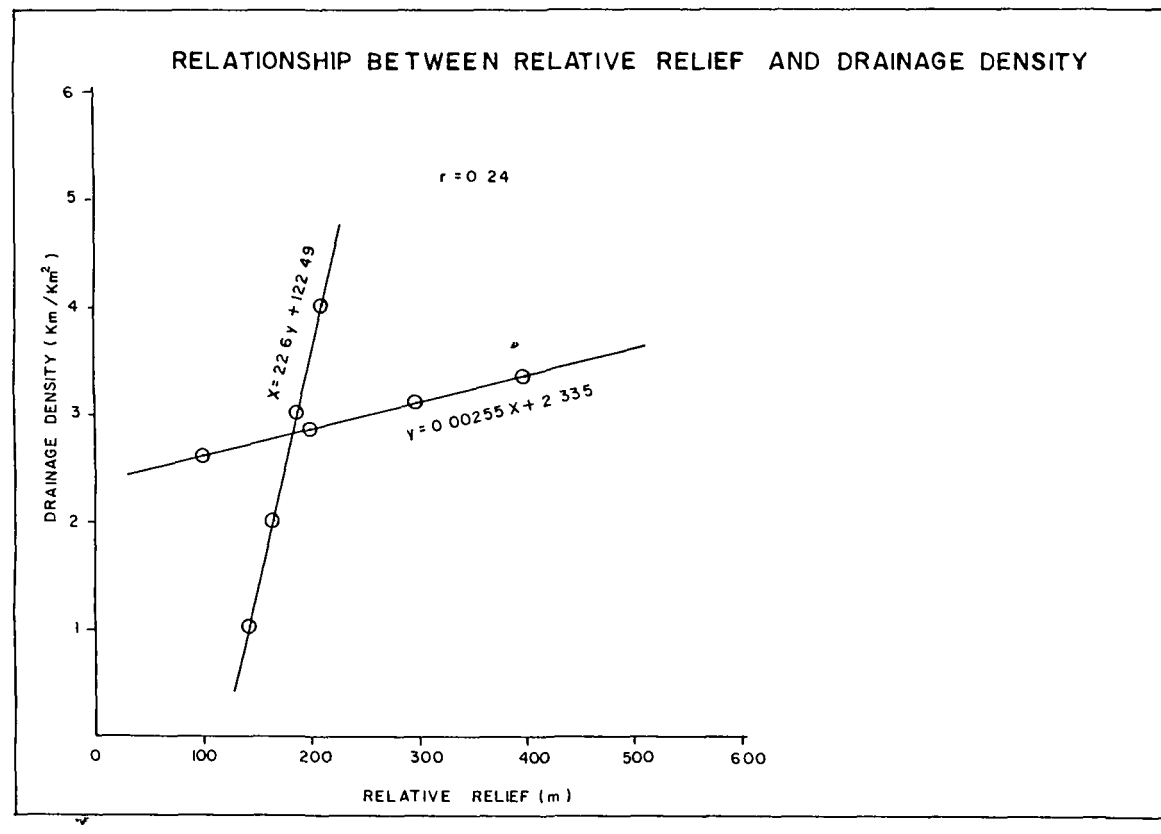


Fig (24b)

density is attempted. The distribution pattern of drainage density frequencies in different relative relief categories is given in Table (27). It is evident that very coarse drainage density has low frequency (8.39%) and is confined in relative relief categories from below 50m to 200m. The fine drainage density has the lowest frequency distribution (2.10%) and is confined in 200m to 300m relative relief categories only. The largest drainage density frequency distribution (59.44%) is shown together by moderately coarse and moderate drainage density. It is distributed in all relative relief categories. The coarse drainage density contribute only (16.08%) frequency distribution and is spread over relative relief categories upto 450m except 350m to 400m category. Similarly, moderately fine drainage density contribute comparable distribution (13.99%) and is spread over all the relative relief categories.

Highest drainage density frequency (21.68%) is shown by 100m-150m relative relief category whereas, the lowest frequency distribution (1.4%) is shown by above 450m relative relief category. In general, it is seen that the lower relative relief category has higher drainage density frequencies with few exceptions.

The correlation Table between the two variables is

TABLE - 27

Distribution of frequencies in categories of relative relief and drainage density
(A two way classification of the units of one sq. km.)

Relative Relief in m.	Drainage Density in Km/Km ²						Total % frequency	
	Total Grid frequency							
	V. Coarse	Coarse	Mod.Coarse	Moderate	Mod. Fine	Fine		
	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6		
Above 450	-	-	1	-	1	-	2	1.40
400 - 450	-	1	-	4	1	-	6	4.20
350 - 400	-	-	1	2	2	-	5	3.50
300 - 350	-	3	1	7	1	-	12	8.38
250 - 300	-	3	9	3	1	1	17	11.88
200 - 250	-	3	4	6	1	2	16	11.19
150 - 200	2	3	6	4	4	-	19	13.29
100 - 150	3	5	9	9	5	-	31	21.68
50 - 100	3	4	6	5	2	-	20	13.99
Below 50	4	1	6	2	2	-	15	10.49
Total	12	23	43	42	20	3	143	
Total in %	8.39	16.08	30.07	29.37	13.99	2.10		100

TABLE - 28

Correlation table of relative relief and drainage density variables

Drainage density Km/Km ² Relative Relief (in m.)			Very	Coarse	Mod.Coarse	Moderate	Mod.Fine	Fine	Total Grid frequency f(x)	Total frequency in %	$\sum_{i=1}^n f(x)$	$\sum_{j=1}^n f(x,y)$
	X_1	Y_1	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6				
			0.5	1.5	2.5	3.5	4.5	5.5				
		U_1	-2	-1	0	+1	+2	+3				
450-500	475	+4	-	-	1	-	1	-	2	1.40	+8	+32
400-450	425	+3	-	1	-	4	1	-	6	4.2	+18	+54
350-400	375	+2	-	-	1	2	2	-	5	3.50	+10	+20
300-350	325	+1	-	3	1	7	1	-	12	8.38	+12	+6
250-300	275	0	-	3	9	3	1	1	17	11.88	0	0
200-250	250	-1	-	3	4	6	1	2	16	11.19	-16	+16
150-200	175	-2	2	3	6	4	4	-	19	13.29	-38	+76
100-150	125	-3	3	5	9	9	5	-	31	21.68	-93	+279
50-100	75	-4	3	4	6	5	2	-	20	13.99	-80	+320
0-50	25	-5	4	1	6	2	2	-	15	10.49	-75	+375
Total Grid frequency f(y)			12	23	43	42	20	3	143		-254	+1184
Total frequency in %			8.39	16.08	30.07	29.37	13.99	2.10		100		
$V_1 f(y)$			-24	-23	0	+42	+40	+9	+44			
$V_1^2 f(y)$			+48	+23	0	+42	+80	+27	+220			
$V_1 U_1 f(x,y)$			+90	+39	0	-48	-60	-6	+15			

given in Table(28). The coefficient of correlation between relative relief and drainage density is 0.24. The correlation is significant at 1% level of significance. The regression lines for the two variables are shown in Fig.(24b). The relationship between relative relief and drainage density is expressed by the following equations.

$$1) Y = 0.00255X + 2.335$$

$$2) X = 22.6Y + 122.49$$

The coefficient of correlation value of 0.24 indicates low correlation between the two variables. It is because of the fact that the terrain has suffered rejuvenation and the drainage network is yet to stabilize.

DRAINAGE FREQUENCY

The drainage frequency is simply the ratio of the total number of channels of all orders in a basin to the area of the whole basin. Numerically, it is defined by the relation $F_u = (\sum L)u/A_u$

where F_u = Drainage frequency in No./Km².

$(\sum L)u$ = Sum of total number of streams of all orders.

A_u = Total area of drainage basin in Km².

The expression F_u gives the average frequency of streams in the area. The computed average drainage frequency of the area is 4.43 No./Km². But, to know the variation of

drainage frequency in the area the frequencies have been computed per 1 sq.km. grid.

The area is divided into one x one km grid and the number of channel segments grid wise are recorded. The value obtained gives directly the frequency per sq.km. The distribution of drainage frequency is given in Table (29).

TABLE - 29
Distribution of drainage frequency

Drainage frequency per Km ²	Frequency of grids	% of total frequency	Cummulative % of frequency	Category
Above 3	6	4.20	4.20	Low
2.25-3	43	30.07	34.27	
1.50-2.25	55	38.46	72.73	
0.75-1.50	31	21.68	94.41	
0-0.75	8	5.59	100.00	
Total	143	100.00		

It is seen from the Table (29) that the drainage frequency of above 3 has the lowest distribution (4.20%). Similarly the drainage frequency fo 0-0.75 has quite low distribution (5.59%). However, the drainage frequencies

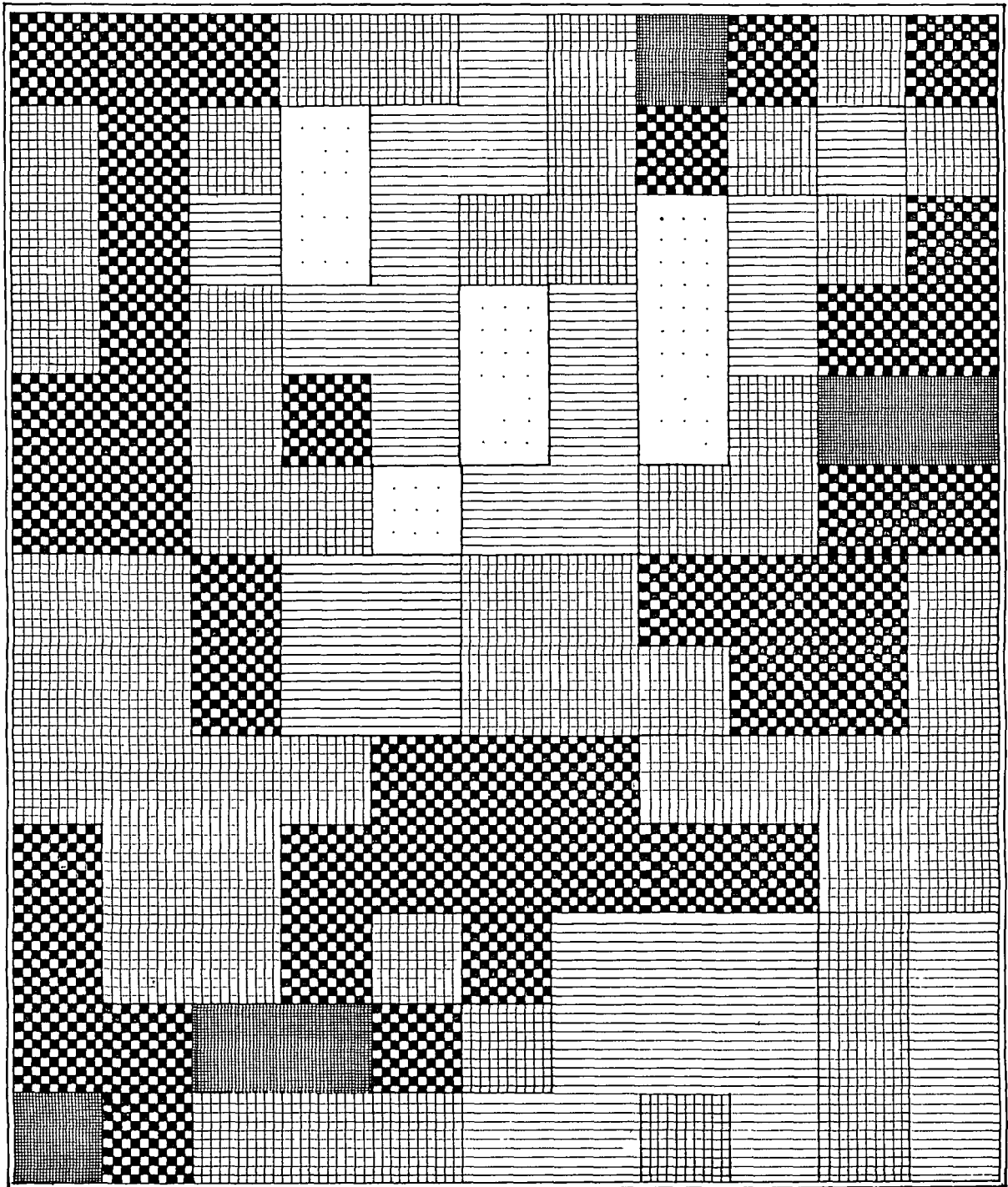
of 1.50 to 3 have maximum distribution in the area (68.53%). While drainage frequency of 0.75-1.50 have moderate distribution (21.68%) or the maximum distribution (90.21%) is shown by drainage frequencies of 0.75 to 3.

It is interesting to note from Fig.(25) that the maximum drainage frequency (>3) is confined in southwestern corner and northeastern corner of the area. The overall drainage texture computed for the area is 13.19 No/Km^2 . In general, the southern half of the area show relatively greater drainage frequency than the northern half of the area.

A comparison of drainage density, drainage frequency, absolute relief and relative relief maps indicate a general correspondence of frequency distribution in the southern half of the area. It implies that the morphometric parameters of the southern half of the area show some variation with the northern half of the area. This fact is corroborated with distinct change in the geomorphic domains between the two halves of the area (cf. chapter III). Conspicuously, the southern half of the area is represented by 'Plateau Domain' while, the northern half is represented by Hill Domain, (Fig.9) resulting in varied geomorphic expressions and drainage network.

DRAINAGE FREQUENCY

km 0.5 0 0.5 1 km



INDEX

NO OF STREAMS PER Sq.Km

-  > 3
-  2.25 - 3
-  1.50 - 2.25
-  0.75 - 1.50
-  < 0.75

Fig (25)

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CHAPTER - VIII

ENVIRONMENTAL DEGRADATION

The general awareness to ecological imbalances has led the scientists world over to closely scrutinise 'development' related human activities. The indiscriminate and unscientific exploitation of land resources has posed serious threat to the various development linked utility services.

The uncoordinated exploitation of land resources lead to rapid environmental degradation ultimately causing severe soil erosion (Fig.P36). Soil erosion and sedimentation is a major environmental concern of modern times. The magnitude of the problem could be realised from the fact that annual loss of agricultural land is as high as 30,000 sq.km. At this high rate of agriculture land loss, it is feared that the world may loose one fifth to one third of its agriculture land by the year 2000 (Lal, 1988). This problem is very acute in hilly and upland regions.

In the study area the environmental degradation has following three aspects.

- 1) Deforestation
- 2) Upland erosion
- 3) Waste disposal



Fig.(P.36)

Road cutting exposing the root network of tree. Note soil erosion due to 'cut'.

DEFORESTATION

The deforestation is attributed to timber exploitation and jhuming in the area (Fig.P37 & Fig.P38). It is responsible for the changing landuse pattern in the area. The peculiar problem in the whole of North Eastern Region is that much of the forest is owned by public or community organisation. The nodal agencies responsible for governing forests in the country have little say in the management of forests in this part of the country. The classification of forests of Meghalaya are given in Table (30).

TABLE - 30
Classification of Meghalaya forests
(Gupta et al. 1986)

Sl. No	Present Type	Approximate area	Ownership
1.	Reserve Forest	821 sq.km.	Owned and managed by State Government.
2.	Unclassified State Forest	7417 sq.km.	Owned and managed by District Council.
3.	Protected Forest	179 sq.km.	Maintained by District Council or State Government.
4.	Raid Forest	768 sq.km.	Owned and managed by Raids.
5.	Village Forest	259 sq.km.	Owned and managed by Village community.
6.	Private Forest	348 sq.km.	Owned and managed by Syiem, Lyngdoh and Sardars etc.
Total		9558.9 sq.km.	

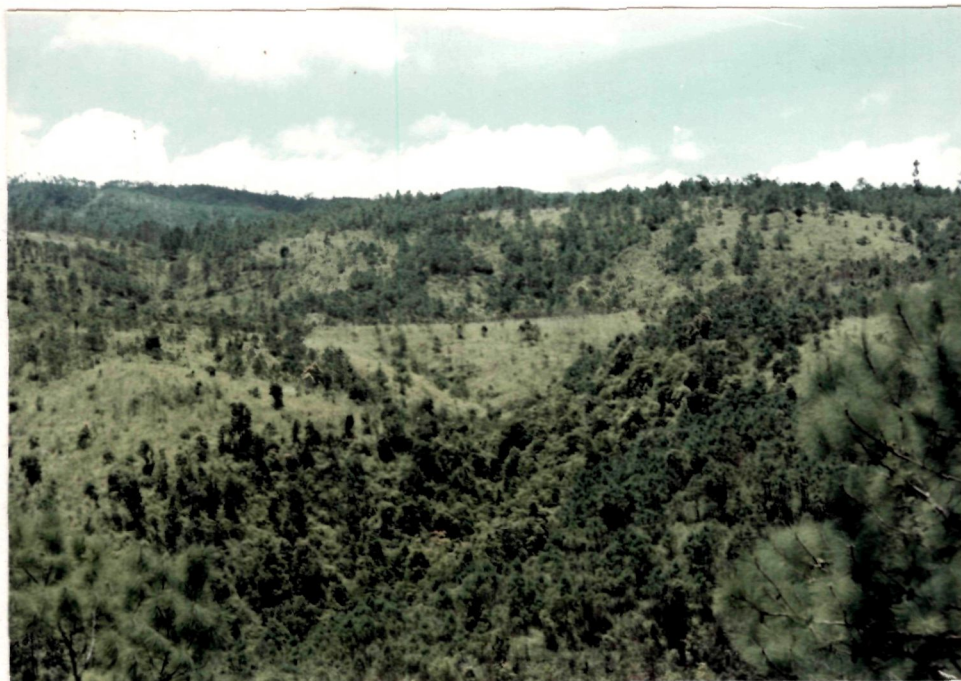


Fig.(P.37)

Deforestation due to timber exploitation. Note immature size of Pine Trees.



Fig.(P.38)

Deforestation due to Jhuming on slopes.

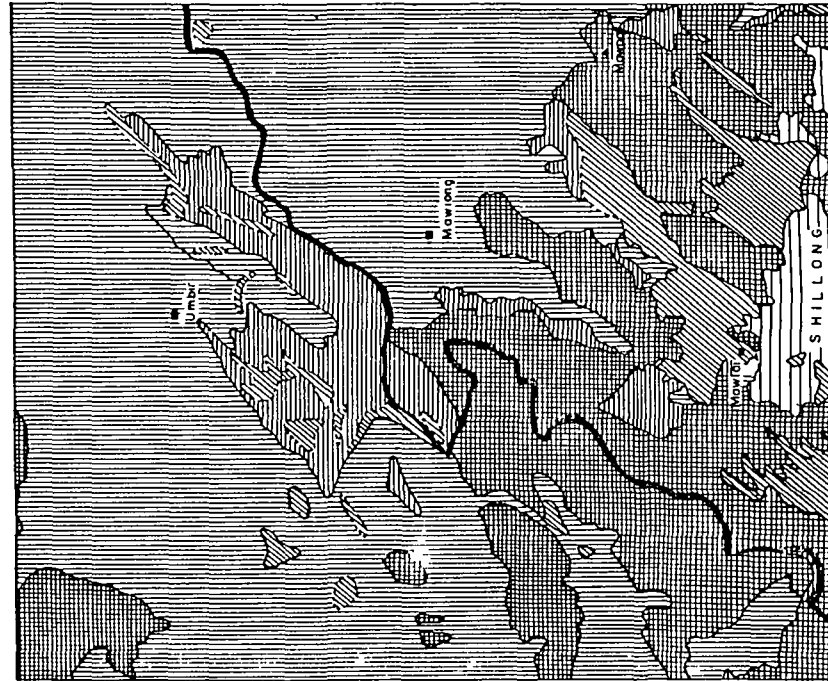
Forests though a renewable resource, has not been exploited in a sustained way. Lack or slow growth of industries in the region made forest resource exploitation an easy income generating proposition. The public ownership of forests (Table-30) led to their rapid and indiscriminate exploitation as it provided easy remuneration with low financial inputs. The situation has aggravated due to jhuming practice on slopes in the region. The resultant scenario is large tract of deforestation.

According to statistical handbook of Meghalaya (1987). East Khasi Hills has only about 129 sq.km. of reserve forest. It represents 15.7% of the total reserve forest of the state and 2.48% of the total area of the district.

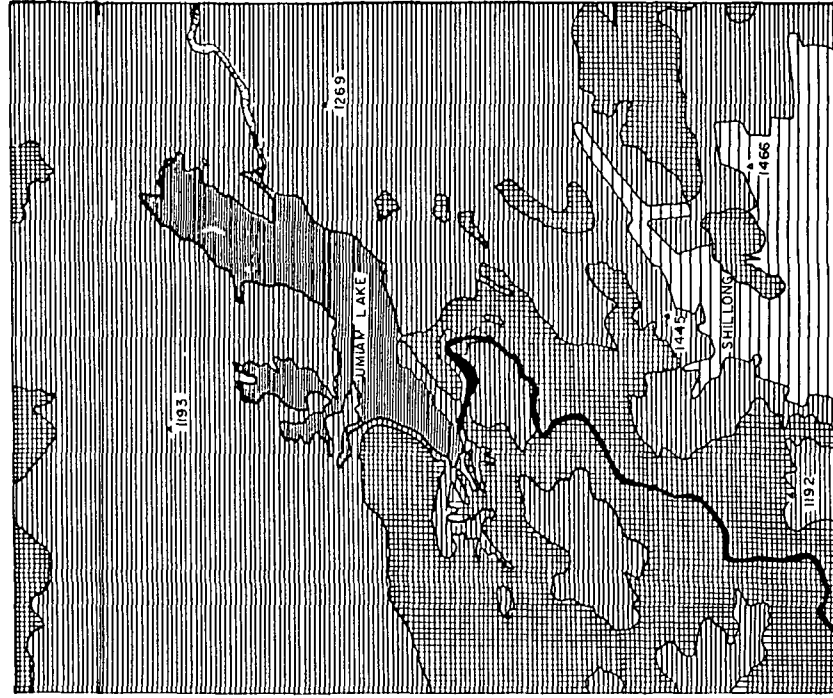
To evaluate the damage due to deforestation in the area, the landuse pattern variation has been studied. A comparative landuse map for last 56 years i.e. 1910-11 and 1966-67 has been prepared basically using toposheets, aerial photographs and landsat imageries. The landuse variation during this period is shown in Fig.(26). The quantified variation of different landforms in the area is shown in Table(31).

LANDUSE VARIATION

0-2 km 0 1 2 km



(a) LANDUSE (1910-II)



(b) LANDUSE (1966-67)

LEGEND

- FOREST COVER
- DEFORESTED AREA
- COMPLETELY DEFORESTED AREA
- CULTIVATED LAND
- SHILLONG TOWNSHIP/AGGLOMERATION
- UMIAM LAKE
- WAH UMIAM
- DRY WAH UMIAM BED
- DAM
- DYKE
- TRIANGULATION STATION
(Height in metre)

TABLE - 31
Landuse variation (Between 1910-11 and 1966-67)

Landuse	1910-11		1966-67	
	Area		Area	
	Total (Sq.Km.)	%	Total (Sq.Km.)	%
1. Forest	38.5	26.9	35.5	24.8
2. Agriculture	11.3	7.9	-	-
3. Shillong Township	4.3	3.0	9.9	6.9
4. Deforested	77.9	54.5	87.6	61.3
5. Completely Deforested	11.0	7.7	-	-
6. Lake	-	-	10.0	7.0
Total:	143.00	100.0	143.0	100.0

It is not possible to separate out deforestation due to timber exploitation and Jhuming separately in absence of basic data. However, in the study area at present, Jhuming activity is almost negligible. This is mainly due to the fact that there is hardly any forest cover left out around villages to support jhuming.

It is worth mentioning that the primary forest of the area has almost disappeared. The present forest cover represents secondary pine forest only. These secondary pine forests are also under indiscriminate exploitation. As a result, large patches of deforested land is visible on the slopes and forests older than 25-30 years are seldom (Fig.P37 and Fig.P38).

A perusal of Table (31) and Fig.(26) reveal the following facts:

- 1) During the period 1910-11 to 1966-67 i.e. 56 years, the forest cover in the area has declined.
- 11) The agricultural land during 1910-11 was confined in the plateau plain domain towards its southern fringe and gentle to level slope segments of hill domain (cf. Fig.9) in its central part of the area. However, after the formation of the reservoir (Umiam Lake), much of the agricultural land of the hill domain has been submerged under the reservoir (Fig.P39).
- 111) The township of Shillong and its suburbs experienced rapid growth during this period. The township has expanded more than two times causing the loss of agricultural land.
- 1v) The deforested area during this period has increased from 54.5% to 61.3% thereby increasing environmental hazards, contributing to rapid soil erosion.
- v) Large segments of the area show completely deforested patches. These patches are direct result of over and indiscriminate exploitation of forest resources. The deforested patches are very prominent in the northern half of the area.

UPLAND EROSION

Upland erosion is related to rainfall and is also known as rainfall erosion. It is one of the most fundamental

and universal process occurring on hill slopes. Management of soil and water resources in hilly and upland tract has assumed paramount importance. It is because, increase in the exploitation in such regions has produced ecological imbalances.

The deforested areas are prone to rapid soil erosion because, the area does not have 'canopy' protection. This results in higher 'raindrop impact' induced soil erosion.

Certain estimates are available indicating the seriousness of the problem of soil erosion. Randhawa (1980) has reported that 50% of agricultural land (80×10^6 ha), 35% of the forest land (20×10^6 ha), 86% of the cultural waste land (15×10^6 ha), 95% of permanent pasture and other grazing land (14×10^6 ha), 75% of the fallow land (15×10^6 ha), 24% of land under trees and groves (1×10^6 ha) and 44% of the total geographical area of India (145×10^6 ha) are subjected to severe erosion.

An estimated 6000×10^6 tonnes of soil and along with it more than 6×10^6 tonnes of nutrients are lost every year (Gautam, 1980). This is more than the total amount of fertilizers used by us at the moment. This is a great waste of the natural resources when we consider that in nature, it

takes 100-400 years or more to generate 10mm of top soil and 3,000-12,000 years to generate 30cm layer of soil.

Soil erosion causes off-site problems as well as on-site soil degradation. Sediment from erosion can cause downstream sedimentation by filling distant reservoirs or nearby road ditches. Soil erosion is a diffuse process having widely varying rates over a landscape. Therefore, direct measurement of soil erosion at number of points is impractical. Physically, erosion is difficult to measure and variability of climate requires that atleast 10 years of data be collected under best of conditions to obtain an accurate measure of annual erosion (Foster, 1988).

According to Walling (1988), abundant 'sediment yields' data on global basis is available. But such data normally refers to the suspended sediment load of the river. The bedload component is not included because of the practical difficulties in obtaining such measurements (Emmett, 1984).

Global maximum sediment yield of $25,600 \text{ t/km}^2/\text{yr}$ is reported from Dali river, China, from a drainage area of 96.1 Km^2 . Values of less than $1.0 \text{ t/Km}^2/\text{yr}$ are reported from several rivers of Poland. The Dali river represent soil

erosion rates of the order of 250 t/ha/yr. However, the sediment yield data does not provide meaningful information about on-site rates of erosion and soil loss within a drainage basin (Walling, 1988). It is because, only a fraction of the soil eroded within a drainage basin reaches the basin outlet and is represented in the sediment yield.

The variation of sediment yield data from river basins to rates of soil erosion in watershed upstream is exemplified in Table (32).

TABLE - 32
Variation in sediment yield and soil loss
(after Walling, 1988)

River	Country	Basin area (sq.km.)	Suspended Yield (t/Km ² /Yr)	FAO estimates of soil loss (t/Km ² /Yr)
Watari	Nigeria	1,450	483	1,000-5,000
Bunsuru	Nigeria	5,900	438	1,000-5,000
Senegal	Mali	157,400	14.6	1,000-5,000
Mesanu	Ethopia	150	1680	5,000-20,000

It is seen from Table(32) that in all cases the estimates of soil erosion rates are about an order of magnitude greater than the reported sediment yield. In general the soil erosion is assessed by USLE for small 'plots' or

larger 'plots' (Mutchler et al, 1988).

SOIL EROSION IN THE AREA

The principal kinds of erosion in the area are:

1. Sheet erosion
2. Rill erosion
3. Concentrated flow
4. Gully erosion
5. Stream channel erosion

The area has presently following landuse patterns, the changes in landuse during the period of 56 yrs (1910-11 to 1966-67) is shown in Fig.(26).

- (1) Forest land
- (2) Agriculture land
- (3) Township
- (4) Deforested land
- (5) Completely deforested land
- (6) Lake area.

The estimates of soil erosion for these different landuse are naot available. However, an idea of total soil erosion can be had from published data estimated for analogous area. Lal (1977) reported from the highlands with hilly catchments under forest covers in Malyasia a soil erosion rate of $245 \text{ cum/km}^2/\text{yr}$. Similarly, the soil loss in Thailand under uncultivated forest is reported to vary from 6.4-7.5

t/Km²/Yr. From the Peninsular Malaysia region, Morgan (1979) reported soil erosion rates of 670 to 1090 t/Km²/Yr from strongly dissected highlands upto an elevation of 2000m under equatorial monsoon climatic conditions (annual rainfall 1750 to 2510mm).

In India, Singh and Singh (1981), reported a soil erosion rate of 1885 t/Km²/Yr from 40 to 50 per cent slopes under natural mixed forests typically of northeast hilly conditions. Singh and Singh (op.cit.) reported soil erosion due to development of roads, expansion of habitation etc. from NEH region of the order of 67.2 t/ha/Yr. Such huge erosion though alarming, often goes unnoticed as the eroded material is efficiently transported to lower levels or main drainage systems. Land slides along the road and erosions from earth fills are the main problems which occur due to road development. Most of the hillside road cuttings in the area are steep. The slope profiles are modified by cuts in excess of 70°. This poses serious soil erosion problems. Singh and Singh (op.cit) reported soil erosion rate of 2.41kg/m²/Yr from 60° slopes on road side.

Singh (1987) reported soil loss rates of 0.2×10^{-4} to 0.5×10^{-1} t/ha/yr under different landuses from Burnihat, Assam bordering Meghalaya.

(Lake) is very complex in view of several independent variables, viz.,

- 1) Topography
- 2) Land use pattern
- 3) Associated Industries
- 4) Associated Developmental activities
- 5) Nature of Drainage
- 6) Rainfall pattern
- 7) Erosion Index.

Unfortunately so far, no on-site sedimentation studies have been carried out in the reservoir area. However, as per the authorities of MSEB, the reservoir had been designed assuming a silt load of 0.75 acre ft/sq.mile/yr from the catchment of the area. However, during the last 24 years, after commissioning of the reservoir the human activities in the Wah Umiam catchment has increased manyfold.

The bottom profile of Umiam Lake is highly irregular (cf. Fig.10). It has lot of submerged hillocks where the depth of water is shallow, such hillocks provide sediment 'traps' in its vicinity.

The upland erosion contributes to floods and sedimentation at lower levels. A survey of 21 reservoirs in the country has revealed that sediments at the rate of 8.51

ha m/100sq.km/yr as against the designed inflow of 3.02 ha m/100 sq.km./yr (Randhawa, op.cit). This represents 182% more inflow of sediment than the designed inflow. According to Priest (1963), the average annual sediment yields from 73 small watersheds of less than 100 ac area varies from 0.04 to 9.8 ton ac for short term observation (5 years) and 0.08 to 10.0 ton ac for long term studies (10 years).

WASTE DISPOSAL

The urbanisation around Shillong depicts very rapid growth as can be seen from Table(33).

A perusal of Table(33) indicates the following growth pattern around Shillong Town:

- (1) The census data of 1911-1951 reveals a growth of urban area around Shillong by 17.8% and corresponding population growth by 329 times. This is due to inclusion of Shillong Cantonment as an urban centre in 1931 census.
- (2) The Census data 1951 and 1961 indicate that towns of Mawlai and Nongthymmai had been included in urban limits around Shillong. As such, in 1961 census, the urban area recorded a growth of 105% and corresponding population growth of 651 times with 1911 as base year.

TABLE - 33
Urban growth history of Shillong

Name of Town	Area in Sq.Km.	No. of house-holds.	Population and Growth Rate (Growth rate in brackets)							
			1911	1921	1931	1941	1951	1961	1971	1981
<u>Shillong U.A.</u>	25.40	33,978	13,639	17,203 (26.13)	26,536 (54.25)	38,192 (43.93)	58,512 (53.20)	102,398 (75.00)	122,752 (19.88)	1,74,703 (42.32)
1)Madanrtung	2.11	1,182	-	-	-	-	-	-	-	6,165
2)Mawlai	6.14	3,593	-	-	-	-	-	8,528	14,260 (67.21)	20,405 (43.09)
3)Nongthymmai	2.93	4,349	-	-	-	-	-	10,084	16,103 (59.69)	21,558 (33.82)
4)Pynthormkhrah	2.02	2,244	-	-	-	-	-	-	-	10,711
5)Shillong Cant.	1.84	1,321	-	-	5,236	7,458 (42.44)	4,756 (-36.23)	11,348 (138.60)	4,730 (-58.32)	6,620 (18.89)
6)Shillong M.	10.36	21,289	13,639	17,203 (26.13)	21,300 (23.82)	30,734 (44.29)	53,756 (74.91)	72,438 (34.95)	87,659 (21.01)	1,09,244 (24.62)

- (3) Towns of Madanrtng and Pynthormkhrah were added in Urban area around Shillong in 1981 Census and the whole area was named Shillong Urban Agglomeration with 6 towns (Table-33). In 1981 Census, the Shillong Agglomeration showed an areal growth of 145% and corresponding population growth by 1180 times with 1911 as base year.

The above urban growth patterns around Shillong forming the Shillong Urban Agglomeration has created serious waste disposal problems. The rapid urbanisation around Shillong has not been provided with comensurate waste disposal systems. At present, the waste generated around Shillong is disposed in following ways:

- (1) Disposal in various streams (by individual house holders) passing through urban localities.
- (2) Intermittent burning in rubbish bins located in the town.
- (3) Shifting of waste to trenching grounds for self decay.

The data regarding the waste thrown into different streams by individual house holders is not available. Similarly, the data on trash burnt in diferent rubbish bins in the town is not known. Nevertheless these two waste disposal

operations ultimately lead the raw waste or the ash component of it into the Umiam lake through the various streams of the catchment. Such waste cannot be quantified in absence of data.

The shifting of waste to trenching ground is being done at present by the following three agencies depending upon their area of jurisdiction:

- (1) The Shillong Municipality
- (2) The Shillong Cantonment Board
- (3) Syiem of Mylliem.

Presently, there are two trenching sites. The cantonment Board throws the waste behind Garrison Engineer's office, into the Um Shirpi stream, a tributary of Wah Ro Ro which joins with Wah Umiam, upstream of the lake. At present, the cantonment Board disposes off about 72 trucks load of waste of 300 cft. capacity each per month.

The Shillong Municipality is maintaining a trenching ground of 18 acres area near village Mawiong since 1938 on lease, in the Riāt Khawan Reserve Forest. (Fig.P40). The trenching ground is presently being utilized for dumping of waste (garbage and night soil) by the Shillong Municipality as well as Syiem of Mylliem. As per the records (per comm., 1989)



Fig.(P.39)

Submergence of agriculture land under lake. Note the submerged NH-40, under lake.



Fig.(P.40)

Trenching ground in Riat Khawan Reserve Forest.

of Shillong Municipality, the daily average quantity of waste dumped in the trenching ground is:

- a) Garbage : 42 tonnes, and
- b) Night Soil: 3200 gallons.

During the present study to assess environmental degradation in the area, it is found that the waste lie scattered in the trenching ground and is rapidly dispersed downslope during rains, into the Umiam Lake through sheetwash and stream flows (Fig. P41).

Such waste disposal operation is a serious threat to the fragile ecosystem of Umiam Lake and its surrounding areas. Studies could be undertaken, to find viability of using such wastes for non-conventional energy alternatives or treatment and conversion into composite.



Fig.(P.41)

Garbage waste sliding
downslope towards
catchment of Umiam
Lake.

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CHAPTER - IX

SUMMARY AND CONCLUSION

SUMMARY

Physiographically Meghalaya is a plateau remnant representing the northeastern extension of the Indian Peninsular shield. It has a chequered history of geological evolution. The Plateau has ^{been} block uplifted to its present height of about 600m-1900m above mean sea level, during post Mesozoic times.

The core of the plateau comprises oldest rocks in the state, the Gneissic Complex with Shillong Group of rocks. Tectonostratigraphically, Meghalaya can be divided into three domains each having distinct evolution.

- a) The Peninsular Shield Extension comprising the Gneissic Complex.
- b) Intracratonic sedimentary basin represented by the Shillong Group.
- c) The Mesozoic-Tertiary sedimentary sequence along with the Sylhet Trap occupying the southern fringe of the plateau.

The Meghalaya massif has manifestation of following important lineaments with varying reactivation history:

- 1) N-S
- 2) E-W
- 3) NE-SW

4) NW-SE

The area of investigation forms part of central Shillong Plateau. By and large the area exposes Shillong Group of rocks. However, the northwestern corner of the area comprises Gneissic Complex. The contact between the two is unconformable, marked by presence of conglomerate.

The Shillong Group of rocks represents late proterozoic cyclothem consisting of argillaceous and arenaceous components. It is intruded by thin lenses of basic/ultrabasic lenses called the Khasi Greenstone.

The Shillong Group of rocks show low grade metamorphism and rare quartz and pegmatite veins related to acid magmatism.

The lowland occupying the central ^hpart of the area fringing Umiam lake have development of minor Quaternary and recent terraces.

South of the Umiam lake, a NE-SW trending zone of sub-vertical dips within Shillong Group represents Tyrsad-Barapani Shear zone.

The Shear zone is an important lineament probably a manifestation of deep-seated basement controlled tectonic fracture. On satellite imagery, it is discernible beyond Barapani upto Karbi-Anglong district in Assam.

On the basis of landforms evaluation, the area has been divided into two geomorphic domains.

1) The Plateau Domain

2) The Hill Domain.

Each Domain has distinct erosional and depositional landforms. In the plateau Domain the important landforms identified are Plateau Relicts, Linear Ridges, Escarpments, Gorges, Stream Valleys and Quaternary Terraces. The Hill Domain depicts Hummocks, Dissected Hills, Hummocky Ridge, Escarpments, Gorges, Elongated valleys, Lake and Recent Terraces.

The important minor landforms and micro relief features identified in the area are (1) Subdued Ridges and Elongated Depressions, (2) Colluvial Fans, (3) Gullies and Spurs, (4) Terracettes, (5) Micro Scarps and (6) Gully and Stream channels.

The Relief analysis revealed manifestation of fragmental or remnantal shapes arising due to diverse

denudational agencies.

The maximum elevation of 1678m is in the southern corner of the area. The lowest elevation of 880m occurs in the northwestern corner of the area. In general, the absolute relief rises towards south. Lithologically, the lowland area below 1000m is underlain by Migmatite-Gneissic Complex. By and large, the terrain above 100m elevation is underlain by Shillong Group of rocks.

The southwestern corners by and large shows higher relative relief. The correlation between absolute and relative relief is only moderate because, the terrain is rejuvenated along deep seated fractures and the topography is yet to stabilize.

The altitudinal distribution reveals a hidden graben structure in the central part of the area. The Umiam lake is located in this structure. The southern limit of this graben is defined by the Tyrsad-Barapani shear zone and the northern limit is defined by the northern fault passing along the escarpments of Sumer ridge.

The slope analysis revealed five categories

slope (below 5° , 5° - 10° , 10° - 20° , 20° - 30° and above 30°) and grouped as per Young's classification.

The below 5° category is confined in the central part where the Umiam Lake is located and the Wah Umiam debouches into the lake. The steep slope category (20° - 30°) shows a NE-SW trend more or less coinciding with the Wah Umiam trend and forms the Umiam gorge section.

The correlation between the absolute relief and slope is only moderate. This is typical of plateau regions where the ridge tops have smooth-skyline or profiles. The correlation between the relative relief and slope is fairly good. It is because, the area forms part of a dissected Plateau.

The climate of the area is 'Selva' type. The high rainfall and Plateau nature of the area is conducive to deep chemical weathering. The soil over different lithologies does not show megascopically much variation because of the fact that the correlating waters transport leached ions to great distances. Number of landslides are identified in the area. The landslide prone zones are confined within the Shillong Group of rock. They are frequent where there is modification of natural

slope profiles particularly, making them steeper because of constructional activities.

The drainage analysis reveals that the channel segments have very spectacular structural control. This is reflected by the reclined 'V' shaped channel network in the right portion of the area. This is a manifestation of tight folded configuration, prevalent in the Basement Gneisses.

The indiscriminate land resource exploitation in the area over last 5-6 decades has posed serious ecological imbalances. Much of the environmental degradation of the area is attributed to deforestation, upland erosion and waste disposal.

CONCLUSION

From the present study, the following conclusions can be drawn:

- 1) The area has two distinct geomorphic domains (Plateau and Hill domains), each having its characteristic landforms.
- 2) The relief (absolute as well as relative) rises from north to south. The Umiam lake low land is confined in the Graben, located in the central part of the area.

- 3) Seven slope categories varying between below 5° to above 30° have been identified in the area. A general pattern of slope rise with rise in absolute relief is observed. But, elevation above 1600m does not have steep slopes. The slope also rises significantly with rise in relative relief.
- 4) The selva climate of the area has formed deep chemical weathering and undifferentiated soil profile. Twenty-two number of landslides are identified in the area which are linked to developmental activities in the area.
- 5) The drainage network of the area show strong structural adaptation in conformity to the lineaments of the Meghalaya massif.
- 6) Indiscriminate land resource exploitation during the last 5-6 decades in the area has resulted in serious ecological imbalances. The attendant upland erosion coupled with unscientific garbage disposal associated with rapid urbanisation is posing serious threat to Uiam Lake environment. After formation of the Lake, large segments of agricultural land has been submerged under the lake.

RECOMMENDATIONS

To check further environmental degradation in the area, following strategy is suggested:

- 1) Terrain characterisation should be made, based on geomorphic parameters to identify different hazard prone zones for rationalising landuse in the area.

- 2) Ban on all constructional activities along NH-40 to avoid initiation of landslides.
- 3) The landslide muck should not be dumped down slope as it enhances silting problem of Umiam Lake. Suitable schemes may be formulated to dispose off this muck.
- 4) The existing garbage disposal system may be stopped forthwith. Alternative available technologies may be utilized for disposal or biogas/composet conversion.
- 5) In the catchment area of the Umiam Lake, to check vigorous soil erosion, large scale planned afforestation programme should be undertaken by the MSEB authorities.
- 6) Keeping in mind the seriousness of silting problem of Umiam Lake the Meghalaya Government should initiate a correct assessment of silting taking place per year and accordingly take the remedial measures to minimise the silting problems.
- 7) The expansion of settlements in the Umiam Lake catchment should be allowed as per terrain "characterisation" only.
- 8) Modern technology should be utilised for waste disposal to avoid silting and pollution in the lake ecosystem.

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