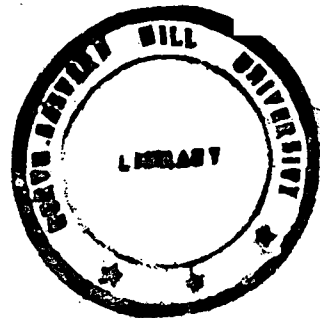


GEOMORPHOLOGY AND RURAL SETTLEMENTS IN KHASI AND JAINTIA HILLS MEGHALAYA

By

P. C. PANDA

THESIS SUBMITTED FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY



DEPARTMENT OF GEOGRAPHY
SCHOOL OF ENVIRONMENTAL SCIENCES
NORTH-EASTERN HILL UNIVERSITY
SHILLONG

JUNE 1983

COMPUTERISED

MEMO Library
Acc. No. 101748
Acc. by 1012/86
Class by _____
Sub. Heading by _____
Date by _____
Transcribed by _____

DS
551.43'0954164
PAN; 1



Phone
Grams : NEHU

North-Eastern Hill University

LOWER LACHAUMIERE, SHILLONG-793001.

This is to certify that the thesis entitled 'Geomorphology and Rural Settlements in Khasi and Jaintia Hills, Meghalaya', submitted by Sri Prakash Chandra Panda to the Department of Geography, School of Environmental Sciences, North Eastern Hill University, Shillong, Meghalaya for the degree of Doctor of Philosophy (Ph.D.) is a bonafide study of the author to the best of my knowledge and belief. All the quotations, extracts and ideas of other studies have been duly referred to. This study may now be placed before the examiners for evaluations.

SHILLONG
The 14 - 6 - 1983

R. K. Rai
(DR R. K. RAJ
SUPERVISOR,
Head,
Department of Geography,
School of Environmental Sciences,
North Eastern Hill University.

COMPUTERISED

ACKNOWLEDGEMENT

The author expresses his heartfelt gratitude to Dr. Raj Kumar Rai, Head, Department of Geography, North-Eastern Hill University, Shillong, for his valuable guidance, kind supervision of the study and painstaking editing of several drafts of the manuscript.

The author is indebted to Prof. R.C. Sharma, Prof. L.R. Singh, Prof. B.N. Sinha, Prof. P. Dayal, Prof. M. Miri, Dr. A.C. Mohapatra, Dr. Anil Kumar and Dr. Majid Husain for inspirations and encouragements at several stages of the study. The author is also indebted to the North-Eastern Hill University, Shillong, for providing Senior Research Fellowship and the Head, Department of Geography, North-Eastern Hill University, Shillong for making available possible facilities for carrying out this research.

Special mention of thanks are due to Mr. N.P. Goel and Mr. B.S. Mipun for their assistance rendered during the progress of this research. Thanks are also due to all the friends, well wishers and the staff members of the Department, who remained unnamed for their cooperation at different stages.

The author is grateful to Dr. Pahuja, Senior Geologist of the Geological Survey of India for his valuable suggestions. Thanks are also due to the personnels of Geological Survey of India and the Deputy Director, Survey of India, Eastern Circle, Shillong for their cooperation. The author is indebted to the Librarian, North-Eastern Hill University, Shillong for making available research materials.

The views expressed in the study are entirely of the author and the views and opinions of other scholars are duly cited in the text. Needless to mention that the omissions in the study are either of ignorance or of negligence and the mistakes, the sole responsibility of the author.

SHILLONG
The 6 - 7 - 1983


PRAKASH CHANDRA PANDA

C O N T E N T S

		<u>Page</u>
	Acknowledgements	
	List of tables	
	List of Figures	
	List of Plates	
	List of Toposheets	
Chapter-I	INTRODUCTION	1
Chapter-II	GEOLOGY OF KHASI AND JAINTIA HILLS	25
Chapter-III	WEATHERING AND MASS WASTING	60
Chapter-IV	DRAINAGE EVOLUTION AND FLUVIAL EROSION	90
Chapter-V	SLOPE ANALYSIS	141
Chapter-VI	QUANTITATIVE ANALYSIS OF TEN SMALL DRAINAGE BASINS	170
Chapter-VII	DISTRIBUTION AND LOCATION OF RURAL SETTLEMENTS (KHASI AND JAINTIA HILLS)	233
Chapter-VIII	INFLUENCE OF LANDFORMS ON LOCATION AND DISTRIBUTION OF RURAL SETTLEMENTS	296
Chapter-IX	SUMMARY AND CONCLUSION	334
	APPENDIX-I	350
	BIBLIOGRAPHY	352
	PLATES	360

LIST OF TABLES

Table No.	Caption	Page
II(i)	General Stratigraphic Sequence of Geological formations (Khasi&Jaintia Hills)	29
III(i)	Maximum and Minimum Teperature	64
III(ii)	Monthly Distribution of Rainfall	71
III(iii)	Percentage Distribution of Rocks	74
III(iv)	Rock type and Porosity Percentage	75
III(v)	Jhumming and Soil Erosion Calender	83
III(vi)	Average Monthly Erosion Index	85
V(i)	Extent of slope Units	163
VI(i)	Number of Stream Segments	184
VI(ii)	Stream Length (km.)	190
VI(iii)	Mean Stream Length (km)	190
VI(iv)	Cumulative Mean Lengths(Km)	193
VI(v)	Bifurcation Ratio (Rb)	198
VI(vi)	Sinuosity Indices	204
VI(vii)	Drainage Density (Dd)	208
VI(viii)	Constant of Channel Maintainance(CCM)	213
VI(ix)	Stream Frequency (Area in sq.km.)	217
VI(x)	Data Matrix	227
VI(xi)	Correlation Matrix	228
VII(i)	Number of Inhabited Villages	250
VII(ii)	Number of Villages classified by size of Population (Khasi & Jaintia Hills)	251
VII(iii)	Number of villages according to population size (Thana level)	253
VIII(i)	Chi-Square Distribution Test of Ten Small Drainage Basins	306

LIST OF FIGURES

Figure No.	Title	Page
1	Khasi and Jaintia Hills, Location	12
2	Khasi and Jaintia Hills, Geology	28
2(a)	Khasi Hills, Geology	33
2(b)		36
3	Khasi and Jaintia Hills, Lithology	39
4(a)	Khasi and Jaintia Hills, Lineaments	45
4(b)		47
5	Khasi and Jaintia Hills, Fault	49
6	Intensity of Rainfall	67
7	Rainfall and Temperature Graph	68
8	Khasi and Jaintia Hills, Drainage	91
9	Khasi and Jaintia Hills, Relief	93
9(a)	Khasi and Jaintia Hills, Contours	110
10	Khasi and Jaintia Hills, Drainage Pattern	107
11(a)	Khasi Hills, Adaptation of Stream to Structure	116
11(b)	Jaintia Hills, Adaptation of stream to structure	114
12(a), (b) (c)	Superimposed, Projected and composite Profile	121
13	Longitudinal Profiles	124
14	Altimetric Frequency Graph	126
15	North-South Profile	121
16	Slope elements	149

Figure No	Title	Page
17(a)	Hill Slope Profiles	151
17(b)	"	152
18	Khasi and Jaintia Hills, Average Slope	162
19	Stream ordering, Drainage density Problem, channel pattern	174
20(a)	Khasi Hills, Stream ordering	180
20(b)	Jaintia Hills, "	181
21	Law of Stream Numbers	186
22	Law of stream length	192
23(a)	Khasi Hills, stream frequency	215
23(b)	Jaintia Hills "	219
24	Khasi and Jaintia Hills Distribution of Settlements	244
25(a)	Shillong Thana, Settlements	254
25(b)	Nongpoh Thana "	256
25(c)	Cherra Thana "	258
25(d)	Dawki Thana, "	260
25(e)	Jowai Thana "	262
26	Settlement Location	268
27	Settlement Types	277
28	Inside Layout of a House	287
29(a)	House types and Building Materials	293
29(b)	-do-	294
30(a)	Khasi Hills, Distribution of Settlements	299
30(b)	Jaintia Hills, Distribution of Settlements	300
31(a)	Khasi Hills, Relief and Settlements	304

Figure No	Title	Page
31(b)	Jaintia Hills, Relief and Settlements	305
32(a)	Khasi Hills, settlements in relation to slope	309
32(b)	Jaintia Hills, settlements in relation to slope	312
33(a)	Khasi Hills, Drainage, Agricultural land and settlements	315
33(b)	Jaintia Hills, Drainage, Agricultural land and settlements	317

LIST OF PLATES

- Stratified horizontal sedimentary bed near Cherra Bazar. The upper section shows effects of solution, lower part in frost shattered.
- Exposed rocks due to intensive weathering and erosion.
- The Magnificent Mawsmi falls, south of Cherrapunjee (348 mts).
- The Yali falls, Garampani (Jaintia Hills).
- The Elephant falls (Upper Shillong).
- The Bishop's falls (Shillong) (121 mts).
- Pot hole drilling in Carboniferous sandstone.
- Pot hole erosion of carboniferous sandstone forming the bed of stream Wah Lynkian near Cherrapunjee.
- Pot hole drilled material seen at the bottom.
- A pot hole - West of Cherrapunjee.
- Action of physical weathering. Note the growth of grass along the fracture zone.
- A typical lime deposit inside Cherrapunjee cave looks like a huge water lily.
- Stalagmite and stalagtite inside Mawsynram cave.
- Stalagtite formation inside Cherrapunjee cave.
- Debris fall along Shillong-Cherra road (Photo taken 5 minutes after the fall)
- Deformed Debris fall. 15 km. south of Shillong along Shillong Cherrapunjee road.
- Streams adjustment to structure (Un Sirpi Nala south of Shillong).
- Rill action on steep hill slope East of Cherrapunjee.
- A youthful valley of Umsohryngtiew river, East of Cherrapunjee.

- Upper Umiew river valley. Note the exposed boulders on the hill slope : Large scale felling of trees and 'jhumming' is practised on the slope.
- Rock sliding. Note the shape & size of the rock pieces.
- An exposed complex structure.
- Residual boulders produced by physical weathering.
- Fluvially eroded boulders on the upper Umiam river bed.
- Derangement of boulders along the (initial stage) stream bed. Note the rectangular shape of the blocks.
- Wah Lynkian valley. In the background-- the hill slope, which is devoid of vegetation is affected by intensive soil erosion.
- An exposed granite boulder North-East Khasi Hills.
- Ripple marks on an exposed boulder.
- A product of chemical weathering in Cherrapunjee area.
- Chemical weathering along the joints.
- Dispersed clustered settlements associated with 'Jhumming' and valley cultivation. Around Myllem.
- A linear settlement along Shillong-Cherrapunjee road Myllem.
- A typical old Khasi house in Laitlyngkot village. Note the shape and building material.
- A typical Bhoi house in Umroi village (Northern Hills region). Note the shape and building material.
- Isolated households near cultivation sites. Umtngar village : Note the location of the house.
- Dispersed clustered settlements near permanent cultivation sites. North Khasi Hills.
- An isolated hill slope settlement near jhum land. Note the length of the pillars and the steepness of the hill slopes.
- A valley settlement facing the Mawsmat falls south Khasi Hills. Umsohryngkiew river valley.

- A mixture of old and modern house types in Myllem village. Left - old type, Right - developed Assam type. Note the variation in building material.
- A hill slope settlement (Assam type) under construction. Note the length of the pillars.

LIST OF TOPOSHEETS

(A) 1: 250,000

Nos 78 - O

83 - C

(B) 1: 63,360

Nos 78 O/1, 78 O/3, 78 O/5

78 O/6, 78 O/10, 78 O/11

78 O/14, 78 O/15

(C) 1: 50,000

Nos 78 O/7, 83 C/1, 83 C/2

83 C/3, 83 C/7, 83 C/11

CHAPTER - I

INTRODUCTION

Geomorphology has been described as the 'earth-shape-science' (Brown 1970).¹ The science of geomorphology which is concerned primarily with the form of the earth, is little more than one hundred years old. Traditionally, the study was essentially that of the origin and evolution of landforms. Many would still, agree with Fenneman that "the study and interpretation of the records left by erosion constitute the larger part of the science of geomorphology."² The historical element in geomorphology is evident from the need to interpret still observable traces of events, which once took place on the earth's surface. On the other hand, geomorphologists like Leopold, Wolman, and Miller (1969),³ while observing that 'much of geomorphology is stratigraphic geology', have made the study of contemporary processes a conspicuous part of their methodological approach to the subject. Much recent work tends increasingly to emphasise the definition of F. Hijulstrom, that

¹ Brown, E.H. (1970), Man Shapes the Earth, Geog. Jour., 136, pp.74-84.

² Fenneman, N.M. (1931), Physiography of Western United States, Mc-Graw Hill, New York.

³ Leopold, L.B., et. al. (1969), Fluvial Processes in Geomorphology.

'geomorphology is the science of landforms and of land-forming processes.'⁴

At the beginning of the nineteenth century, the science of geology became distinguishable from "natural Philosophy". As facts and theories about the origin of rocks and mountain ranges accumulated, they were absorbed into regional or descriptive geomorphology as an aid to understanding the origin of landforms. Thus 'explanatory description' evolved, in which a landscape is not simply described by the heights of its hills and the declivities of its slope but by the reconstructed geologic history of its evolution. Explanatory description is a higher form of analysis than regional description in that it requires inferences about past events. In a sense, a landscape can not be understood until the entire geologic history of the rocks and the slopes is known.

The subject of landform analysis can also be organized on the basis of the processes that have operated and now operate to shape the land. Many recent geomorphological works deal with specific demorphic processes for example, Leopold et al, (1969);² Olier (1969);³ Birkeland (1974).⁴ Process-oriented geomorphology is closely related

¹Hjulstrom, F. (1935), Studies of the Morphological activity of rivers as illustrated by the River Fyris, Univ. Upsala, Geol. Inst. Bull., 25, pp.221-527.

²Leopold, L.B. et. al.(1969), Op.cit.,

³Olier, C.D. (1969), Weathering, Oliver & Boyd.

⁴Birkeland, (1974),

to climatology, because air temperature, precipitation, winds and atmospheric humidity largely determine the response of rocks to subaerial exposure.

How can regional description, historical reconstruction, and the details of the chemical and physical response of rocks to water and air be unified into a science of geomorphology? The best solution that has evolved is summarized by the trinity of 'structure', 'process' and 'time'. Although generally attributed to the greatest geomorphologist William Morris Davis, the organization of geomorphic information under the three headings is implicit in many earlier writings and is such a natural organization that it was probably unconsciously used many times before Davis codified it with such great force and clarity.

There has been a phenomenal development in the field of geomorphological studies in the twentieth century. The earlier works in this field led to a variety of approaches and this resisted in the development of several schools of thought. According to C.A.M. King (1966)¹ these are three major groups; (1) the first arises out of the work of Walter Penck and may be called the 'mobilistic view', (2) the second gives priority to the effects of climate in studying the characteristics of the landscape; (3) the

¹King, C.A.M. (1966), *Techniques in Geomorphology*, Edward Arnold, London.

third is based essentially on the idea of 'correlation by altitude, and therefore, be termed the 'eustic view'.

Modern trend in geomorphological study is towards the increasing importance of the quantitative methods. Under the impetus of R.E. Horton (1945),¹ the description of drainage basins and 'channel network's were transformed from a purely qualitative and descriptive study to a rigorous quantitative science, capable of providing hydrologists with numerical data of practical value. Horton's work was developed by A.N. Strahler (1952,² 1954,³ 1956,⁴ 1957,⁵ 1964⁶) and his associates (Melton, 1957;⁷ Morisawa, 1957;⁸ and Schumm, 1956).⁹

¹Horton, R.E.(1945), Erosional development of Streams and their drainage basins; hydrological approach to quantitative Morphology, Bull. Geol. Soc. Amer., Vol. 56, pp.275-370.

²Strahler, A.N. (1952), Dynamic Basis of Geomorphology, Bull. Geol. Soc. Amer., Vol. 63, pp.923-38.

³_____, (1954), Statistical Analysis in Geomorphological research, Jour.Geol., Vol.62, pp.1-25.

⁴_____, (1956), Quantitative Slope Analysis, Bull. Geol. Soc. Amer., Vol. 67, pp.571-96.

⁵_____, (1957), Quantitative Analysis of Watershed Geomorphology, Trans. Amer. Geophys. Union, 38, pp.913-20.

⁶_____, (1964), Quantitative Geomorphology of drainage basins and channel networks, In Chow, V.T.(ed.), Handbook of Applied Hydrology, IV, p.39 & IV, p.76.

⁷Melton, M.A.(1957), An analysis of the relations among elements of climate, surface properties and geomorphology, Columbia Univ., Dept. Geology, Tech. Report II. p.102.

⁸Morisawa, M.E.(1957), Accuracy of determination of stream lengths from topographic maps, Am. Geophys. Union. Trans. 38, p.86.

⁹Schumm, S.A.(1956), Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey, Bull Geol. Soc. Am. 67, pp.597-646.

The application of the tools of mathematical statistics to applied geomorphology is essential if, meaningful conclusions are to be achieved. Mathematical statistics is concerned with the derivation inferences from a small-size-sample, about the characteristics of a vast population, whose absolute parameters can never be known. Tests are concerned with ascertaining the probability of being right or wrong in stating some hypothesis concerning the relation of one or more sample to the population, from which they have been drawn essentially, an inductive methodology.

It may also be noted here that a great deal of modern geomorphology is based on the 'dynamic approach'. There is another systematic approach for the better understanding of geomorphology. It is the regional geomorphology which is necessary primarily to analyse the broad characteristics of the area and to fill in the details of the regional characteristics afterwards. Mention must be made of some of the most important names in the science of geomorphology. The works of W.M. Davis, J. Playfair, G.K. Gilbert, L.C. King, W.D. Thornbury, and B.W. Sparks are the outstanding contributions in the field of world geomorphology.

Since 1960, a phase of intensification and concentration has emerged during which attempts have been made to place the study of geomorphology in the correct

perspective. This has been fostered by increasing use of the 'systematic approach', facilitated by model building and design of experiments and affected by the use of more sophisticated techniques and methods of analysis. Certain themes have been detected which are common to many of the branches of geomorphology and notably amongst these, is the significance of 'man as an agent of the geomorphological processes.' Study of the impact of man, directly and indirectly, upon both surface forms and processes have provided the study of geomorphology with an orientation, which is increasingly becoming relevant, within the framework of geographical studies as a whole.

A paradox has, therefore, been realised where the outcome of diversification and the emergence of several distinctive approaches in geomorphology have been accompanied by integration within geomorphology, within physical geography and within geography as a whole. Indices of this integration are illustrated by increasing attention to the spatial distribution of contemporary physical processes in climatic geomorphology, to the consideration of physical landscape evaluation to the perception of environmental hazards and their economic significance, and to the effect of man upon environment (Brown, 1970).¹ These apparently,

¹Brown, E.H. (1970), Op.cit., pp.74-84.

diverse approaches are united by focussing attention upon present systems, their content, mechanics, spatial variations, and inter-relationship as the basis for studies of the past and of the future geomorphological processes can now be visualised as a landform - process science and it is the purpose of this study to elucidate this theme in the context of geomorphic features and their impact on location and distribution of rural settlements.

The science of geomorphology has its importance not only as an academic discipline but also in the present day world, has more applied applications in the field of soil science, economic geology, geohydrology, military geology, engineering geology, and for landuse and landscape planning. For the development of agricultural resources, the terrain assumes special significance. So far as the agricultural planning is concerned, regional geomorphological studies have become of greater importance. In an agricultural country like India, the application of geomorphology in the field of land utilization particularly, those of agriculture, horticulture, forest development, selection of sites for construction of dams, transportation and communication networks and settlements location may be of great help.

In India, among those who have contributed significantly on some aspect or other, to our knowledge of the

'geomorphology' (quite a few of them have not used the term, though) of parts of peninsular India since the 1930s are A.M. Heron, D.N. Wadia, J.A. Dunn, W.D. West, J. B. Auden, R.N.P. Arogyaswami, and B.P. Radhakrishnan among the geologists and S.P. Chatterjee, H.L. Chibber, S.C. Bose, R.P. Singh, Enayat Ahmad and K. Bagchi among the geographers. Thanks to the initiative of W.D. West, a seminar on geomorphological studies in India was held at Sagar in Madhya Pradesh in 1965 (the proceedings were published in 1967), which can be said to have been the first forum where geomorphologists gathered from different parts of India. Some geomorphological works have been done also, by the Oil and Natural Gas Commission and National Atlas Organisation. During the past few years numerous papers have been presented in a number of seminars, but a majority of them have not been published.

A number of studies on regional geomorphology of India have also been done by some geographers and geologists in different Universities. A number of regional geomorphological studies, such as some parts of Andhra Pradesh (R. vaidyanadhan, 1964),¹ Chotanagpur plateau (R.P. Singh, 1960),²

¹Vaidyanadhan, R. (1964), Recognition and correlation of erosion surfaces in the southern part of Cuddapah Basin. Jour. Geol. Soc. India, Vol. 5, pp.121-127.

²Singh, R.P. (1960), Structure, Drainage and Morphology of Chota Nagpur Highlands, Geog. outlook, 2.

savindra Singh and A. Kumar, 1981);¹ Mysore plateau (B.P. Radhakrishnan, 1967;² H. Brunner, 1968a³); Rajasthan region (B. Ghose and S. Singh, 1969;⁴ Depawati Sen, 1971);⁵ Gujrat region (K.R. Dixit, 1970);⁶ Maharashtra (R.B. Gupte and S.W. Rajaguru, 1971).⁷ Apart from these, R.K. Rai (1980)⁸ has discussed the geomorphology of Sonar-Bearma basin, Madhya Pradesh, Biswas (1974)⁹ has presented the geomorphology of Kutch region, Sen (1972)¹⁰ has described quite a few geomorphic features from parts of Aravalli range. It was West (1964)¹¹ who reactivated

¹Singh, S. and Kumar, A. (1981),

²Radhakrishnan, B.P. (1967), The Western Ghats of the Indian Peninsula, Proc. Semi. Geom. Std. Ind., Sagar, pp.4-14.

³Brunner, H. (1968a),

⁴Ghose, B. and Singh, S. (1969), Geomorphological Control on the distribution of evaporites in W. Rajasthan.

⁵Sen, D. (1971), Effects of rock types on stream slopes around Jawai Bandh, S.W. Rajasthan, Jr. Geol. Soc. India, 12(2), pp.189-91.

⁶Dixit, K.R. (1970), Polycyclic landscape and the surface of erosion in the Deccan trap country with special reference to upland Maharashtra, Nat. Geog. Journ. India, 14(3 & 4), pp.236-52.

⁷Gupte, R.B. and Rajaguru, S.W. (1971), Late Pleistocene Geomorphological history of rivers of Western Maharashtra, Int. Symp. Deccan traps and other Flood Eruptions, Proc. Pt. I, Bull. Volcanology, 35(3), pp.686-95.

⁸Rai, R.K. (1980), Geomorphology of Sonar-Bearma Basin, Concept Publ. Co. N. Delhi.

⁹Biswas, (1974),

¹⁰Sen, D. (1972), Geomorphology of the Aravalli Range, Rajasthan and a reinterpretation of residual surfaces, Geog. Rev. India, 3.

¹¹West, W.D. and Choubey, V.D. (1964), The Geomorphology of the Country around Sagar and Katangi, Jour. Geol. Soc. India, Vol.5.

interest in the study of geomorphology in Madhya Pradesh. R. Vaidyanadhan (1971)¹ has presented the 'geomorphology of Cuddapah Basin' and 'Hill Slope elements and surficial deposits near Vishakhapatnam, Andhra Pradesh.

Geomorphology of parts of Bihar have been studied by a number of geomorphologists and among them those by Singh (1979)² on the Ranchi plateau. Pathak (1968)³ on Chelhari Basin and Mukhopadhyaya (1969)⁴ on Subarnarekha Basin and Verma on Chhotanagpur plateau are noteworthy. Recent publications on geomorphological studies in India such as 'Geomorphology of India' S. Roy (1980)⁵, 'Ravine erosion in India H.S. Sharma (1980)⁶ and 'Perspective in Geomorphology' in four volumes edited by Sharma (1982).⁷ It is a collection of a number of Scholarly articles on descriptive and quantitative geomorphology.

¹Vaidyanadhan, R.(1971), Studies in Applied Geomorphology, Studies in Earth Sciences, pp.318-21.

²Singh, S. (1979), "A Geomorphological Study of drainage density of small drainage basins of the Ranchi Plateau, India," Trans.Inst.Indian. Geog. Vol.2, No.2, pp.49-60.

³Pathak, M. (1968), Geomorphology of Chhelhari Basin, India, Proc.Symp.Erosion Surfaces, 21st. Int.Geog.Cong. Nat.Commtt.Geog.Calcutta, pp.49-51.

⁴Mukhopadhyaya, S.C.(1969), Some aspects of geomorphology of part of Subarnarekha basin around Mahali, Murup, Bihar, Geog. Rev. India, 31(2), pp.33-40.

⁵Roy, S. (1980), Geomorphology of India.

⁶Sharma, H.S.(1980), Ravine erosion in India.

⁷Sharma, H.S.(1982), Perspective in Geomorphology, 4 Volms. (Ed.).

Application of satellite imagery is becoming more and more popular in geomorphological research. Most basic, of course, is the mapping of drainage patterns, stream beds, canyons and other topographic features. More subtle watershed information which can be derived from colour infrared imagery includes erosion history, for example, what is the distribution of gully and sheet erosion on the site and surrounding area? Of even greater importance is an assessment of erosion susceptibility. This information can be inferred by examination of the imagery for erosion history, in combination with data on the amount of vegetation cover, the area's topography, immediate drainage area, and other factors, most of which can be obtained directly from the imagery.

Broad Objective of the Study

Applied geomorphology deals with solving practical planning problems. The application of the detailed geomorphological maps is one of the examples often quoted. From these geomorphological maps, other maps can be compiled, providing informations about landforms favourable or unfavourable for agricultural landuse, transportation, or housing etc. of any region. Therefore, the importance of geomorphology in the location and distribution of rural settlements cannot thus, be exaggerated.

KHASI AND JAINTIA HILLS LOCATION

13 0 13 km

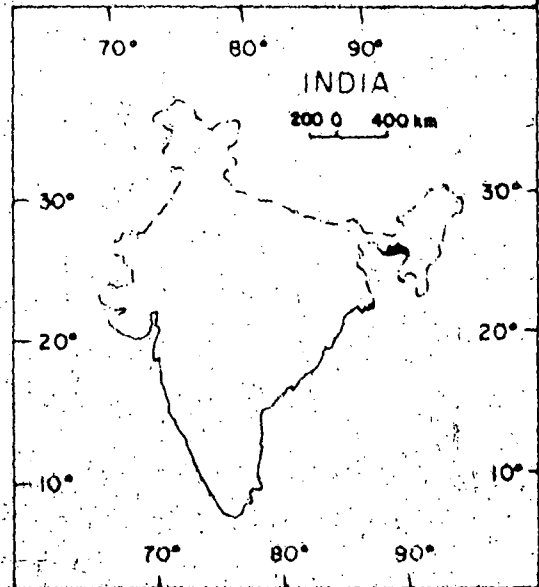
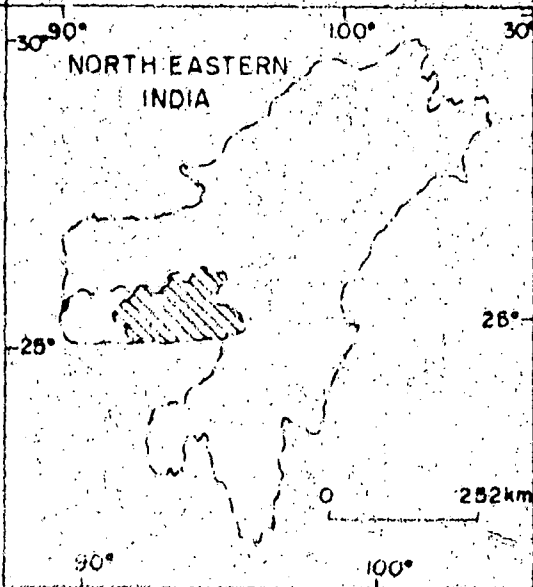
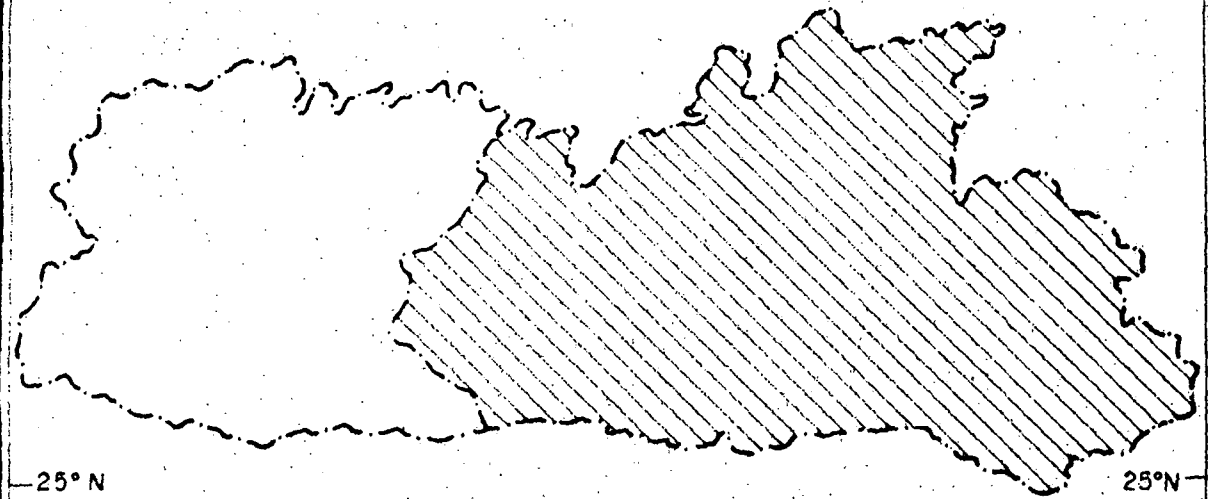


Fig 1.

In the present study, an attempt has been made to find out the links and the influences of the regional geomorphological factors on location and distribution of rural settlements in the Khasi and Jaintia Hills of Meghalaya. As the Khasi and Jaintia Hills present a great variety of topography, lithology and structural characteristics of rocks, it has ample scope for the investigation into geomorphological processes there in the region. It is also interesting to note that the location, structure of the houses and distribution of rural settlements of the region have emerged under clear influence of the regional processes of landforms and their characteristics manifestation. The present study is an humble attempt in the same direction.

Location

The state of Meghalaya comprising the Garo Hills; Khasi and Jaintia Hills districts which previously formed part of the undivided State of Assam, came into existence on 19th January, 1972. For this study, the author has chosen only the district of Khasi and Jaintia Hills (1971 census) which covers the maximum part of the Shillong Plateau.

The area of study lies between longitude $90^{\circ}40'E$ to $92^{\circ}45'E$ and latitude $25^{\circ}N$ to $26^{\circ}10'N$ (Fig. 1). The region is demarcated by Garo Hills in the west, Assam in

the north and east, Bangladesh in the south. The total area of the region covers 14,463.6 sq. kms. (11,168.1 sq. kms. of Khasi Hills and 3,295.5 sq. kms. of Jaintia Hills) with 2245 rural and five urban settlements (1971 census).

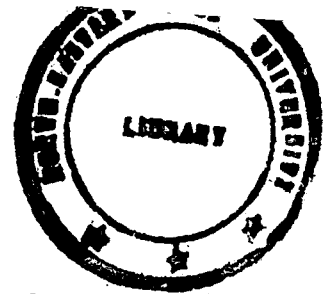
Salient Features of the Khasi and Jaintia Hills

The Khasi and Jaintia Hills districts consist almost entirely of hilly areas. Only about 15 per cent land is available for agriculture. This region may be sub-divided into three sub-regions:

- (1) The Northern Hills Region,
- (2) The Central Plateau Region, and
- (3) The Southern Hills Region.

The Northern Hills Region has an undulating topography, hills after hills rising almost to the same height and extending northwards to the Brahmaputra valley. The accordant summits of these hills vary between 170 and 820 mtrs. The Nongpoh town, lying half-way between Shillong and Gauhati stands on the flat top, 700 mts. high, typical of a topographical peculiarity of the region.

The Central Plateau Region of the Khasi Hills covers about an area of 5,000 sq. kms. Its outer limit defined roughly by the 1,500 mt. contour line. It contains remnants of multicyclic landscape, ranging in heights from 1,500 mts. to above 1,900 mts. The Shillong hills towering



above Shillong city contain the highest peneplained surface, trending E.S.E. to W.N.W., over which streams pass before plunging into the deep valleys of the Umiam and Umken. The presence of many rapids and water falls in the neighbourhood of the city of Shillong indicates that this region has a youthful topography, due to perhaps, a recent rejuvenation. To the south of the Shillong hills around Myllem occurs a typical granite topography with rounded hills and shallow valleys.

Farther south occurs a vast structural platform on which stands Cherrapunjee. This part of the region is built up of gently dipping sandstones of the Cretaceous Age, and over its edge are found the magnificent Mawsmi waterfalls. Small rounded limestone hills of the Eocene period are found scattered all over the Cherra plateau. Some of them contain small caves with narrow underground passages and characteristic cave deposits. From Cherrapunjee, the plateau slopes gently southwards for about 6 kms. and then falls rapidly to the plains, the ground slope conforming to the high dip of the sedimentary rocks.

Earlier Investigations

As a matter of fact, very little work has been done on geomorphic aspects of this region. S.P. Chatterjee's (1941)¹ pioneering work on the 'Meghalaya Plateau', from

¹Chatterjee, S.P., (1941):

which the name 'Meghalaya' came into existence ('Megha' meaning cloud and 'alaya' meaning abode i.e. 'abode of cloud'). R.P. Singh (1968)¹ has presented the 'geomorphology of Shillong Plateau, Assam'. N.C. Barua (1968)² threw light on the 'geomorphology of Barapani area in Meghalaya Plateau'.

Apart from this, some of the recent works have been done by the following persons such as, M. Taher (1971-72)³ has presented some interesting relationship in his paper titled 'Man - Environment Relationship in the Cherrapunjee Region'. S.N. Pattnaik (1979)⁴ has discussed the general geomorphic characteristics of Meghalaya plateau and after that, has analysed the geomorphic influence on agricultural landuse. He observed that the practice of agriculture is also going on at a gradient of 60 degrees. Rai et al (1980)⁵ in their paper titled 'Hill slope and landuse

¹Singh, R.P.(1968), Geomorphology of the Shillong Plateau of Assam, Proc. Pre. Cong. Symp, IGU, Gauhati, pp.1-9.

²Barua, N.C.(1968), Geomorphology of Barapani area in Meghalaya Plateau, Proc.Pre-Cong.,Symp,IGU,Gauhati, pp.25-32.

³Taher, M.(1971,72), Man Environment relationship in the Cherrapunjee Region.

⁴Pattnaik, S.N. (1979), 'Geomorphology and Agriculture in Shillong Plateau, Meghalaya". Unpublished M.Phil Dissertation, Department of Geography, N.E.H.U., Shillong.

⁵Rai, R.K. et. al. (1980), Landuse, soil erosion on hill slopes around Shillong. Geog. Rev. vol. 41, No.4.

around Shillong' analysed the characteristic features of different hillslope elements and the pattern of landuse over those slopes. They found that in the slope profiles the scarp face is missing. Rai (1980)¹ discussed the 'morphometric analysis of Umrang basin of Meghalaya', and studied the 'geomorphology and rural settlement of Meghalaya'. Rai and Panda (1980),² have discussed in their paper entitled 'Morphometric analysis of Umkhri basin' of Khasi Hills. They have used some of the quantitative techniques, such as stream ordering, law of stream numbers, law of mean stream length, drainage density and stream frequency in a systematic way.

In a recent study on 'Environmental frame work and landuse on hill slopes around Shillong' Rai and Panda(1982)³ have analysed the problem of soil erosion on the slopes and suggested their remedies to check soil erosion. Panda (1982)⁴ has analysed the 'slope characteristics of Khasi and Jaintia Hills' by dividing the whole region into five distinct slope regions.

¹Rai, R.K.(1980), Morphometric analysis of Umrang Basin of Meghalaya, Trans. Inst. Indian, Geog. Vol.2, No.2.

²Rai, R.K. and Panda, P.(1980), Morphometric analysis of Umkhri Basin.

³Rai, R.K. and Panda, P.(1982), "Environmental frame-work and landuse on hill slopes around Shillong", Proc. Symp. Allahabad University.

⁴Panda, P.(1982), "A Study on average slope of Khasi and Jaintia Hills, Meghalaya", Hill Geog.Vol.1.No.1, pp.

Regarding the study of settlements of this region, Jafri (1977)¹ has discussed some of the factors in his paper titled 'Levels of settlement development : A Case Study of United Khasi and Jaintia Hills District,' Panda (1980)² in a paper titled 'Patterns of Rural House Construction in Khasi and Jaintia Hills, Meghalaya', has discussed the impact of building materials and shape of the houses in different parts of Khasi and Jaintia Hills. Panda (1981)³ in a paper entitled 'Climate and Rural Architecture of Khasi Hills' has analysed the influence of climatic factors on the shape, size and location of rural settlements. Panda and Rai (1981)⁴ in their paper 'Influence of Landform on Location and distribution of rural settlements in Khasi & Jaintia Hills', have discussed the influence of Relief, slope, drainage, agricultural land etc. on location and distribution of rural settlements in a systematic way. They found that large size settlements are generally located along the ridge and isolated hamlets which are used as farmhouse are seen sprinkled all over the cultivated area.

¹Jafri, S.S.A. (1977), Levels of socio-cultural development of Settlements : A Case Study of United Khasi and Jaintia Hills District, North-East. Geog. 10(1-2), pp.51-55.

²Panda, P. (1980), Patterns of Rural House Construction in Khasi and Jaintia Hills, Meghalaya, Himalaya, Man & Nature, pp.11-13.

³Panda, P. (1981), Climate and Rural Architecture of Khasi Hills, Himalaya, Man & Nature, pp.13-14.

⁴Panda, P. and Rai, R.K.(1981), Influence of Landforms on location and distribution of rural settlements in Khasi and Jaintia Hills, Meghalaya, National Geographer Vol.49.No.4,

The systematic geological history the areas of their occurrences, tectonic movements etc. have been studied by several eminent geologists that have been discussed in Chapter II.

Data Base and Source of Materials

The necessary materials for the study were collected from the publications of Memoirs and Records of the Geological Survey of India, toposheets on various scales published by the Survey of India landsat imageries of the region, latest publications of geomorphological literature, journals, Census of India, Khasi & Jaintia Hills District Census Handbook and other reliable sources. Geomorphological data have been collected through extensive field studies in various parts of the region. The published literature and their details are given in the bibliography section as well as foot-notes on respective pages.

Regarding figures and photographs given in the thesis, it was found necessary to illustrate and supplement the statements and discussions in the thesis by diagrams and photographs, which provide a clear picture of the natural configuration of the region. To illustrate different

aspects and to give a birds eye view of the area under study, all the maps and diagrams of the Khasi and Jaintia Hills have been prepared by the researcher. To exemplify the significant geomorphological features of the region, different photographs illustrating the house types, taken in the field by the researcher during field study such as erosional features, landslides, weathering, slope character etc. have been presented in the text of the thesis.

Methods of Study

For analytical purposes, various morphometric techniques have been applied. For example, the morphometric techniques which have been used in the present study include the characteristics and nature of average slope, drainage density, stream frequency, erosion surfaces etc.. In Chapter-VI some mathematical calculations have been done with the help of various data obtained from the drainage basins. In this chapter the following techniques have been used : stream ordering, law of stream numbers, law of mean stream length, stream frequency, drainage density, sinuosity indices etc.. The above methods have been used to compare the results and for further generalization and correction of accuracy, considerable field studies have been undertaken.

In the last two chapters on rural settlements;

location and distribution, and the impact of landforms on rural settlements the following method has been undertaken, cluster analysis (chi-square distribution test). Cluster analysis is an important statistical techniques in any analysis of regional distribution of settlement patterns. It is based on the concept of a random distribution which is analysed using chi-square test method (see Chapter VIII).

Plan of the Work

For the better understanding and correlation of the landform characteristics and its influence on the location and distribution of rural settlements of Khasi and Jaintia Hills, the study has been divided into different chapters. In the last but one chapter, an attempt has been made to correlate the influence of landforms on location and distribution of rural settlements. The study has been limited to 10 selected small drainage basins only to get clear picture at micro-level.

In the second chapter, the whole account of geology, tectonic and structural characteristics of rock formations have been discussed. In this region the important rock formations are the granite, gneiss, the Shillong series, the Jaintia series (Simsang formation: siltstone, sandstone; Shella formation: alternation of sandstone, limestone). While discussing the geology, the rock formations and their

age and distribution, the geological history have been considered in detail.

Chapter three deals with the geomorphic processes. In this chapter, different types of weathering, the intensity of impact of weathering on different rock formations and the factors which influence weathering have been discussed.

In chapter four, drainage analysis and fluvial erosion have been discussed. In this chapter main emphasis is given on the evolution of major river basins, drainage patterns, adaptation of streams to structure. In the end the stage of cycle of erosion and erosion surfaces using various morphometric techniques are discussed.

Chapter five deals with evolution of hillslopes, hillslope-elements and profiles, average slope (areal extent). In the average slope map of the region, areas of maximum and minimum slopes have been marked. The areal extent and percentage distribution of different slope categories have been calculated.

In the sixth chapter, quantitative analysis of ten selected small basins (five each from Khasi and Jaintia Hills) have been presented. In this chapter, the researcher has taken the various morphometric techniques in two separate

aspects, such as, 'the linear aspect' and 'the areal aspect'. In the linear aspect; stream ordering, law of stream numbers, law of mean stream length, sinuosity indices and in the areal aspect, stream frequency, and drainage density have been discussed. The stream frequency map show the regional variation in space. Various aspects affecting stream frequency and drainage density have been discussed separately. This chapter also includes the correlation matrix i.e. the researcher has studied the multiple relations among morphometric properties.

In the study of distribution and location of rural settlements (Chapter VII), an attempt has been made to examine the various aspects of location, regional distribution and house types. Different forms of settlement patterns have been identified and discussed with the help of maps and photographs taken during the field work. For regional distribution of rural settlements, the study has been restricted to the Thana level.

Chapter eight of this work deals with the study of the influence of landforms on rural settlements. In this chapter, effort has been made to explain the relationship between landforms soil, underlying rock structure, average slope, drainage and agricultural land with the location and distribution of rural settlements of Khasi and Jaintia Hills of Meghalaya. In order to get more clear picture, the

study has been restricted to the ten selected small drainage basins of the area as case studies. To test the distribution of rural settlements, the chi-square (χ^2) distribution test has been used to identify whether the settlements are distributed in cluster or random form. It is seen that, there is a close relationship between drainage, average slope, terrain character and transport and communication lines of this region with the location and distribution of rural settlements. Apart from this, the climatic aspect of geomorphology on rural settlement can not be overlooked.

In the last chapter the general conclusion of the study is presented.

CHAPTER - I I

GEOLOGY OF KHASI AND JAINTIA HILLS

Introduction

The Shillong plateau is made up largely of Pre-Cambrian rocks acutely folded and steeply dipping with an overturned fringe of Mesozoic and Tertiary sediments. The Shillong plateau, therefore is best regarded as geologically part of the Indian Peninsula, cut off therefrom by the intervening spread of the Ganges and the Brahmaputra alluvium. Its prevailing rocks are more in common with the gneissic and Dharwar rocks of Bengal and Bihar than with those of the more neighbouring Himalayan sequence. The strike in the foliation of the gneiss of the Shillong plateau is much the same as that in the Chotanagpur gneiss of Bihar and Bengal. A further resemblance is seen in the marine transgression which affected the southern shores of the plateau in Cretaceous time and which left the Cretaceous deposits, much of which lie undisturbed upon the older rocks, as do similar deposits along the Coromandal coasts of the Peninsula.¹

¹Spate, O.H.K., (1967), India & Pakistan.

The ancient (Pre-Cambrian) peneplaned surface of the plateau is still preserved, with marks of different cycles of denudation, in the central and northern parts; it is hidden beneath the Mesozoic traps along the central-southern fringe and Cretaceous-Tertiary and Post-Tertiary sediments over the southern, south-eastern and south-western parts. The plateau standing as a watershed between the Surma valley of the Bangladesh on the south and the Brahmaputra valley on the north, is dissected by several rivers and a network of their tributaries and lateral streams. The present physiographic configuration of the plateau was attained through different geological events since Mesozoic to present day as initiated by the polycyclic erosion surfaces at various levels.

(1) Geological Formations

The earliest geological reference on the region was made by T. Oldham (1860).¹ The systematic geological mapping of the region was subsequently carried out in detail by H.B. Medlicott (1869), Godwin Austin (1869), La Touche (1883, 1887), and F.R. Mallet (1887). Their accounts helped considerably in continuation of systematic mapping of different parts of the region by later workers viz; R.W. Palmer (1923), C.S. Fox (1936-38), V.R. Khedkar (1938-39),

¹Oldham, T. (1860), On the Geological relations and probable geological age of the several systems of rocks in Central India and Bengal, Mem. Geol. Surv. India, Vol.2.

D.N. Mukherji (1938-39) and S.M.N. Ghosh (1936-39), which led to the establishment of the stratigraphic sequence of different rock suits of the region.

Since the inception of the Assam circle (of late, the Assam-Meghalaya circle) of the Geological Survey of India at Shillong in 1961, a programme of systematic detailed geological mapping along the northern, central and southern parts of the plateau was undertaken and continued. The Archaean and Pre-Cambrian rocks of the plateau have been mapped systematically by K. Gogoi (1961-62, 1962-63, 1965, 1967-68 and 1972-73); K. Gogoi and M.D. Limaya (1963-64); M.M. Mushi (1964-65), M.K. Das and B. Dayal (1964-65); M.K. Das - 1965-66-67); S.K. Mazumdar (1965-66 to 1967-68); and M.G. Rao (1966-68). Their work not only led to the delineation of the individual rock units of the Archeans and Pre-Cambrians (Shillong - Group) but also revealed the relationship of these two major rock groups and brought interesting structural features.

The shelf sediments over the southern part of the plateau have been systematically mapped by A.C. Goswami, M.K. Das, S.C. Talukdar, A.C. Bhattacharya, G. Burman, B.K. Duara, C. Chakravarty, B.D. Adhikari, K.K. Sen and S.K. Srivastava during the field seasons from 1961-62 to 1972-73. Their work led to the delineation of different

litho-stratigraphic units of the Tertiary shelf sediments (as given in the Table-II(i)) and their sedimentological history. Further, as a result of this later work, many interesting discoveries on the geological structure and tectonic history of the plateau were revealed. The recent investigation along the southern Khasi Hills (Talukdar and Murthy 1971)¹ threw new light on the Sylhet Trap volcanism and on the composition and type of the lava flows.

The above investigations and systematic geological informations helped very much to list out a general stratigraphic sequence of the formations given in the Table-II-(i). (Fig. 2)

TABLE-II-(i)

General Stratigraphic Sequence of Geological formations (Khasi and Jaintia Hills)

Geological Age	Group Name	Formation Name	Rock Types
1	2	3	4
Recent	Newer Alluvium Thickness not known	Unclassified	Sand, Silt and Clays
Unconformity			
Pleistocene	Older Alluvium Thickness not known	Unclassified	Sand, clay, Pebble, Gravel, and Boulder deposits
Unconformity			
			Table cont.

¹Talukdar, S.C., and Murthy, M.M.N., (1971), The Sylhet Traps, their tectonic history and their bearing on problems of Indian Flood basalt provinces, Bull. Volcanologique, Tome, XXXV-3, pp.602-18.

Table-II-(i) contd

1	2	3	4
Eocene	Jaintia Group	Simsang Formation (1150 M.)	Silt stone - Santstone alternations, sand.
		Shella formation (600 M)	Alternation of sand stone, limestone.
		Langpar formation (100 M.)	Calcareous shale, sand- stone, lime- stone
Upper Creta- ceous	Khasi Group	Mahadek Formation (150 M.)	Arkose glauconite
		Bottom Conglomerate Formation (25 M.)	Conglomerate, arkose
		Jadukata formation (140 M.)	Sandstone Conglomerate alternations
		Unconformity	
Jurassic	Sylhet Trap (600 m.)	-	Basalt, alkali- Basalt, rhyolite acid tuff.
		Unconformity	
Pre-Cambrian	-	Intrusives (Acid & Basic)	Porphyrite, coarse granite, pegmatite, aplite, quar- tzveins, epido- rite, dolerite, basalt.
		Shillong Group	Quartzite, Phyllite Conglomerate
		Unconformity	
			Table contd..

Table contd..

1	2	3	4
Archacan	-	Gneissic complexes	Biomite-gneiss, biolite-hornblends - gneiss, granitic-gneiss, Magmatite, Mica schist, silliminite - quartz schist, biotite - granite, pyroxene, granulite, etc.

Source: Geology and Mineral Resources of the states of India, Part IV -, Miscellaneous publication No.30, Geological Survey of India, Dec. - 1974, (69-79).

Archacan Gneissic Complex

The Archacan metamorphic gneissic complex consists of grey and pink mica-gneisses, at places traversed by quartzite veins. The contact between the Shillong series and the Archacan metamorphic runs in a general N.E. - S.W. direction. The epidiorite bands, intrusive into the Shillong series, trend in a general N.E. - S.W. direction, at places swinging to N.N.E. - S.S.W. The rocks are believed to be the north-eastern extension of the Indian Peninsular Block separated from it by the Garo-Rajmahal trough fault. The rocks are composed predominantly of para and ortho-gneisses, magmatites and meta-sedimentary bands. Different rock-types come under this complex has been given in the Table (II-(1)).

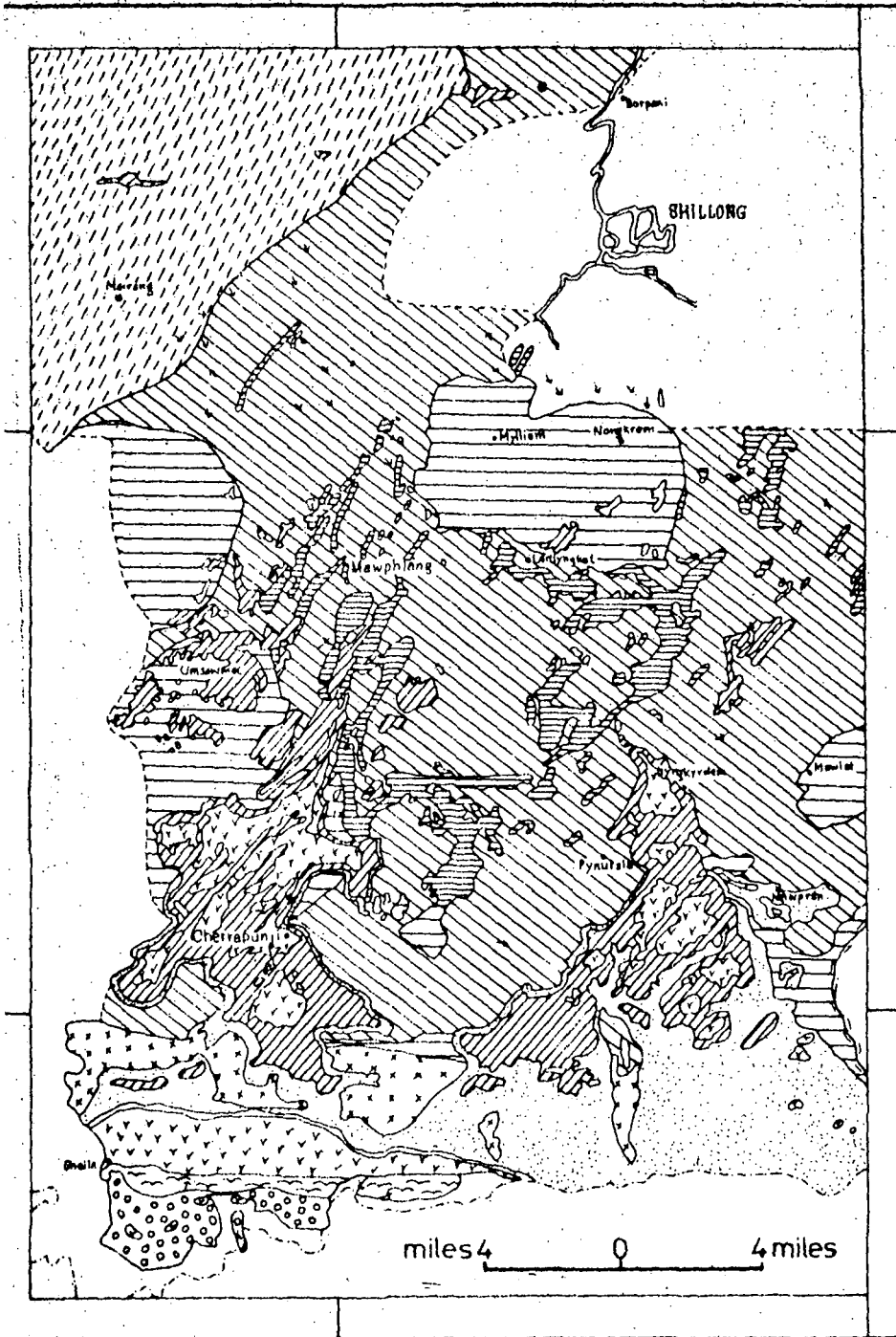
Pre-Cambrian

(1) Shillong Group :- The Shillong group of rocks comprising quartzite, usually friable with subordinate phyllite, quartzsericite schist, conglomerate, etc. are exposed in the central and eastern part of the Shillong Plateau. Current bedding is commonly noticed in these rocks. Rocks of this group rest unconformably over the gneissic rocks with a basal thick bed of conglomerate in the western part. These rocks generally strike in a N.E. - S.W. direction. The mildly folded sediments have suffered low grade metamorphism and are dissected by numerous faults along which the different blocks apparently moved up and down at various times during the Tertiary period.

Gogoi¹ carried out systematic geological mapping around Umpyrtha village ($25^{\circ}52'$: $91^{\circ}35'$, $78^{\circ}/9$) in the northern part of the Nongkhao state in the Khasi Hills. An area about 148 sq. km. was mapped and he found, medium - grained granitic gneiss, exposed in the northern part of the area, is greyish white to light pinkish, being composed of felspar, quartz and the accessories like biotite and magnetite. To the south of Umpyrtha and Umsam ($25^{\circ}53'$: $91^{\circ}37'$) biotite - gneiss is predominant; it is dark grey and medium grained, injected with numerous veins of quartz

¹Records of the G.S.I. (1967): Vol. 99, Part-I, p.7.

KHASI HILLS GEOLOGY



INDEX













-  OLD ALLUVIUM
-  KOPLI & OTHER TERTIARIES
-  SYLHET LIMESTONE STAGE
-  CHERRA STAGE
-  CRETACEOUS
-  SYLHET TRAP
-  GRANITE
-  GRANITE GNEISS
-  KHASI GREENSTONE
-  SHILLONG SERIES
-  DIPS
-  VERTICAL

FIG. 2a

and pegmatite, and composed of felspar, quartz, biotite and the accessories magnetite and siliminite.

(II) Intrusives (Acid & Basic) :- These rocks are intruded by ultramafic and acidic sills and dykes. The basic and ultramafic intrusives are represented by epidiorite, dolerite, amphibolite, pyroxenite etc. which show rarely specks/disseminations of sulphide minerals (Pyrite, chalcocopyrite etc.). The acidic intrusives comprise large bases of granites with pegmatite and quartz veins. The granite intrusive along the axial region of the Shillong group of rocks around Myllem, south of Shillong town is termed as Myllem granite (Fig. 2a). The Myllem granite is the name given by H.B. Medlicott to a structureless granitic rock around Myllem village.

Late Prof. H.C. Das Gupta subsequently called it as Shillong granite. Megascopically it is porphyritic and flesh coloured. Microscopic studies show that Microcline, quartz, orthoclase and biotite are the essential mineral constituents of this rock.

S.K. Mazumdar mapped 450 sq. km. on 1:63,360 scale in sheet Nos. 78 O/11, O/12, O/14, O/15 and O/16 over a large part, the Shillong series is very weakly metamorphosed; but, to the south, Metamorphism, spatially related to the

intrusions of granites, has caused schists to develop from pelitic bands and quartzite from sandstones of the Shillong series. The porphyritic granites are disharmonious and are forceful intrusives into the Shillong series. Contact metamorphism around their walls has given rise to granctiferous muscovite-biotite schists, quartzites with siliminite needles, altered and alusite porphyroblasts, etc. Petrographic evidences of disharmonious intrusion supplement structural evidences of forceful emplacement.

The unconformity between the Shillong series and the Archacans have been eliminated at the northern contact of the Lyngkhai-Lyngiong batholith due to force of intrusion of the batholith which has warped all structural planes into peripheral attitudes.

Jurrasic (Sylhet Trap)

The Sylhet Traps are of the nature of plateau basalts, exposed in a narrow E. - W. strip 80 km. long and 4 km. wide along the southern border of the Shillong plateau; the maximum thickness is 550-600 mts. They apparently overlie the eroded precambrian basement and are themselves overlain non-conformably by the upper cretaceous-eocene sediments. The sediments and the lavas form a monocline becoming a flexure southwards; the sediments at the crest of the flexure have subsequently been eroded at places

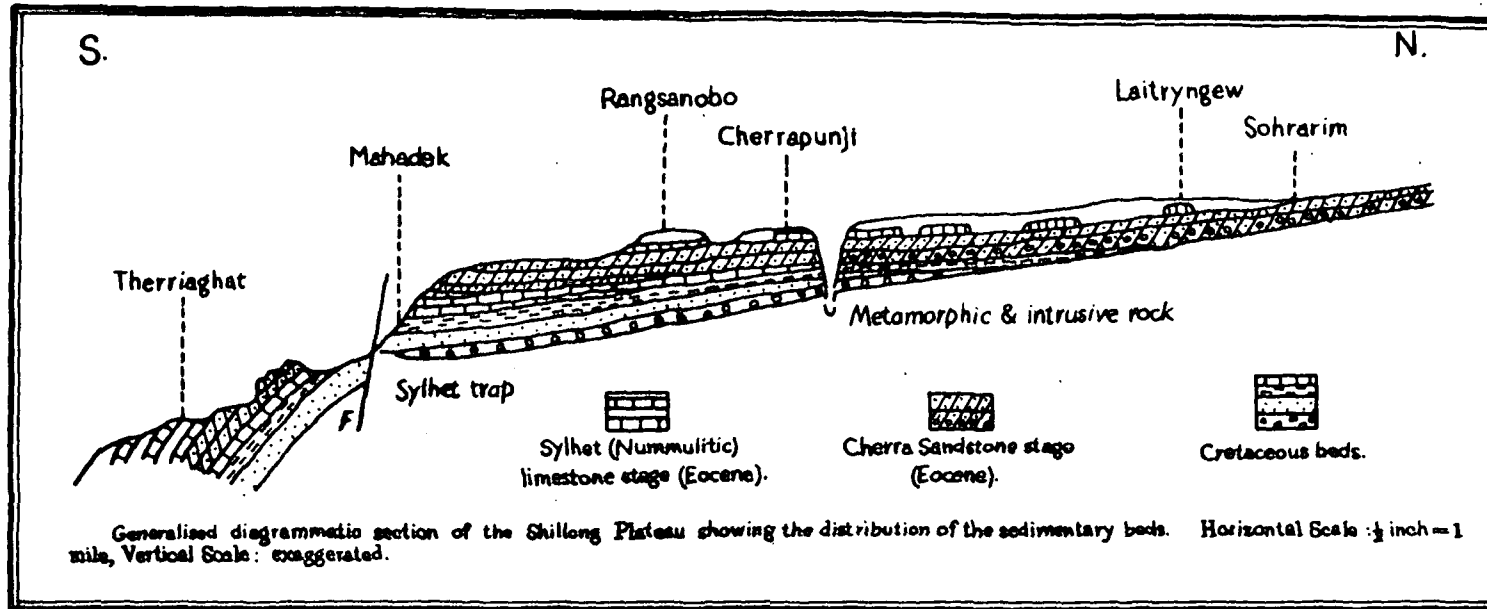


FIG. 2b

exposing the Traps as inliers. The flexure in the Therriaghat-Shellia sector with its E.-W. axis changes along its trace westward to a high angle reverse fault through normal and vertical fault and marks the exposed limit of the Sylhet Traps to the south (Fig. 2b). To the north, the traps at Therriaghat are in contact with the gneisses, granites or Shillong group of rocks along an E. - W. fault, termed the Raibah fault; immediately south of this fault the Traps dip at 45° - 50° to the south. At the southern most limit, they again dip at 10° - 35° along the monocline or at 50° against the Dawki fault (ex. Umngi-river section, Fig. 2a). Laterally they plunge together with the sediments - south-west along the Jadukata river; to the east, the last exposure of the traps is seen in the Dawki river.

Cretaceous - Tertiary Sediments

The cretaceous-Tertiary sediments occupying the southern part of the Meghalaya plateau are thick and extensive and are considered to be physically continuous with the cretaceous-tertiary sediments of the Bengal Basin. These sediments are affected mostly by basement controlled faults. The sediments are mainly sandstones and shale (Mudstone), excepting for the three well defined fossiliferous limestones, and occur as (i) discrete outliers and (ii) a continuous narrow belt fringing the southern margin

of the state bordering the Bangladesh plains. Here the sediments are divided into two major groups, viz;

- (a) the Khasi group and
- (b) the Jaintia group.

The Khasi group is a distinct arenaceous facies consisting of the oldest Jadukata formations followed by the predominantly conglomeratic Mahadek formations.

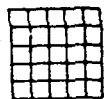
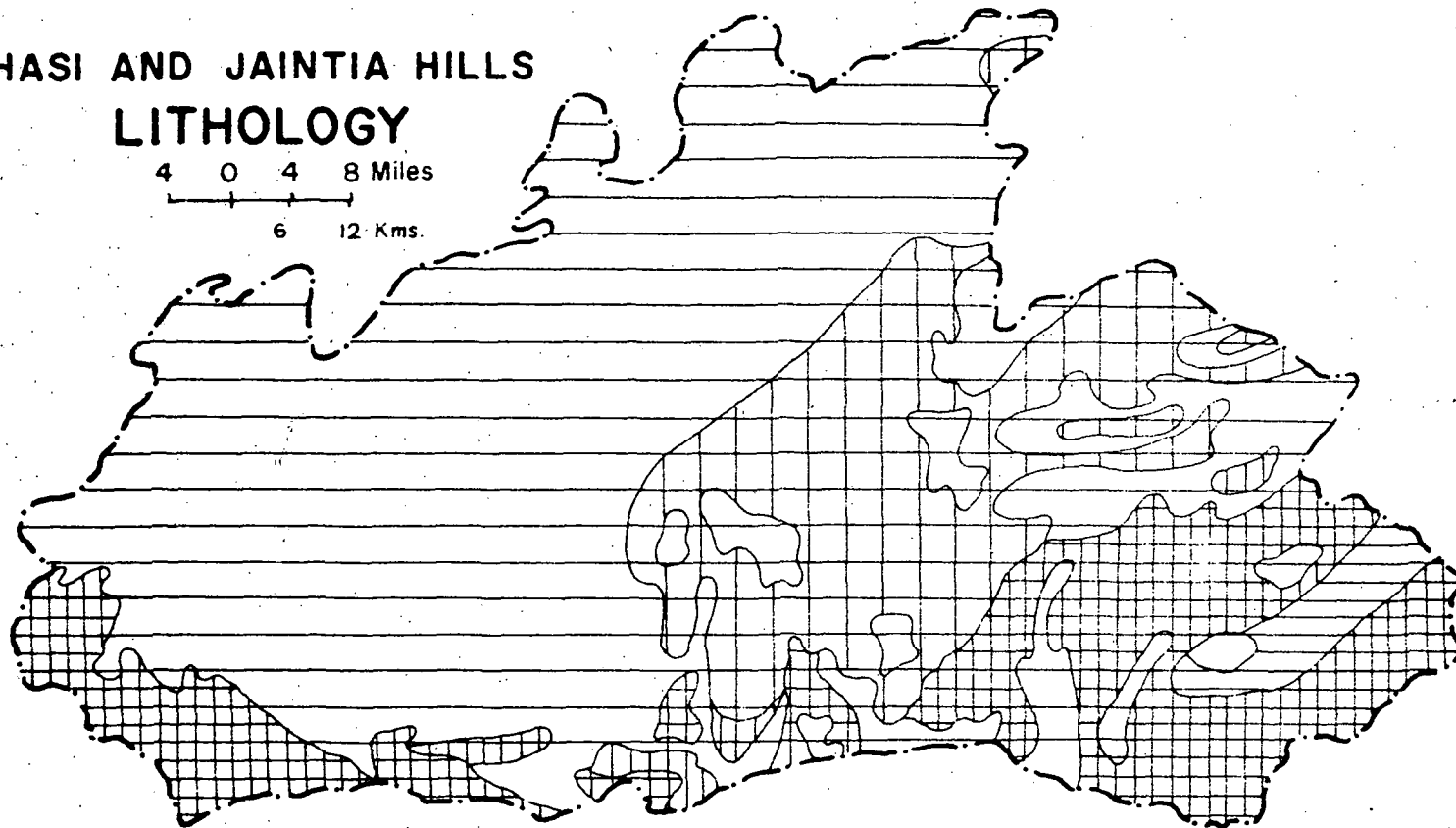
The Jaintia group is a calcareous facies (shelf facies) and has been divided into three formations, viz.; the Langpar the Shella and the Kopili formations.

(a) The Khasi group :-

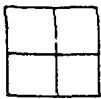
(i) The Jadukata Formations:- Jadukata formation consists of alternations of conglomerate and sandstone (with characteristic zone fossil inoceramus). These rocks overlie nonconformably the Sylhet trap and their distribution is limited to the north of the Raibah fault which formed the shore line during their deposition. The deposition of the Jadukata formation and progressive migration of the shore line towards north followed by the deposition of a thick horizon of conglomerate pebbles and cobbles of vein quartz and rare gneiss) on the plateau over the Pre-Cambrian basement north of the Raibah fault; this is designated as the bottom conglomerate formation. The maximum exposed thickness of the Jadukata, Bottom conglomerate and Mahadek

KHASI AND JAINTIA HILLS LITHOLOGY

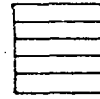
4 0 4 8 Miles
6 12 Kms.



SILTSTONE, CLAYSTONE,
GRIT SANDSTONE,
CONGLOMERATE SHALE



SANDSTONE, LIMESTONE,
QUARTZITE, SILTSTONE
SLATE, SCHIST, SHALE



LIMESTONE
(KARST)



GNISSIC COMPLEX



BASALTS

Fig. 3

formations are 140 m., 25 m. and 150 m respectively.

(b) The Jaintia group :-

(i) The Langpar Formations :- The Langpar formation of the Jaintia group overlies the Mahadek formation of Khasi group. The rock consists of (Fig. 3) calcareous shale, sandy limestone and five calcareous sandstone. The deposition of these sediments marks the beginning of a table shelf condition which was firmly established later with the deposition of the Shella Formation (600 m. thick) represented by the alternating limestone and sandstone sequence. The Langpar band of calcareous shale and sandy limestone is more consistent and widespread in a northerly direction.¹

(ii) The Shella Formations :- The Shella - formation consists of three sandstone and limestone members beginning with a sandstone over the Langpar Formation. These have been designated successively the Lower (Therria - sandstone/Lakadong limestone), Middle (Lakadong sandstone/Umlatdeh limestone), Upper (Narpur sandstone/Prang limestone/Siju limestone and Sylhet sandstone/limestone member. The Upper Sylhet limestone member has been traced north-eastwards through Jaintia Hills into the North Cachar and Mikir hills, and westwards into the Garo Hills below which an

¹Records of the Geological Survey of India, (1940); vol. LXXV, No.4, p.7.

undifferentiated sandstone member, termed as Sylhet sandstone is traceable above the basement rocks, possibly representing the facies variant of the two lower limestone members.

The Chengpara Formation which appears in the Khasi Hills near Balat ($25^{\circ}13'$: $91^{\circ}22'$) an erosional unconformity can be seen.

Areas of Quarternary and Recent Deposits

Isolated patches of older alluvium overlie the Tertiary rocks (Fig. 2b) along the southern fringes of Khasi Hills. Such patches are also found along the northern fringes of Garo Hills. These deposits consist of beds of assorted pebbles with loose sand and brownish clay. The pebble beds at places occur in irregular repetition. These rocks usually form exceptionally flat-topped low hillocks and mounds with red soil cover.

Along the southern border of Khasi Hills, the older Alluvium mainly consists of assorted boulder deposits,¹ (Fig. 2b).

Geological History

It is interesting to study the different orographic

¹Ibid., p.78.

features which are moulded up by the different diastrophic movements, experienced through geological ages. To trace the earliest geo-tectonic earth movement, it is plausible to point to the movements which brought disruption in the Gondwana land. There is enough reason to believe that the Shillong plateau was once part and parcel of the Peninsular Shield (as discussed earlier).

Prior to any major earth-movements, a part of the Peninsular Shield must have been submerged under the sea. During the encroachment of the sea to the land mass, the sedimentary rock types of the Shillong series must have been deposited. The sea eventually retreated during the carboniferous period during which the Gondwana land - experienced diastrophic earthmovement, as a result of which the trough faults were formed.¹ During this period, the fresh water deposits were laid down in those troughs. The vegetable organisms of this terrestrial accumulation after the modifications through the geological processes gave rise to the valuable coal deposits of the southern Khasi and Jaintia Hills.

After that, there was a sequence of earthmovements along the zone of weakness. In order to restore the isostatic readjustment, a pile of basaltic extrusive rocks have been poured out upon the surface of the ancient rock

¹Goswami, D.N.D., (1960), Geology of Assam, Gauhati University, p.61.

mass along the zone of weakness in the form of fissure eruption during the Jurassic period.¹ These lavas which are arranged along a narrow zone, south of the Khasi Hills, having an East-West extension are known as the Sylhet Trap (from the district of the same name, which is politically belongs to the Bangladesh). There is a fault near this Sylhet Trap which is known as the Raibah fault, along which the southern block subsided and the northern block upheaved. The rate of sinking of the former increased, soon after the cessation of the volcanism, resulting into the marine invasion and deposition of the upper cretaceous sediments over a rapidly down sinking basin. The rate of subsidence gradually slowed down towards eocene periods during which the the area attained a stable shelf condition and the calcareous formations of the Jaintia Group were deposited.

Another earth movement occurred during the Miocene period. This movement was stronger than the former and later diastrophic movements in intensity. Two thrust movements viz., one northerly and the other easterly exerted pressure upon the sediments of the Geo-syncline. The pile of marine sediment in front of the central Himalayas was uplifted and formed the ridges. These formed the outer Himalayas and are represented by the sediments of the Siwalik system.² This movement also uplifted the Shillong

¹Goswami, D.N.D., Op.cit., p.61.

²Ibid.,

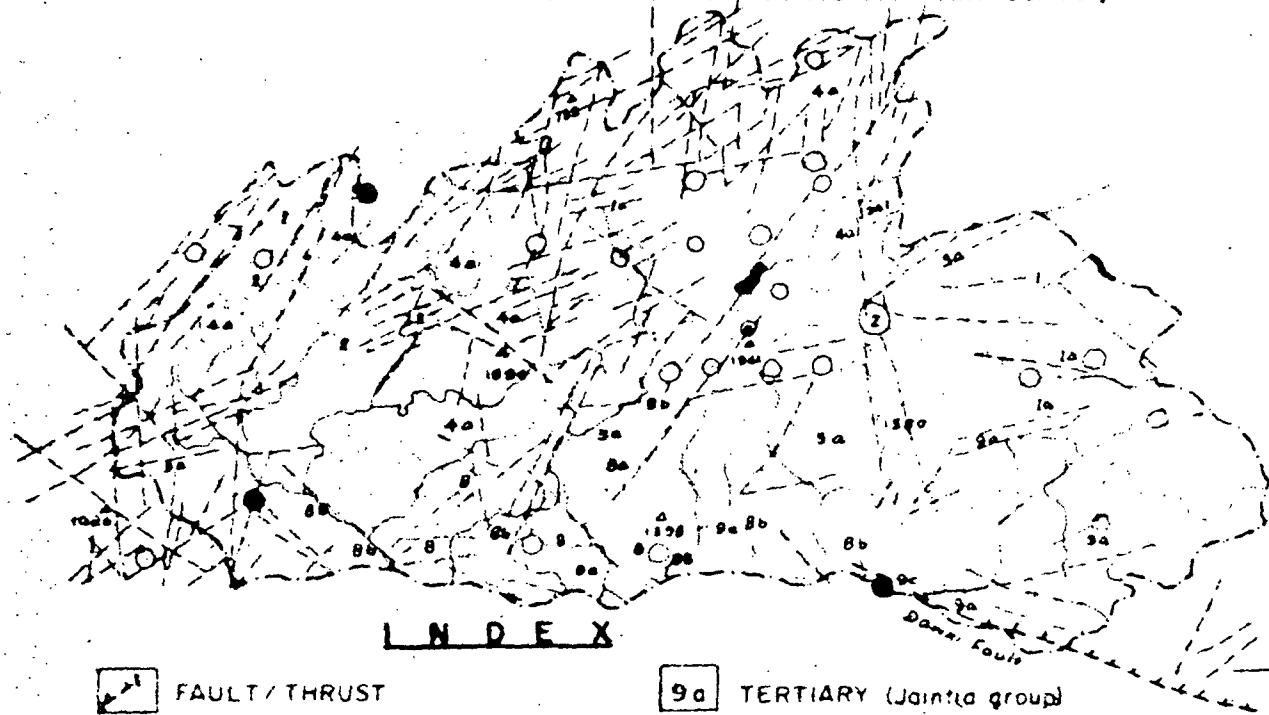
Plateau, by forming the faults around the plateau. The most notable one is the Haflong-Disang fault, striking in a E.W. direction. The Shillong plateau, a titled block of the basement rises as an undisturbed monocline and gently meets the Brahmaputra valley in the north. It disappears gradually under the alluvium towards N.E., and again it appears once more as the Mikir Hills which finally in turn, underlies the alluvium.

The peneplained surface of the Shillong Plateau gradually rises in its height from the alluvial tract towards south. It attains an average height of 1500 metres. The increase in height towards south is also marked by another important geological development. The sedimentary rocks with the Abor or Sylhet volcanics appear towards the southern part of the plateau. Further south, the plateau dips very steeply and continues beneath the plains of Sylhet. It appears to be a vertical fault plane. But a careful study reveals that the sediments are folded steeply downward with small scale faulting.

During Miocene, sedimentation continued uninterruptedly over the southern fringe of the Khasi Hills; the Jaintia Block became uplifted and remained a landmass. The major upliftment of the plateau as a whole started at the end of the Miocene (as discussed earlier) resulting into the formation of landlocked shallow water lacustrine

KHASI AND JAINTIA HILLS LINEAMENTS

(BASED ON VISUAL INTERPRETATION OF LANDSAT IMAGERY)



- | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|----------------|--|------------------------|--|-----------------|--|---------------------------------|--|---------------------------------|--|------------------|--|------------|--|---------------------------|--|--|--------------------------|--|-------------------------|--|-----------------------|--|-----------------------|--|------------------------|--|-------------------------------|--|---|--|----------------------------------|
| <table border="0"> <tr> <td style="text-align: center;"></td> <td>FAULT / THRUST</td> </tr> <tr> <td style="text-align: center;"></td> <td>INTERMEDIATE LINEAMENT</td> </tr> <tr> <td style="text-align: center;"></td> <td>MINOR LINEAMENT</td> </tr> <tr> <td style="text-align: center;"></td> <td>SEISMIC EPICENTRE > 7 magnitude</td> </tr> <tr> <td style="text-align: center;"></td> <td>SEISMIC EPICENTRE < 7 magnitude</td> </tr> <tr> <td style="text-align: center;"></td> <td>GEOLOGIC CONTACT</td> </tr> <tr> <td style="text-align: center;"></td> <td>WATER BODY</td> </tr> <tr> <td style="text-align: center;"></td> <td>RIVER STREAM / RIVER SAND</td> </tr> </table> | | FAULT / THRUST | | INTERMEDIATE LINEAMENT | | MINOR LINEAMENT | | SEISMIC EPICENTRE > 7 magnitude | | SEISMIC EPICENTRE < 7 magnitude | | GEOLOGIC CONTACT | | WATER BODY | | RIVER STREAM / RIVER SAND | <table border="0"> <tr> <td style="text-align: center;"></td> <td>TERTIARY (Jaintia group)</td> </tr> <tr> <td style="text-align: center;"></td> <td>TERTIARY (Barail group)</td> </tr> <tr> <td style="text-align: center;"></td> <td>JURASIC (Sythet trap)</td> </tr> <tr> <td style="text-align: center;"></td> <td>JURASIC (Khasi group)</td> </tr> <tr> <td style="text-align: center;"></td> <td>PRE-CAMBRIAN (Granite)</td> </tr> <tr> <td style="text-align: center;"></td> <td>PRE-CAMBRIAN (Shillong group)</td> </tr> <tr> <td style="text-align: center;"></td> <td>PRE-CAMBRIAN (Basics/Ultrabasic intrusives)</td> </tr> <tr> <td style="text-align: center;"></td> <td>PRE-CAMBRIAN (Gneiss and Schist)</td> </tr> </table> | | TERTIARY (Jaintia group) | | TERTIARY (Barail group) | | JURASIC (Sythet trap) | | JURASIC (Khasi group) | | PRE-CAMBRIAN (Granite) | | PRE-CAMBRIAN (Shillong group) | | PRE-CAMBRIAN (Basics/Ultrabasic intrusives) | | PRE-CAMBRIAN (Gneiss and Schist) |
| | FAULT / THRUST | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | INTERMEDIATE LINEAMENT | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | MINOR LINEAMENT | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | SEISMIC EPICENTRE > 7 magnitude | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | SEISMIC EPICENTRE < 7 magnitude | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | GEOLOGIC CONTACT | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | WATER BODY | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | RIVER STREAM / RIVER SAND | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | TERTIARY (Jaintia group) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | TERTIARY (Barail group) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | JURASIC (Sythet trap) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | JURASIC (Khasi group) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | PRE-CAMBRIAN (Granite) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | PRE-CAMBRIAN (Shillong group) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | PRE-CAMBRIAN (Basics/Ultrabasic intrusives) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | PRE-CAMBRIAN (Gneiss and Schist) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

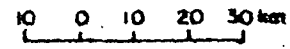


Fig. 4a

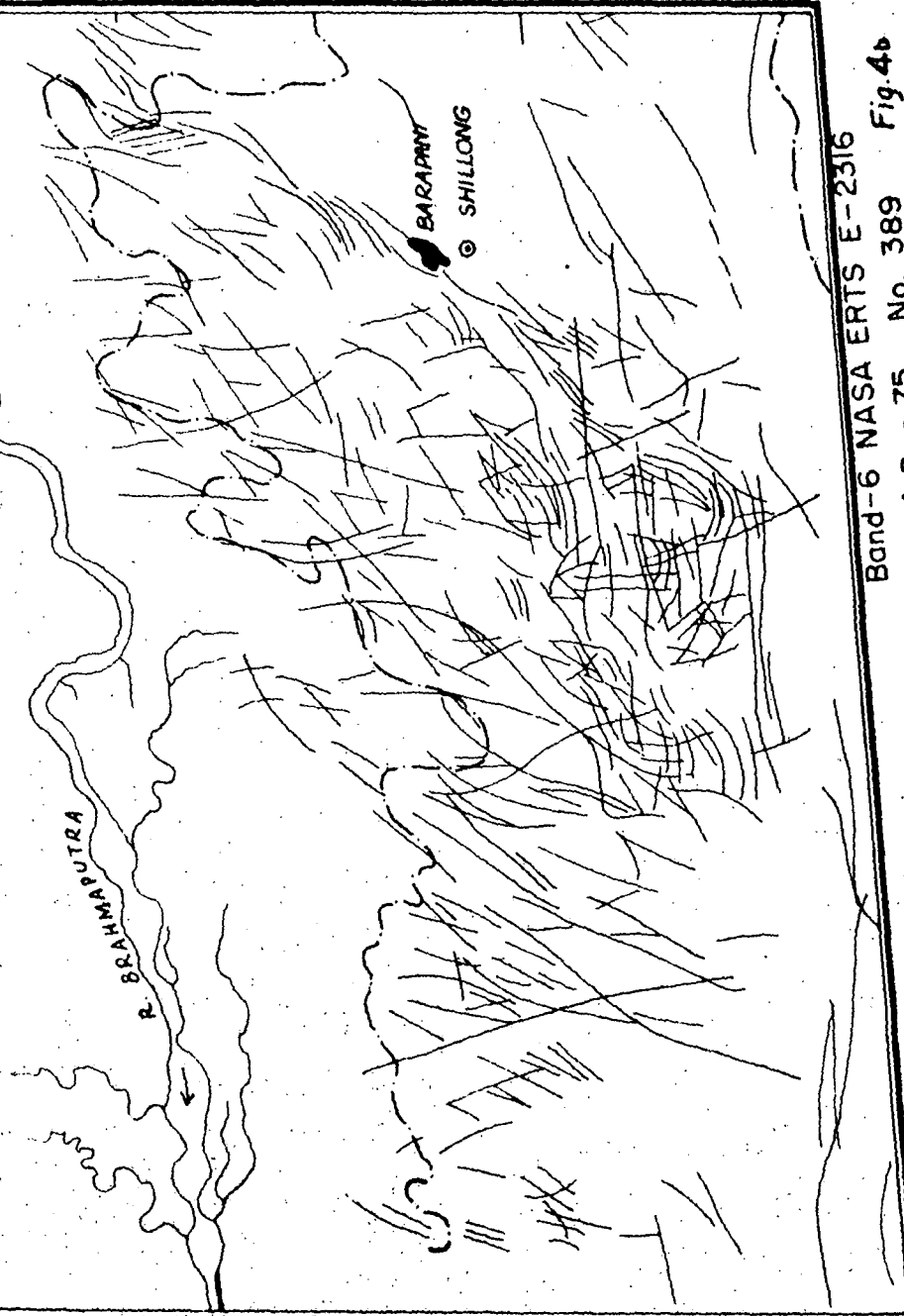
basins along southern fringe of the Khasi Hills. The pliocene sediments were deposited in these basins. The sub-recent older alluvium deposits along southern border of the Khasi and Jaintia Hills, along old river valleys of the Umiew and Um sohnyngkew river of Khasi Hills (Fig. 2a).

Tectonic and Structural Characteristic of Rocks

The tectonic history of the Shillong plateau begins with the effusion of Plateau basalts (Sylhet Traps) through fractures and faults in the basement, and uplift and subsidence of adjacent basement blocks. These were followed by Upper Cretaceous - Tertiary sedimentation into the relatively down thrown portions along faults. The trend of these faults is found to be E-W. in the south Khasi Hills and NE-SW in the eastern margin of Khasi Hills. The tectonic force has been vertically dominated and controlled by differential movements along these basement fractures. (Fig. 4a).

Basement deformation is evident in the gneissic group of rocks. Various rock types of this group are intricately folded and show a high degree of flow age indicative of high mobility of rocks due to deep burial. In some of these areas evidences of cross folding are present

**KHASI HILLS
LINEAMENTS**
1: One million



Band-6 NASA ERTS E-2316
4 Dec. 75 No. 389 Fig. 4b

present. The foliation trend of the rocks seems to be mostly NE-SW in the western part and E-W. in the southern part of the Khasi Hills. (Fig. 4b).

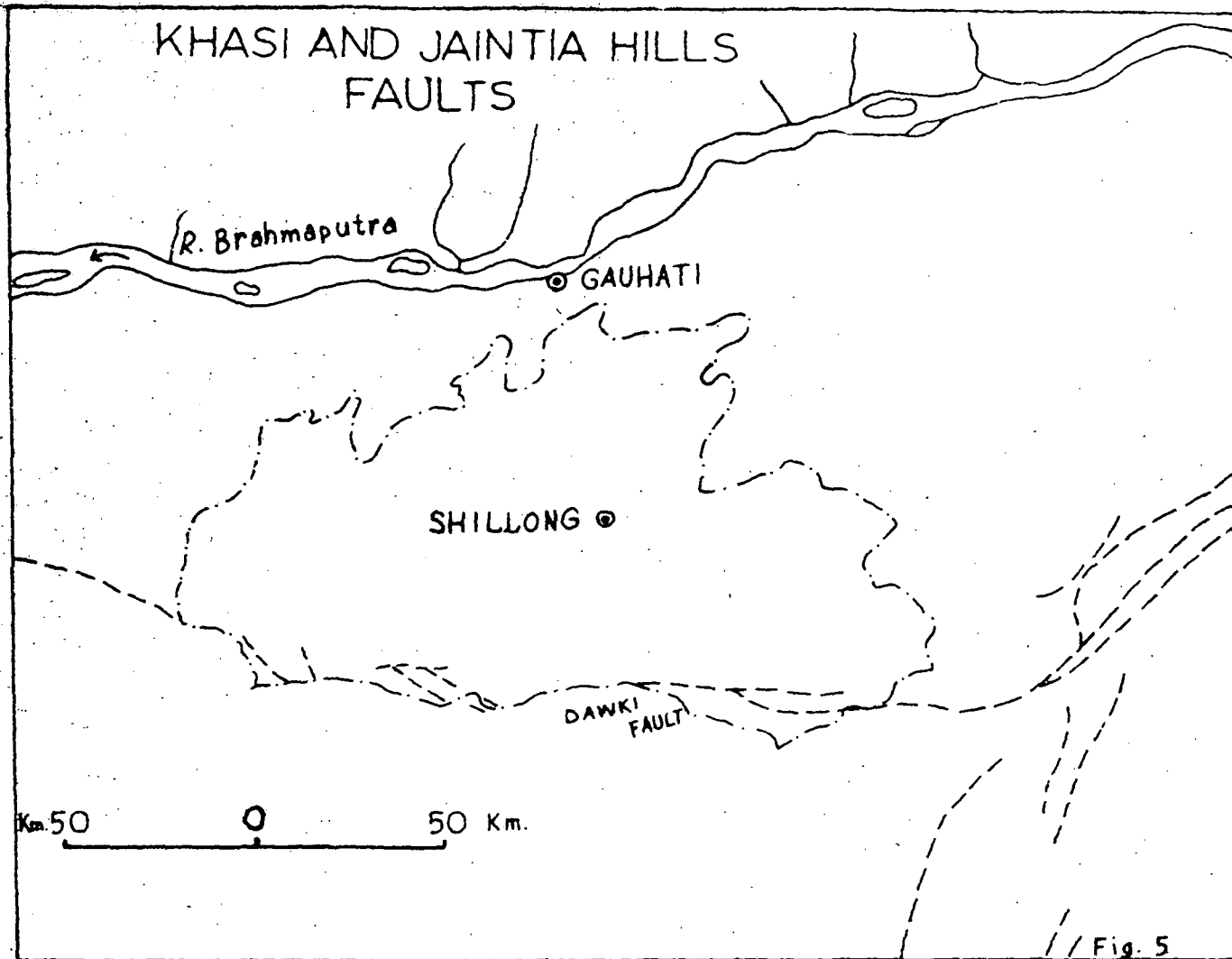
✓ The Shillong group of rocks usually show broad open folds with a few steeply dipping zones, apparently due to faulting. Some rocks of the sheer zone shows evidences of sulphide (mostly pyrite) mineralization : The general strike direction of the Shillong series is N.E. - S.W. and the amount of dip varies from 25° to 85° towards the south-east. In the southern parts of the area, the dips are very gentle towards the south-east¹(Fig. 2a).

Several lenticular bends of amphibolite, exposed conformably in gneiss in the neighbouring areas of Jirang village ($25^{\circ}56'$: $91^{\circ}35'$) are dark green, medium-grained and gneissose with sharp contacts against the gneiss.²

The Dawki fault in the southern fringe of the Khasi Hills is a predominant structural lineament which comprises at least four E-W running normal faults and at places becoming reverse faults (Fig. 4a). The upthrown side of these faults are to the north and the system represents a major plans of dislocation. In the southern

¹Records of the Geological Survey of India, Vol.101, Part-I, p.167.

²Ibid., p.168.



source: Geological Survey of India , 1973.

fringe of the Jaintia Hills one of these faults continues further east to the North Cachar Hills and then joins the Disang Thrust (Fig.5).

A rectilinear drainage pattern in the NE-SW, NW-SW, and E-W directions is a distinctive feature of the Shillong plateau (Fig. 8). Some of them appear to represent faults, many of them are master joints and fractures and the whole pattern has been developed due to upliftment of this horst in the tertiary period.

The Shillong Plateau was indeed a chequered evolutionary history of emergence, submergence and peneplanation with several phases of erosion, sedimentation, diastrophism, intrusion, movements of land and sea and emissions.¹ The higher parts of the plateau preserve marks of Gondwana surface, while later cycles are traced below them. Thus, emergence of the pre-Cambrian Gondwana Block is attested in this plateau. Later it was submerged partially by the encroaching sea during the Mesozoic and early Tertiary times and was uplifted slowly from the bed of the sea at the time the Himalaya rose from the floor of the Tethys. The orogenic movement was so slow and free from buckling

¹Singh, R.P. (1968), "Geomorphology of Shillong Plateau of Assam", Proc. Pre-Congress, Symp. on Meghalaya, II, (IGU, Gauhati), p.1.

that the sedimentary beds retained their horizontal character and gave rise to structural platforms well-developed in the Cherrapunjee area.¹

The rocks of the plateau are isoclinally folded and lineated with a plunge from moderate to steep. The plunge of lineation at places becomes vertical, or good example of which is a fold at Ranga Pahar area where lensoid bodies of massive sillimanite occur in the core. But folds in the Shillong series, comprising mostly quartzite with shale, slate and conglomerates, are not frequent and those that occur are in general open, asymmetrical folds with steep axial planes and gently plunging axes.² The pre-Tertiary and Tertiary rocks on the plateau lie almost horizontally except in its southern parts where beyond Mahadek they become moderately to steeply inclined and conceal themselves below the Bengal alluvium.³

Structural Features

A detailed study of the geology of the plateau is yet to be made, but geological structures occurring in the rocks in separate and often distant areas are studied by

¹Chattarjee, S.P. (1968): "India - A Physical Geography", (Chapter on Physiography in the Gazetteer of India, I), p.40.

²Bhattacharjee, C.C. (1968), "Structure and Petrology of the Shillong Plateau", Proc., Pre-Cong., Symp. (IGU, Gauhati), pp.18-19.

³Singh, R.L. (1971), "Meghalaya-Mikir Region", India, A Regional Geography (Ed.), pp.676-97.

workers of different government and educational institutions. It is generally believed that the plateau is an autochthon of crystalline rocks that constitute the Foreland spur of the Indian Shield and it has been overthrust from the north-west by the Himalayas and from the south-east by the Naga Hills (Haflong-Disang Thrust). The general structural trend of the crystalline rock is N.E.-S.W. These trends refer to the trend of the planar structures like schistosity and gneissosity in the rocks. The rocks are folded and lineated. The folds are generally tight and isoclinal, but these may become increasingly the folds of the elasticus type in more and more metamorphosed rocks. Both folded and mineral lineations are seen. The plunge of the lineation is moderate to steep, but at places it becomes vertical or nearly so. A good example of this is a fold at Ranga Pahar area, where lensoid bodies of massive sillimanite occur in the core and its immediate portions of the flanks of the fold that plunges vertically.

Folds in the Shillong series are not frequent and those that occur are in general open, asymmetrical folds with steep axial planes and gently plunging axes. The folds that occur in the rocks of the Shillong series surrounding the granite pluton, commonly known as the Myllem granite, have their axes, as nearly as possible, towards the pluton. The trend of the rocks also veers

round the pluton, becoming sub-parallel and often parallel to the margins of the pluton. These structural relations between the rocks of the Shillong Series and the Myllem granite are seen on the Shillong-Cherrapunjee road on both the northern and southern margins of the pluton at about 12 km. and 24 km. away from Shillong at Upper Shillong and Umtyngar respectively. Folds are generally of concentric type but similar type folds, although in small scale, occur along the contact of the Shillong series of rocks with the Myllem granite and in the Jowai area. Rocks in these areas not only differ structurally from the main mass but they are also more metamorphosed, being schists - instead of shales or slates as in the main mass.

The pre-Tertiary and the Tertiary rocks on the plateau lie almost horizontally except in its southern parts, where beyond Mahadek they become moderately to steeply inclined and conceal themselves below the Bengal alluvium. The plateau abuts against the Tertiaries along its southern margin, the line of contact being a tear fault - the Danki Tear Fault.¹ This fault continues westward from Haflong, reaches the boundary of the alluvium of the Surma valley at Danki and continues the Dalu in the Garo Hills. The Fault continues north-eastwards from Haflong along the

¹Evans, P.(1964), The Tectonic Framework of Assam, Jour. Geol. Soc. Ind., Vol. 5, pp.80-96.

Disang Thrust. Movement along the Danki Tear Fault is estimated at 250 kms., the southern part moving 250 kms. westwards in relation to the northern part. It is supposed that before the movement took place, the Rajmahal trap and the Sylhet trap were the parts of the same volcanic mass.¹

The southern part of the plateau which forms an east-west near rectangular horst between the Brahmaputra valley in the north and the plains of Bangladesh in the south is characterised by the Dawki lineament. The Dawki lineament is exposed along the southern margin of the Shillong plateau for about 170 km. from Jadukata river in the west to Haflong in the east where it passes into the Haflong Disang thrust. Present work has brought out that the lineament is actually a system of east-west faults; four major east-west faults have been traced between Jadukata river and Theriaghata.² In all the faults of the Dawki system, the northern side is upthrown with basement rocks and the sedimentary capping at higher topographic level. Upthrusts in nature also commonly show plunging character.³

¹Mathur, L.P. and Evans, P. (1964), Oil in India", Int. Geol. Cong., Twenty Second Session, India, New delhi.

²Murthy, M.V.N., Talukdar, S.C., Bhattacharya, A.C., and Chakrabarti, C. (1969), The Dawki fault of Assam. Bull. Oil and Natural Gas Commission, Vol. 6, No.2, pp. 57-64.

³Chakravarti, C. (1977): The Dawki Lineament along the southern part of the Meghalaya Plateau. Misc. Publ. No. 31, Geological Survey of India, pp.92-93.

Geomorphic History

Over 2000 million years ago, a large part of the area was a landmass upto the present day Himalayas, Upper Assam and perhaps the Bengal-Tripura area. About 472 million years ago, the eastern part of the Khasi Hills, the Jaintia Hills and the west of the Mĕkir Hills became a basin of sedimentation in which were deposited the sandstones and the shales of the Shillong Series.¹ These were later uplifted and became a landmass.

The region including Upper Assam remained a landmass till Permocarboniferous times. Then, about 250 million years ago in the NEFA Himalayan region to the north, and to the south and west of the Shillong Plateau, sedimentation began. In these basins were deposited the coal-bearing sediments of the Gondwanas-marine in the Himalayan region and fresh water west of the Garo Hills. The Buxas comprising ortho-quartzites and shales and dolomitic limestones were apparently laid down on the margin of the same landmass at about the same time; this is suggested by recent work by Mullick and Basu Chowdhury in the Siang District. These sediments were uplifted, became a landmass possibly during Triassic times, about 180 million years ago.

The area to the south experienced peneplanation

¹Sarkar, S.N., Polkanov, A.A., Gerling, E.K. and Chukrov, F.V. (1964), Pre-Cambrian Geomorphology of Peninsular India, Int. Geol. Cong. Twenty Second Session, India, New Delhi., In M.V.N. Murthy's "An Outline of Geomorphological evolution of the Assam region.", p.10.

resulting in the formation of a flat levelled surface, one of the most remarkable sight even today. By the end of Jurassic times about 150 million years ago, the southern margin, especially in the Khasi Hills experienced plateau volcanism, through east-west fissures, along which the southern block foundered and the northern block rose. Not long after the ceassation of volcanism, the rate of sinking of the southern block increased resulting in the invasion of the sea and deposition of the Upper Cretaceous sediments about 110 million years ago. This movement was evidently rapid first and then slowed down until and during Eocene times, about 60 Million years ago, when the area had reached stable shelf conditions and fossiliferous calcareous formations began to the deposited.

During Paleocene times large parts of the Shillong Plateau and the Mikir Hills became basins of fresh water sedimentation - in which the Therria sandstones were deposited. The younger Sylhet formations comprises three district, successively younger limestone bands, interbedded with coal-bearing sandstones. On the plateau in the Khasi Hills only the oldest of the limestones, viz., the Lakadong limestone and the immediately overlying Lakadong sandstone are exposed. The younger beds are exposed only to the south nearer the Bangladesh plains. This is evident because the area to the north was experiencing uplift while

the area to the south continued to sink. The Garo Hills, the Jaintia Hills and the Mikir Hills remained a landmass till Mid-Eocene times when sedimentation began and the topmost limestone bank began to be deposited when these areas sank; the sea invaded to the maximum extent during Middle Eocene times. Upper Assam became an area of sedimentation since Eocene times more or less continuously upto late Tertiary times.

During late Eocene times sedimentation continued in the submerged portion of the southern Garo Hills, in the southern margin of the Khasi Hills and the depressed south-eastern part of the Jaintia Hills. The Mikir Hills stood as high ground and there was no sedimentation. The Khasi hills were rising relatively more compared to the Garo and Jaintia Hills.

Sedimentation continued during the Oligocene (about 40 million years ago) in Upper Assam which had become depressed, and the Barail sediments were deposited. At the end of the Oligocene, part of Upper Assam experienced uplift exposing the earlier deposited sediments; some 4,000 to 5,000 metres of sediments are estimated to have been eroded away during this time.

During Lower Miocene times (about 25 million years ago) sedimentation continued uninterruptedly in the Garo

and Khasi Hills; the Jaintia Hills uplifted and become a landmass. The Mikir Hills and the adjoining area to the east became depressed after having remained a landmass from late Eocene times, and Surma sediments were deposited.

During Middle Miocene times Upper Assam was still under water; at this time the northern margin, in the Himalayan area also became a basin of sedimentation. These sediments contain rock fragments and also jasper and abundant epidote showing that much of the sediment came from the landmass to the north and north-east from the Himalayas which had started rising.

After Miocene times uplift started on a large scale first slowly and then rapidly. First the Patkai region began to be uplifted with some folding; over the eroded sediments were later deposited the Dupitilas in Mio-Pliocene times when sedimentation continued in the Himalayan basin. In Upper Assam movement of basement blocks continued resulting in partial interruption of the sedimentation.

A spectacular feature of the drainage pattern of the Shillong Plateau and the Mikir Hills is the straight stream courses which evidently follow joints and faults, produced during the uplift.¹ This contrasts with the tortuous course of the Brahmaputra which has also been

¹ Mathur, L.P., & Evans, P., (1964), Op.cit., p.26.

changing courses; this is not only due to lateral erosion because of the low gradient of the river, but is also aggravated by periodic, local and sudden uplift of the basement during earthquakes. Such movements have resulted in both the Ganga and the Brahmaputra changing courses in the last few hundred years.

The deep gorges in the South Khasi Hills is the result of the relatively greater uplift of the block, headward erosion massive along joints by antecedent streams, and the control exercised by the well-jointed Cretaceous Tertiary sandstone cover. Further west in the Garo Hills, however, uplift was relatively less; the basement was not exposed, and the consequent streams are mostly controlled by the structures (Monoclines and faults) in the sediments. The long incisive valley on the northern margin of the Plateau represent headward erosion along the joints, especially favoured by the absence of thick sedimentary cover as in the south.

CHAPTER - I I K

WEATHERING AND MASS WASTING

The physical landscape of Khasi and Jaintia Hills of Meghalaya is the cumulative function of the exogenetic and endogenetic processes acting upon the surface since its upliftment. The prolonged geological evolution both in time and space, makes it necessary to identify relict or inherited landforms developed under different climatic conditions of the past. There is no doubt that lithology, structure and climate had played a very significant role in moulding the physical landscape and evolution of its present terrain. In most places, bedrock is hidden from view by a mantle of soil. We can see in road cuts that the soil is weathered rock, with greatest alterations near the surface and grading downward to fresh rock.

Deep weathered soil cover and the presence of the laterite cover are characteristic features not only of the hilltops but also of several areas in Khasi and Jaintia Hills of Meghalaya. Soils of this region have developed insitu on various types of rocks. The major area of Khasi Hills formed from gneiss. The rocks comprise mainly of biotite-gneiss, tourmaline-schist etc.. The soils around Shillong have originated from quartzite and granites.

Jaintia series occupy the Eastern Jaintia Hills. Jaintia series is represented by a monotonous sequence of grey shale with minor mud stone, silt stone and siliceous limestone.

Factors Affecting Weathering

It has been noticed that the agents of denudation like surface water, rain and change in temperature have played a dominant role on the rock types in moulding the landscape of the area. But far more important in this respect are the weathering and erosion which under the tropical monsoonal climate exert a significant influence on the landscape of this region. Factors responsible for creating the weathering environment of the area under study have been climatic, biotic, geologic, geomorphic and site conditions. All these factors have played an important role individually and collectively, but to what extent each factor has influenced - weathering processes would be difficult to assess. It is true that structure and lithology have a great role to play in the intensity and extent of weathering. The impact of weathering can be seen more at two planes : foliations and joint planes. Relief in part depend on climate. The influence of climate is principally felt in an indirect way through the medium of vegetation and the soils which depend on it. In general,

the plant cover reduces the intensity of mechanical weathering and favours chemical weathering and mechanical accumulation. The roots of the trees penetrating along the vertical joints split the rocks and as the roots penetrates deeper, the joints and cracks of the rocks are widened (Plate-1). Extensive areas of mechanical weathering have been noticed during field work.

Climate

The climate of Khasi and Jaintia Hills has been very much controlled by the seasonal winds as in other parts of the country. The seasonal winds are the south-west monsoon. This region presents a typical monsoon type of climate conditions which get sufficient rains in summer season due to its location. This type of climate encourages more fluvial processes and weathering which are engaged in changing the shape of the landscape.

Temperature

During months of March and April, the atmosphere gradually warms up and there is the advent of spring. From the middle of April to the Middle of May the temperature reaches the maximum point and this period may be termed as the summer season. The maximum temperature recorded at Shillong is 29°C in the month of May in 1975. The mean

temperature goes down to 9.92°C in January. Occasionally the temperature goes down below freezing point in winter and frost appears at night and early morning.

Table-III(i) reveals the variation in temperature in Shillong and adjoining areas. The mean maximum in this area is highest in the month of July (24.1°C) and August (24°C) and lowest in the month of January (15.5°C). The same months recorded the highest and lowest temperature also. The mean minimum temperature varies from 3.6°C in January to 18.1°C in July. It is clear from the Table-III(i) that the temperature variation is more in this region.

The table-III(i) shows that the variation between monthly maximum and minimum is very high in the month of January (maximum is 15.5°C and minimum is 3.6°C). As summer advances the difference between monthly maximum and minimum temperature seems narrowed the gap from the month of May to September. Again the difference is gradually higher and higher towards December.

The effect of average annual temperature and monthly average temperature in weathering processes is quite significant. During high variation in temperature the mechanical disintegration of rocks are frequent. High temperature helps the surface of the terrain getting heated and the subsequent fall in temperature cools down the surface. Hence

TABLE -III(i)

Months	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Max ^o C	15.5	17.1	21.5	23.8	23.7	23.7	24.1	24.1	23.6	21.8	18.9	16.4	
Min ^o C	3.6	6.4	10.5	14.1	15.5	17.4	18.1	17.8	16.6	12.9	7.7	4.5	

alternate heating and cooling causes the rocks to expand and contract and helps the mechanical disintegration of rocks easily.

The durnal range of temperature in Shillong (Khasi and Jaintia Hills), shows that in the month of May till September (the summer months) the daily maximum temperature is very high. In 1974 the daily maximum was highest in the month of June and August (26.2°C). In 1975 it was highest in the month of May (29.0°C), June (26.5°C) in August (28.4°C). In 1976 the daily maximum was highest in the month of April (27.0°C) and in the month of May, June and August it was (26.0°C). In the year 1977 the daily maximum was highest in the month of August (26.5°C). In 1978 also it was highest in the month of August (28.2°C).

The above five years data show that the daily maximum was highest in the month of August in every year ranging from 26.2°C - 28.4°C . As the temperature plays the important role in mechanical weathering, from the temperature distribution, it could be considered that the process of mechanical weathering shows greater impact in the months of May to August.

The minimum temperature being not falling below 5°C in average. But the five years data show that the daily minimum was recorded as low as 1.2°C and 1.3°C in the month

of January in 1977 and 1978 respectively. During these two years the month of January was the coldest month. The daily minimum temperature varied between 1.0°C to 8.2°C in 1977 and 1.0°C to 6.1°C in 1978 in the month of January respectively.

Humidity

If one asks what is the element of climate whose variations appear to exercise the greatest influence on the evolution of relief, the answer would seem to come without hesitation : humidity. The amount and incidence of atmospheric precipitation determines the mode of weathering and even the characteristics of rocks decomposition. Temperature is a factor which certainly can not be neglected but its action is for the most part indirect low temperature leads to a predominance of solid precipitation, high temperatures stimulate evaporation and tend to diminish the volume of streams and drying out of streams and drying out the soil, exposing it to the action of torrential streams or even, if the vegetation is not sufficiently fixed, to wind action.

High atmospheric humidity, generally associated with abundant rainfall, favours chemical decomposition by the action of water infiltrating below the surface. In South Khasi Hills around Cherrapunjee-Mawsynram areas humidity with high rainfall helps in chemical decomposition

KHASI AND JAINTIA HILLS RAINFALL

Km. 6 0 6 12 Km.

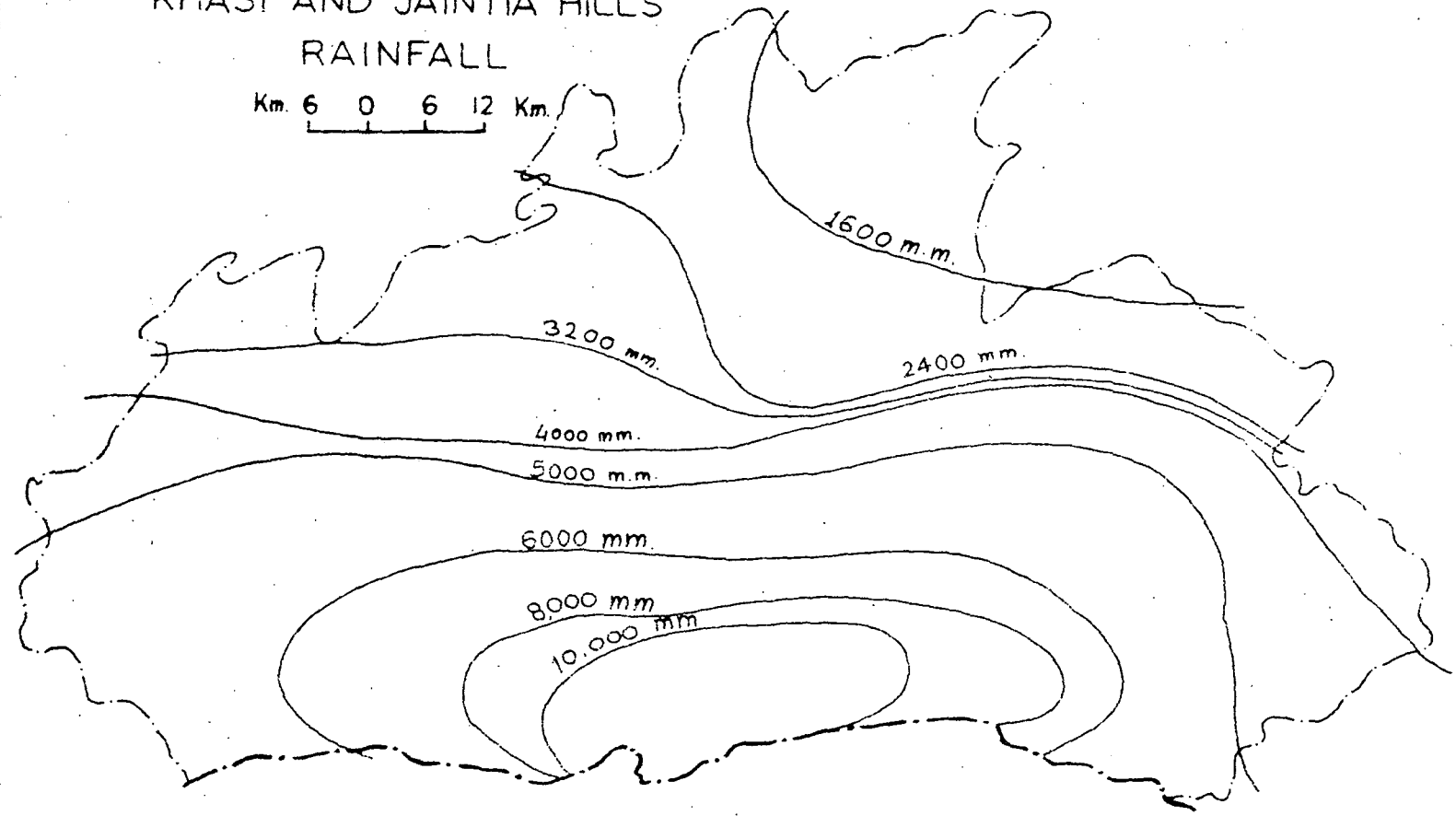


Fig. 6

KHASI AND JAINTIA HILLS RAINFALL & TEMPERAURE

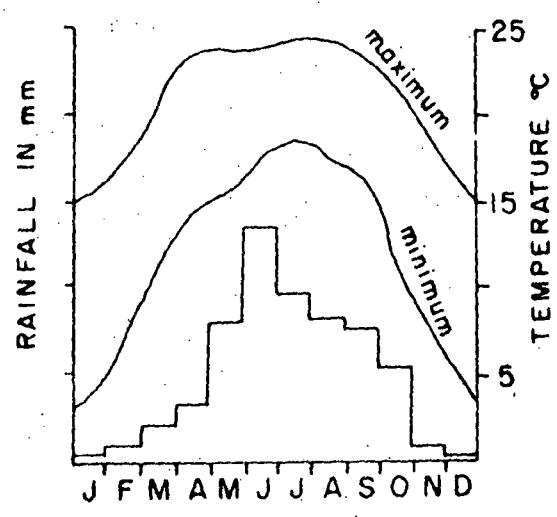
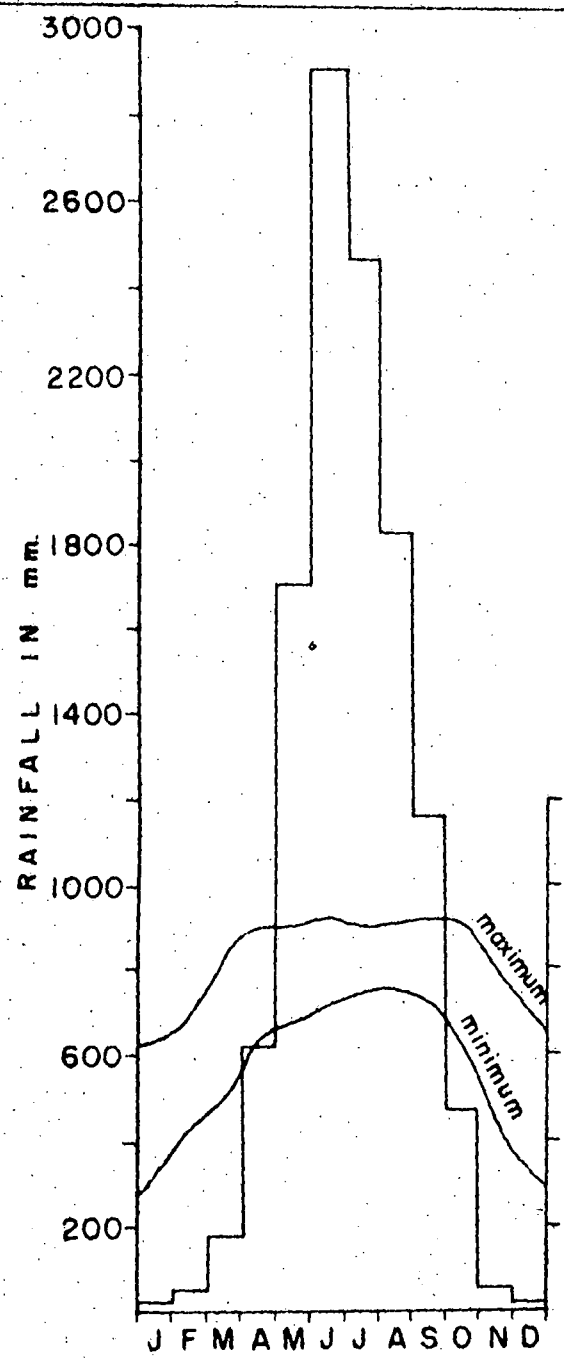


Fig. 7

of the exposed horizontal sedimentary rocks. Evidences of chemical weathering are seen during the field work undertaken in this part of Khasi Hills, (Plate-2).

Rainfall

The rain begins to fall by the third week of April and continues upto the end of September and sometimes well upto the middle of October, after which it gradually diminishes. The maximum rainfall occurs over the southern face of Khasi and Jaintia Hills, i.e. Cherrapunjee and Mawsynram region. The amount of rainfall diminishes uniformly on the leeward side of the rain-shadow i.e., the northern belt at the Adiabatic rate (Fig.6).

Cherrapunjee is situated at an altitude of 1339 m (4455 ft.). Its location on the immediate windward side of the Shillong plateau mainly determines its climate. A part of the Bay of Bengal branch of Monsoon enters the funnel shaped Sylhet plain lying just to the south of Cherrapunjee. This is assumed to be the main cause of high rainfall in this area. The place however, has an average annual rainfall of 1143 cm (450") (Fig.7).

On the eastern region rainfall is slightly less than in the central region but it is definitely scanty in western Meghalaya (Garo Hills). Shillong has an average annual

annual rainfall of 2417.3 mm (206 cm.)

From above discussion it is clear that there is a marked variation between the eastern-western as well as southern-northern parts of the region. The table-III(ii) shows that the annual rainfall in the Garo Hills is 3331.6mm of which more than two-third is received in the four months (May - August). The rainfall in the eastern part around Shillong is 2417.3 mm. The most remarkable feature is that the rainfall in the winter months is more in Shillong than in any other parts of Khasi and Jaintia Hills. The rainfall in Cherrapunjee (Table-III(ii) which is located in the structural platform in the south is as high as 11,418.7mm, while Shillong being located only 50 km. to the north with a rainshadow effect gets only 2417.3 mm. The highest rainfall in Cherrapunjee-Mawsynram region is due to the fact that the south-west monsoon laden with great amount of moisture from the Bay of Bengal blows over Bangladesh and is suddenly cut by the cliffs of the table land in the south with an average elevation - above 1200 mtrs., which juts out like a peninsula into the surrounding gorges about 600 mtrs. deep on either side and as a result the monsoon having reached the heads of the gorges ascends vertically upwards and causes very heavy rainfall.

TABLE - III-(ii)

Name of the Place	Monthly distribution of Rainfall Shillong and Cherrapunjee in mm											
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Shillong	15.2	28.5	59.4	136.4	325.4	544.6	396.9	334.6	314.9	220.2	34.9	6.3
Cherrapunjee	19.8	37.3	178.9	605.2	1705.1	2921.5	2456.7	1827.5	1167.7	447.4	46.7	4.9

The major climatic factors of temperature, rainfall and humidity determine not only the fluvial processes but also the rate at which weathering proceeds whether chemical or mechanical processes predominates. It is worth mentioning here that the area under study is quite vast to have a detailed and complete field observations. However, the researcher has done the field work of some selected regions viz., Cherra limestone area, Myllem-Umtyangar granite area, Lythngkot granite area, Shillong and its adjoining area, Barapani dam-site area. Nongpoh-Burnihat peneplain area to mention a few and some portion around Umroi, Bhoilymbang area. During field observation, the researcher tried to identify those weathering and erosion surfaces where climatic factors might have played a significant role.

In order to understand the effect of temperature on rocks we need to know the temperature range which effects them and the frequency with which certain critical limits are passed, such as the freezing point of water. The usual Meteorological data concerning temperature are, unfortunately not obtained in a manner that satisfies our needs. We are provided with monthly averages (average temperature, average maximum and average minimum), rather than with frequential distributions.

Weathering

Formally, we may define weathering as the spontaneous and essentially irreversible response of rocks to conditions at the earth's surface. Physical disintegration and chemical decomposition transform massive rock into the elastic, colloidal, and soluble states. The visible product of weathering is an unconsolidated mantle, which includes in varying proportions (i) fragments and residues of the original rocks and minerals, (ii) newly formed substances produced by regrouping of constituents present in the original rocks, and (iii) organic matter in various stages of decomposition. The importance of weathering in the preparation of land surfaces for action by agents of landscape sculpture is recognised; however, the detailed knowledge of weathering is meagre and restricted to certain aspects. Thus, with regard to some of the principal problems of geomorphology the pertinent information regarding weathering is qualitative.

The composition and abundance of rocks exposed to weathering at the earth's surface are of importance in viewing weathering processes. Although there are nearly 2000 minerals, dozens of named varieties of rocks, 90 odd natural chemical elements, only a few in each of these categories occur at the earth's surface in appreciable amounts.¹

¹Leopold, L.B. and et al., (1969) Fluvial Processes in Geomorphology, p.100.

Five classes of rocks occupy more than 90 per cent of the continental area, distributed approximately as follows :

TABLE - III(iii)

Classes of rocks	% distribution
Shale	52
Sandstone	15
Granite (and granodiorite)	15
Limestone (and dolomite)	7
Basalt	3
Others	8

Source: Fluvial Processes in Geomorphology,
p.100

Combining the mineralogic data with the relative abundance of rock types gives the approximate proportions of common minerals exposed to weathering at the earth's surface.

Rocks of similar chemical and mineralogical compositions may react very differently to the same weathering environment. For example, coarse-grained granites weather more rapidly than fine-grained granites. Weathering requires the presence of water, and hence rock texture is important because it largely controls penetration of water into rocks porosity data for the common rocks are given in table below:

TABLE -III(iv)

Rock type	Porosity	Unconsolidated	Porosity
Granite	1%	Clay	45%
Basalt	1%	Silt	40%
Shale	18%	Sand	35%
Sandstone	18%	Gravel	25%
Limestone	10%	-	-

Source: Leopold, L.B. and et. al. 'Fluvial Processes in Geomorphology', p.101.

Depending on the operative factors, weathering processes are roughly sub-divided into two types:

- (1) Physical or Mechanical Weathering
- (2) Chemical Weathering.

The two types act together and at the same time and only the intensity of their manifestation is different. It depends on climate, relief, time, the composition of the rocks, and other factors.

(1) Physical Weathering

Physical weathering is caused by a variety of factors, but the decisive role is played by those causing mechanical movement of rock particles, which disturbs the mechanical bond between the rock constituents. Various processes have been recognised as mechanical by Ollier (1965)¹, Thornbury

¹Ollier, C.D. (1965), Some features of granite weathering in Australia, Zeitschrift fur Geomorph, N.F.I, pp.285-304.

(1961)² and Sparks (1952)². Of these, however, only slaking and weathering caused by temperature are noticed in this area. Alternate wetting and drying of rocks is a very important factor in weathering, a process known as slaking. The researcher has observed during field work, the disintegration of fine-grained sandstones into a number of large pieces of about equal size in between Umlynger and Cherrapunjee and around Cherrapunjee area. A large variation i.e. diurnal and monthly rainfall in this region helps the process of slaking.

Weathering, as may be expected, starts at two planes: foliations and joint planes. Both the vertical and horizontal joints planes are present in the quartzites (near Barapani area) and as a result of weathering along those planes rectangular blocks and slabs are produced and which ultimately under the action of gravity roll down along the slopes (Plate-3). These blocks near Barapani form masses of talus below vertical cliffs. Because of the hardness and compactness and particularly the vertical joints in quartzites the surface water flows over the rock in the south in the form of rapids and falls viz., Fuller Falls near Umsning (Plate-4). The isolated harder gneissic hills on the north and north-west are formed as a result of

²Thornburry, W.D. (1961), Principles of Geomorphology, pp.34-61.

³Sparks, B.W. (1952), Rates of operation of geomorphological Processes, Geog., Vol. 47, pp.145-53.

weathering. The soft and brittle mica-schist, phyllites and other clay rocks which are very susceptible to weathering have been eroded away and hence are found to expose on the lower elevations. Spheroidal weathering is a noticeable feature in the epidiorites, this is because of the irregular joints developed in rock and subsequently shapeless blocks are produced during weathering (Plate-5).

In Cherrapunjee area, during field observation the researcher came across some evidences of physical weathering. Especially it shows the action of water in the joints indicating the initial stage of weathering. The development of cracks along the joints (Plate-6) can be clearly seen. Growth of vegetation along these cracks can be seen clearly (Plate-7).

Blackwelder (1933)¹ has pointed out that a good deal of thermal expansion and contraction of rock is caused by forest fires, which cause nonuniform heating of rocks. Areas of higher relief in Khasi and Jaintia Hills where extensive jhum cultivation is practised shows spalls and flakes of rock which are produced due to exfoliation caused by unequal heating and cooling. When temperature fluctuates, the mineral grains composing rocks alternately

¹Blackwelder, E. (1933), The Insolation hypothesis of rock weathering, Am. J. Sci., 226, pp.97-113.

expand and contract. In view of the slow penetration of heat into the depth of a rock, the surface layer expand more than those within. The frequent result is the appearance of cracks parallel to the surface of rock blocks, and disquamation of the later.

Thermal weathering is more intense on the steep slopes of high mountains, where the air is more transparent, and insolation more stronger than in the adjacent lowlands. Jumming is practised on the hill slopes. The rock fragments produced by weathering are readily removed from the slopes by gravity, due to which the surface of the slopes remains exposed and undergoes further weathering. This results in the accumulation of hillside waste or talus at the foot of mountain slopes or in their lower parts,(Plate-8).

Chemical Weathering

Chemical weathering is the result of interaction of rocks of the superficial layers of the lithosphere with chemically active constituents of the atmosphere, the hydrosphere, and the biosphere. The following substances are the most active chemically: Oxygen, water, carbondioxide and organic acids. The processes involved in chemical weathering may be classified as :

- (1) Oxidation,
- (2) Hydration
- (3) Dissolution and
- (4) Hydrolysis.

Oxidation process is seen active in Khasi and Jaintia Hills, in the areas where hornblende rock structure are found. These hornblende rock structure always contain ferrous iron which rapidly oxidizes under surface conditions, coating the mineral with a brown crust. Oxidation process is found active in areas south of Shillong, Cherrapunjee and other areas of Khasi and Jaintia Hills, where sedimentary rocks, such as sandstones, clays, which have inclusions of ferruginous minerals often show a brown colourization, indicating that the minerals underwent oxidation and turned into iron hydroxide. The soft and brittle mica-schist, phyllites and other claying rocks which are very susceptible to weathering have been eroded away and hence are found to expose on the lower elevations. Spheroidal weathering is a noticeable feature in the epidiorites, this is because of the irregular joints developed in rock and subsequently shapeless blocks are produced during weathering. With further action of running water these blocks later turn into spheroidal bodies. The presence of loose and friable quartzites with brownish grey colour, and the decomposed products of epidiorites with their peculiar reddish colour are the evidences of chemical weathering in Barapani area North of Shillong.

Dissolution and hydrolysis involve the combined

action of water and carbondioxide on rocks. Water is an active chemical reagent because it is always to some extent dissociated into ions of H' and OH'. It is the hydrogen ion of water that is the most powerful agent of chemical weathering.¹ Naturally, whatever is dissolved in the water, will affect the chemical reactions that occur chemical composition of rain water is highly variable, depending on distance from the sea, terrastrial contamination by natural means, and contamination by man. The major dissolved constituents are sulphate, bicarbonate, chloride, nitrate, calcium, sodium, magnesium, ammonium, potassium and hydrogen ions.

The proportion of ionic constituents vary seasonally and areally. It is the hydrogen ion of water that is the most powerful agent of chemical weathering. The higher the hydrogen ion concentration, the more dissociated is the water and the stronger its action as a chemical weathering agent.

Complete dissolution of minerals in water is observed in salt bearing series in gypsums, limestones and dolommites etc. It is with these rocks that the formation of karst, sinks and cavaties are associated. Water enriched with free carbon dioxide dissolves limestones, but then under

¹Gorshkov, G. and A. Yakushova, (1967), Physical Geology, p.66.

different environmental conditions, under different pressures and temperatures, it relatively readily redeposits the dissolved carbonate of lime. It is through this process that cave deposits of stalactites and stalagmites are found in Cherra limestone region. During the field observation, the researcher has experienced some peculiar shapes of these deposits inside the Cherra-Mawsynram caves. It has been found that, the stalactites join with other neighbouring stalactites. Then they appear like so many shawls, hangings and draperies. If one looks at the plate No.(9) it is really fascinating to observe that the lime deposits looks like a huge water lily.

The geological map of Khasi and Jaintia Hills (Fig. 2) shows that the region is widely occupied with igneous and metamorphic rocks. The exposed Archaeans in the central and north-eastern parts are believed to be remnants of chemical weathering (as discussed earlier) processes. Abundant biotite and potash feldspar show that these rocks have been subjected to chemical weathering throughly.

The Shillong group of rocks are generally composed of quartzite-schists which show an interaction of mechanical and chemical weathering. On the southern part of the Shillong plateau the Sylhet traps are exposed in a narrow

E-W strip. They are of the nature of plateau basalts. They comprise mainly of basalts and minor alkali basalts, rhyolites and acid tuffs. This is the region of intensive chemical weathering. The general chemical composition of the basalts show that the constituents like SiO_2 , Al_2O_3 , Fe_2O_3 etc. are abundant. The Fe_2O_3 is very susceptible to water which undergoes the process of hydration which involves a conversion of limestone. The solution goes as follows :



Effect of Vegetation and Precipitation

Vegetation is also important in governing the rate of removal of weathering products. Root mats tend to hold soils in place, prolonging the weathering period until the protective plant cover is breached. Failure of the protective root system generally is not uniform under natural conditions, and this leads to uneven erosion (gullyng) - and consequently an uneven thickness of the weathered material above the bed rock. Due to shifting (jhum) cultivation in Khasi and Jaintia Hills, the burning of the slashed materials destroys the vegetative cover of the area. Subsequently, it leads to the failure of the protective root system of the vegetation, thereby, causes soil erosion. The table below shows soil erosion associated with jhum cropping round

the year. Since several slopes with varying types of crop mixture were selected for study, the information in soil erosion calendar have been compiled considering minimum and maximum soil erosion values observed.

TABLE -III(iv)

Jhumming and Soil Erosion Calendar				
Month	Agricultural operation	Erosion Problems	Soil Erosion t/hac	
			Min.	Max
January Feb. & March)Jungle cutting,)burning and)clearing of)hill slopes	Displacement of loose soil materials to down hills and rolling down of earth-worm castings.	0.0	3.7
April	Clearing continues showing begins	Soil erosion as above and wash due to rains	0.0	22.4
May	Showing/weeding	Heavy soil wash, faint rilling at foot-hills on silt deposits	0.2	61.9
June	Weeding	Heavy wash of soil aggregates	0.2	45.4
July	Weeding/harvesting begins	Heavy wash of soil aggregates, crop roots exposed. Firm soil visible	1.8	21.9
August	Harvesting and occasional weeding	Soil was continues	1.0	29.6
Sept.	Harvesting	Moss appears. Soil erosion slows down	0.1	13.8
Oct.	Harvesting	Soil erosion very much reduced	0.0	2.7

Table contd..

Table contd..

Month	Agricultural operation	Erosion Problems	Soil Erosion t/hac	
			Min.	max
Nov.	Harvesting	No erosion, Moss turns blackish	0.0	0.0
Dec.	Harvesting	No erosion	0.0	0.0
Year	Cropping with zero tillage on steep slope	Heavy soil-wash	3.3	201.4

* Soil erosion hazards in North Eastern Hill Region, ICAR, Research Bulletin No.10, 1981. Shillong, pp.11-13.

Soil erosion values are the quantity of soil which moves down to foot hills and does not include, the portion which escaped with runoff from the collection point.¹

Effect of precipitation - The various constituents of soils are influenced unequally by total rainfall, but no universal generalization can be drawn from the empirical data. Leaching of certain soluble is sensitive to total precipitation. In Khasi and Jaintia Hills since 90 per cent of the rain comes during the monsoon period, it is reasonable to assume that most losses occur during this period.

(Table-III(v)).

¹ Ibid., p.13.

TABLE - III(vi)
Average Monthly Erosion Index Values (Metric Unit)

Months	Gauhati	Shillong
January	-	-
February	-	-
March	5.6	4.8
April	40.6	17.8
May	74.2	55.4
June	146.9	122.4
July	149.5	56.7
August	139.3	50.0
September	65.7	84.7
October	9.6	15.7
November	3.7	-
December	-	-
Annual	635.4	407.5

Source - Rambabu et al 1978, Rainfall erosion potential and Iso-erodant map of India, Bulletin No.2, Central Soil and Water Conservation Research & Training Institute, Dehradun.

Rainfall is the major factor in causing soil erosion in this region. Its potential ability to cause erosion is defined as 'Erosivity' which is the function of physical characteristics of the rainfall.

In the agro-ecosystem of this region, over 50 per cent loss of water is accounted for by run-off and infiltration and this was drastically reduced in a 5 and 10 years

fallow land.¹ They claim that, the loss of particulate sediment in the run-off water dropped from 31 m. tonnes /hec. in the agro-ecosystem to 1.13 m. tonnes and 0.76 m. tonnes/hec. respectively in a 5 year and 10 year fallow land.

In Shillong and surrounding areas the soils are gneissic derived. Of the two main soil types, laterite soils are reddish and granitic derived soil range from light brown to dark brown. The soil texture varies from coarse to medium fine in the upper horizons to fine in the lower horizons. The soil pH generally is between 4 and 6 but may be as low as 3.5 in pine forests.²

The slopes where potatoes were cultivated about 35 per cent of the annual precipitation is lost as run-off declining drastically with the length of the fallow period. Infiltration, on the other hand, increased slightly in a 10 year fallow. The sediment yield in the agro-ecosystem is 39.3 m. tonnes/hect. but dropped markedly to 3.45 m. tonnes/hect. in a 5 year fallow and to 1.92 m. tonnes - per hect. in a 10 year fallow. The sediment yield in the agro-ecosystem is 39.3 m. tonnes/hect. but dropped markedly to 3.45 m. tonnes/hect. in a 5 year fallow and to 1.92 m tonnes/hect in a 10 year fallow.

¹Ramakrishna et. al. (1980), p.13.

²Ibid., p.13.

Mass Wasting

Weathering and mass wasting contribute to the gradation of the earth's surface to a much greater degree than is usually realized. These processes, along with sheet wash, are important not only in the general lowering of the land but in the shaping of the details of the topography of interstream areas. Only within recent years mass-wasting processes have received the attention which it merits.

In the study of weathering, mass wasting is also an important process, which is a part of weathering. The weathered material which cannot rest on the sloping ground, comes down under the influence of gravity. The process of mass wasting starts when due to the long-continued process of weathering surface rock becomes weak or is converted into a loose mass. Such material starts moving down under the gravitational force. Hence, it is more effective on steeper slopes, as well as on slopes which have bare or near bare rock surface. Of course, vegetation binds the loose material and does not allow it to move down readily. This process is commonly observed in the area under study.

The intensity of mass wasting depends on such factors like, (i) lithology (unconsolidated or weak material), (ii) stratigraphy (thinly bedded rock and alternating weak and strong or permeable and impermeable beds); (iii) structure (closely spaced joints, faults and foliation

planes); (iv) topography (steep slopes and vertical cliffs); (v) climate (large diurnal and annual range of temperature, abundant precipitation); (vi) organic factors (scarcity of vegetation).

Different factors being effective in different parts of the region. The dominating types of mass-wasting observed in Khasi and Jaintia Hills are as follows:

- (a) Debris fall,
- (b) Rock slide, and
- (c) Rock fall.

(a) Debris fall - Debris fall is the nearly free fall of earth debris from a vertical or overhanging face. Debris fall are common in Northern and southern part of Khasi Hills. If one travels from Gauhati towards Shillong on the National Highway, the exposed vertical faces made by road cuttings are seriously affected by debris fall. During the rainy season, the whole length of the National Highway between Naya Bungalow to Nongpoh and a little downward is affected by minor to major debris fall. This sometimes seriously affect the traffic movement along this road. Plate (10) shows the debris fall from the vertical face produced due to road cutting near Umtng village. Photo taken a few minutes after the debris fall. Plate(11) shows deformed debris fall near the village.

(b) Rock slides - Rock slide is the process of the sliding or falling of individual rock masses down usually along bedding joints or fault surfaces. Well known rock slides are seen along the Shillong - Gauhati National Highway near Barapani area. (Plate 12). It appears that due to the action of mechanical and biological weathering along joints, the compactness of rock mass is lost and the boulders fall down the slope under the effect of gravity. Around Barapani area both the vertical and horizontal joint planes are present in the quartzites and as a result of weathering along those planes rectangular blocks and slabs are produced and which ultimately under the action of gravity roll down along the slopes. These blocks form masses of talus below vertical cliffs.

(c) Rock Fall - The free falling of rock blocks over any steep slopes take place when recently detached rock blocks, usually small, move precipitously down a steep cliff or rock face. (Plate 13).

CHAPTER - IV

DRAINAGE EVOLUTION AND FLUVIAL EROSION

"Rivers and valleys have a special place, for it is impossible to treat the development of landforms, or to describe existing forms in a rational manner, without constant reference to the valleys that have been worn to them and to the rivers by which the waste is washed along the channel in the valley floor."

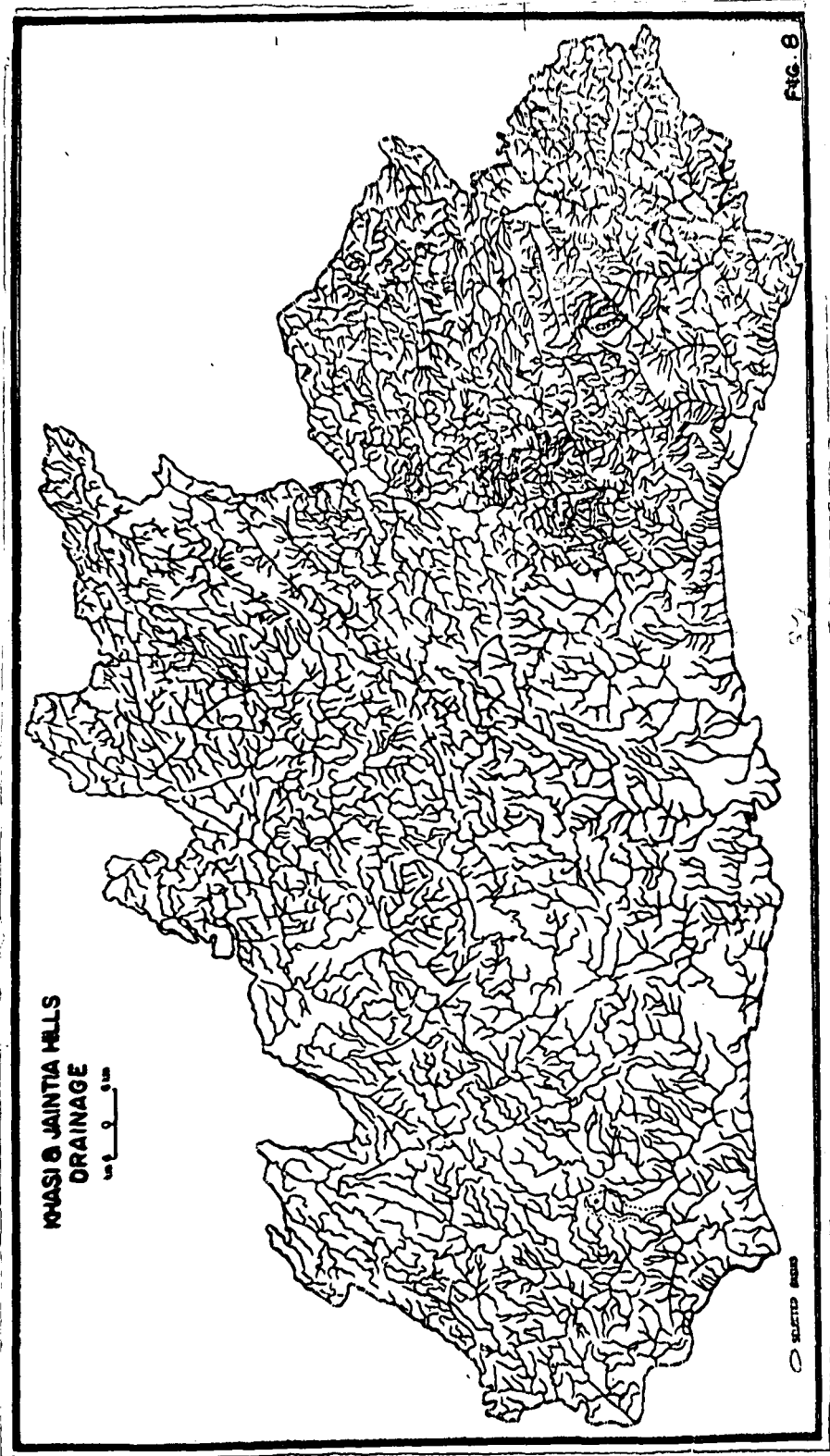
- W.M.DAVIS(1900).

Introduction

Probably nothing else "so epitomizes the history of a region's physiography as the history of its rivers."¹ In this region which enjoys a humid tropical climate and where chemical weathering is the dominant process of landscape sculpturing, drainage constitutes the most important element of surface geodynamics. In the absence of the wind, the frost actions and running water is the only agency of shaping the relief by subaerial processes. Progressive dissection and degradation of the higher lands is caused by fluvial action.

A landscape has a definite life history during which it shows a series of gradual changes, whereby the

¹Fenneman, N.W. (1938), Physiography of the Eastern United States, McGraw Hill, New York, Preface(iv).



KIASI & JAINTIA HILLS

DRAINAGE

1:100,000

FIG. 8

SELECTED POINTS

initial forms pass through a series of sequential forms to an ultimate form landscape evolution is thus envisaged as a cycle which runs through a definite course of development. It is, therefore, of prime importance to recognise the stage of evolution attained in landscape development. But as in the case of single valley, the process of sculpture stamps its character on the country, while rock character, conveniently summed up under the term "structure", are also potent factors in determining form. According to W.M. Davis, "Landscape is a function of structure, process and stage."¹ Throughout the world run-off waters are the dominant geomorphic agency. So, in any geomorphological study fluvial cycle of erosion becomes the most important aspect.

Drainage systems

With an average annual rainfall of 26,889 mm., Meghalaya is drained by a number of consequent and subsequent streams with a large number of their small and big tributaries.

A glance at the drainage Map (Fig. 8) of Khasi and Jaintia Hills of Meghalaya would reveal that the drainage system of this area is to a great extent directed by the central upland zone, which acts as the major water divide

¹Thornbury, W.D.(1969), Principles of Geomorphology (2nd Ed.), p.17.

KHASI AND JAINTIA HILLS RELIEF

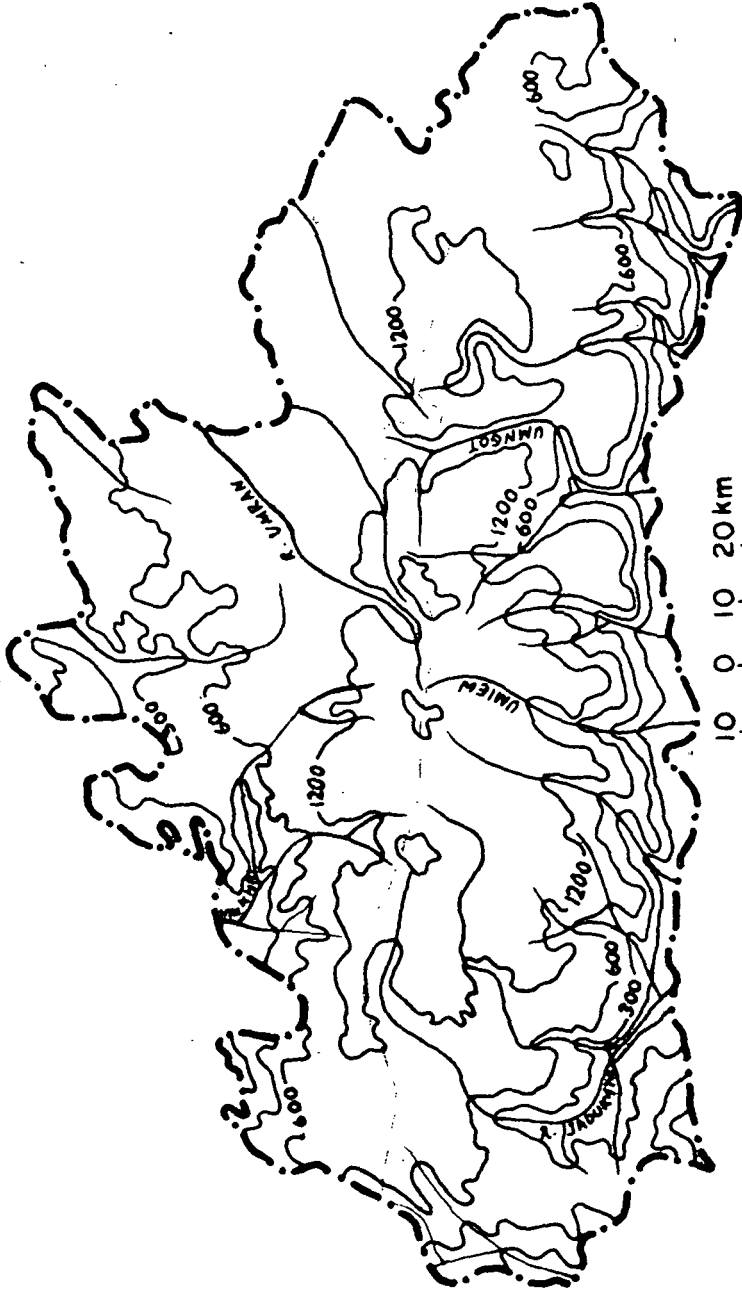


Fig. 9

from which the rivers flow down to the Sylhet plain in the south and Brahmaputra valley in the north (Fig.9). The important rivers flowing towards the Brahmaputra in the north area : (i) the Kopili, (ii) the Umkhen (called 'Barapani' in the plain), (iii) the Umiam, (iv) the Umtru with its major tributary the Umran (called 'Digaru' in the plains) and (v) the Um Khri. The southern river systems are :

(i) the Khynsiang (called 'Jadukata' in the plains), (ii) Mawpa (iii) Umiew or Umiam (known as 'Bogapani' in the plains of Bangladesh), (iv) Wah Sohrynkiew, (v) Myntdu (known as 'Hari' in the plains of Bangladesh) & (vi) Munga (known as 'Pein' in the plains). Apart from these major river systems there are a number of small tributaries also flowing towards north and south respectively.

The characteristic feature of the northern rivers is that most of them have formed plain embayment at their entrance into the plains, thereby making the northern boundary of the plateau fairly irregular. Conversely, the southern rivers entering the plains of Bangladesh in deep gorges in the faulted face of the southern boundary with a number of waterfalls varying in heights between 14 ml. to above 400 ml. such as the magnificent Mawmai falls 348mt. (Plate No.14) on the southern fringe of Cherrapunjee.

Evolution of Major River Basins

Kynsiang basin - The Kynsiang or Jadukata river rises from the southern part of Nongthliew village ($91^{\circ}42'$ E and $25^{\circ}33'$ N) approximately 28 km south-west of Shillong, at an altitude of 1775 mt. (5750 feet) above Mean Sea Level. After flowing in a south-west direction it turns towards north making a sharp bend near the Bynther village and it flows near the foot of Kynsi peak 1757 mt. (5799 ft). Near Nongshillong it meander down towards south at Lawbyrtun and flows in a zig-zag manner till it descends to 1500 mt. (5000 ft). Till this point the Kynsiang river is flowing along the contact line between gneissic complex and granite. Near Nonglwai (roughly $26^{\circ}26'$ N - $91^{\circ}21'$ E) it takes a turn and flows along a major lineament in a straight course. After flowing in a zig-zag manner it makes entry to 1200 mt. (4000 ft.) forming a waterfall 50 mt. (150 ft). From this point the river forms a meander along deep gorges and the first major tributary Umkyrtha flows into the Kynsiang river in the form of a right bank tributary. Two more small tributaries enter the main river after forming waterfalls 49 mt (160 ft.) and 80 mt (264 ft), The trunk river receives a number of small nalas at different heights. The second major tributary which flows across the gneissic complex, originates from a height of

of 154 mt. (508 ft.). Before entering into Bangladesh the river valley becomes wider. Umrilang stream rising from a height of 1666.6 mt (5500 ft) and fed by one or two first order streams as it flows across the granitic surface. But as soon as it enters the gneissic complex the erosion process becomes more rapid and development of valley is clearly noticed. It enters the Jadukata river at Rilang village ($25^{\circ}13'$ N and $91^{\circ}12'$ E). The Kynsiang or Jadukata is the largest river of the region.

Umngi river basin - The Umngi river originates from 1800 mt (6000 ft) surface from the central plateau region. Near a patch of Shella formation (Jaintia group) it makes a eastward bend for roughly 3 kms and turns to southward entering the gneissic complex. Near Malairim village ($25^{\circ}16'$ N and $91^{\circ}31'$ E) it flows to west direction all along the gneissic complex with a second order stream (Umsaurata) on its right bank, this is an example of stream's adaptation to local structure. After flowing roughly for 3 km it enters the Sylhet trap in a zig-zag way with only two or three finger-tip streams. Before entering to Bangladesh it flows across three geological formations viz., Shella formations, Chengpara formations and Dupitila group. At this point the river is incised. There is a large river island where Moiland village is located ($91^{\circ}3'$ E and $25^{\circ}11'$ N).

It is divided into two branch just before entering to Bangladesh as Dhamalia river flowing towards south-west and another branch which flows in a south-east direction and meets Surma river as a right bank tributary. From Jakrem till it entered Bangladesh Umngi river with its numerous tributaries dissected the southern face of Khasi Hills forming interlocking spurs deep gorges and steep slopes. The area is covered with fairly mixed dense forest.

Umiew or Bagra basin - The Umiew river originating from the Shillong peak 1952 mt (6441 ft.) is flowing along a major lineament in a south-east direction. This stream separates Nongkrem and Smith village and makes a sharp bend and flow towards west and meets its first second order tributary which is flowing from Shillong peak across the Myllem granite. Till it enters Mawphlang the Umiew river flows along a major lineament all along the contact line between Shillong series and granite. At this point the river receives a tributary which originates from Dympep south of Mawphlang parallel to the major river as a left bank tributary. It enters the trunk river, forming a waterfall 32 mt (107 ft). Here it makes a nearly 90° bend and flows towards west. Near the 671 mt (2215 ft) spot neight it turns to south with a number of feeder streams. The main river is flowing in a deep gorge making

inter-locking spurs with steep slopes. Till the Umiew river reaches approximately 6 kms. west of Cherrapunjee it receives numerous small tributaries which forms several small waterfalls with height ranging between 13 mts to 213 mts. After Tynrong village it enters into newer alluvium, Sylhet Trap and Mahadek formations and finally enters into Bangladesh flowing along newer alluvium deposits. After Shella ($91^{\circ}37'E$ & $25^{\circ}10'N$) the river becomes incised and the newer alluvium are deposited on both sides of the valley. It is divided into two branch before entering to Bangladesh near Chhikin village ($91^{\circ}37'E$ & $25^{\circ}7'N$) One branch as Nawaganga towards south west and another towards south as the main branch Umiew or Bagoariver.

Umsohryngkew river basin - Umsohryngkew river originates from Laitlyngkot Peak 1849 mt (6071 ft.) and takes a turn near Mun Peak 1883 mt. (6214 ft.) and flows south ward. It receives two 2nd order tributary which also originates from the Laitlyngkot Peak on its left bank. Near 532 mt (1757 ft.) spot height it receives one third-order tributary on its right bank, which cuts accross the Shillong group of rocks and Shella formations. It flows in a southward direction cutting accross the Shillong series in a straight course on the 600 mt (2000 ft.) surface. Gently taking a south-west turn at the 126 mt. (418 ft.) spot height it receives two major right bank

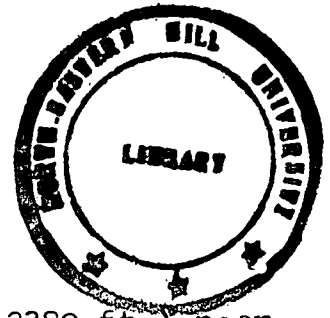
tributaries namely Umstew and Umsohra.

Umstew originates from Laitryngew Peak, 1653 mt (5454 ft.) and after making a large waterfall 312 mt. (1028 ft.) as it descends to 1200 mt. (4000 ft.) surface suddenly from 1500 mt. (5000 ft.) platform flows in a deep gorge with few fingertip feeders on its both banks. which cut accross the Shella formations of Jaintia group.

Umsohra originates from Dympep Peak 1934 mt (6382 ft) and flows down towards south in the form of a second order stream till it makes almost 90 degree bend to its left near Laitryngew for about 3 kms and again turns towards south. It flows in a deep gorge with steep slopes in a zig-zag manner through inter-locking spurs covered with dense mixed forest till it joins with Umstew and finally with Umsohmyngkew river. Another 2nd order stream originates from the Cherrapunjee structural platform over the 900 mt. (3000 ft.) surface forms the largest and the magnificent Mawsmal falls 348 mt (1150 ft.) near Mawsmal 4 km south of Cherrapunjee, which cuts across the Shella formation. From here the river takes a south direction cutting through a small fatch of granitic complex, Sylhet trap and finally near Theriaghat ($25^{\circ}10'N$ & $91^{\circ}45'E$) it enters the Bangladesh plain with a braided course.

Umkhri river Basin - Umkhri river originates from south of Dienges range (west of Shillong) 1500 mt. (5000 ft.) surface. It flows in a east-west direction and turns roughly at a 90 degree angle towards north with a few second order feeder streams. The Khri river at this point flows along a major lineament and turns to north-east. Near Nongwput villages it flows towards north in a zig-zag manner till it descends from 1500 mt. (5000 ft.) height. It receives its first major tributary on its left bank a consequent stream Umnongkrem which originates from north of Dienge range on 900 mt (3000 ft). height. After flowing for approximately 7 kms, changes its direction towards west. Another tributary Umrina stream joins Khri river as a right bank tributary. Umrina rises from 1500 mt. (5000 ft.) height from a Peak 1782 mt. (5881 ft).

The Khri river before turning to north makes a waterfall of 9 mt. (30 ft.) and after entering to 600 mt. (2000 ft.) height it makes a sharp bend cutting across a major lineament. It receives another right bank tributary Umrit which is flowing along a lineament, originates from Kariang peak 677 mt. (2233 ft.). After 7 kms. it receives another right bank tributary which is also flowing along a major lineament and its tributaries are also adjusted to minor lineaments. The Umshait stream



originates from Tepkilabam peak 724 mt (2380 ft.) near Jirang ($90^{\circ}35'E$ & $25^{\circ}55'N$) flows from north to south.

After the Khri river receives the largest tributary Khrisynnia and Umkanrem it receives a number of feeders streams which are flowing all along the lineaments. The major tributary Khrisynnia which is also a right bank tributary originates from northern slope of Mautherrichan peak 1912 mt (6308 ft.). At its origin it flows along the lineaments. There is a small water-fall 6 mt (20 ft.) near Domuah Peak 1605 mt (5296 ft.). The stream flows in a north-west to north-east and again changes its course till it enters the gneissic complex. The river originates from gneissic complex and flows cutting across the granite topography for at least 18 kms. Again it cuts its valley deep along the gneissic topography with a number of feeder streams on both the banks till it meets the Umkanrem stream. The Umkanram streams originates from 1500 mt (5000 ft.) surface and flows across the granite land forms with a few first order feeder stream until it meets the Khrisynnia as its left bank tributary. The Khri flows into Assam and is known a Kulsi river in plains.

The interesting feature of this river system is that its major to minor tributaries are adjusted to the structural lineaments.

101748

Umtru, Umran river basin - The Umtru river originates from a height of 1136 mt (3750 ft.) surface. It cuts across the Dolerite basic dykes, 9 km. east of Umsning ($25^{\circ}44'N$ & $91^{\circ}52'E$) entering the Shillong series it receives Umryleng tributary on its left bank at the 698 mt. (2304 ft.) surface. Umryleng stream originates from the northern slope of Diengei range. From this point it turns to north making an arc cutting across the gneissic complex. The valley deepening starts clearly as it enters the 600 mt (2000 ft.) surface.

Umtaser a right bank tributary which originates from the Mawkyndah peak 962 mt (3173 ft.) as a obsequent stream and joins the Umtru river as a second order stream. It forms almost a rightangle and enters the major lineament in a North-west direction roughly after 3 km North of Nongprut Peak 739 mt (2437 ft.). It flows along the base of Mawkyndah Hill. At the point where it takes a right angle turning towards north, it receives its major tributary, the Umram river over 275 mt (909 ft.) surface.

The Umran river originates from a height of 900 mt. (3000 ft.) near Syngku village a hilltop settlement ($25^{\circ}51'N$ & $91^{\circ}59'E$). It flows all over the queissic complex in an east-west direction. The Umran receives its first right bank tributary the Umngot which originates from a

peak 972 mt (3209 ft.) north of Mawrong in a north-west to east-west direction. Umphi another tributary joins the Umrans river as a left bank tributary.

The Umtrew-Umrans basin is very much controlled by the local structure. Parts of the main rivers as well as their small tributaries are well adjusted to the structure. The presence of criss-cross water of minor joints are controlling the pattern of drainage in this basin. A left bank tributary the Umthna is forming the boundary between the Kamrup district of Assam with Khasi Hills in the north.

Umngot river basin - The Umngot river former the political boundary between Khasi and Jaintia Hills. The interesting part in the river net work is that all the major tributaries with its small and large branches originates from the central plateau forming deep gorges and valleys have dissected this part of the central plateau very much. The western part due to the presence of a north-south ridge (along the queissic complex and the Shella formation of Jaintia Group) the river runs parallel to the ridge with very few streams flowing into the Umngot river. The main river separates two geological formations viz., Shillong series on the west and Gneissic complex on the east.

Drainage Pattern

"Drainage pattern refers to the particular plan or design which the stream courses collectively form."¹ A study of drainage patterns often reveals a very delicate and intricate adjustment with structure and lithology. Hence, a knowledge of the drainage pattern of a region or river basin, may throw considerable light on the structure of the underlying rocks. It is generally recognised that drainage patterns reflect the influence of such factors as initial slopes, inequalities in rock hardness, structural controls, recent diastrophism and the recent geologic and geomorphic history of the area under study.

While emphasizing the importance of drainage and structure, Sparks (1972) has expressed his view that the arrangement of the relief is merely the pattern of the interfluves, so that in an area of well adjusted drainage, the study of the drainage pattern is automatically the study of the relief pattern, both being basically dependent on structure.²

"The drainage net is the pattern of tributaries and master stream in a drainage basin as delineated on a planimetric map. In theory, the net includes all the minor

¹Thurnbury, W.D. (1957), Principles of Geomorphology, p.117.

²Leopold, L.B. et. al (1964), Fluvial Processes in Geomorphology, p.131.

rills which are definite water courses, including all the ephemeral channels - in the furthestmost headwaters. In practice, the detail of the drainage net is dependent on the scale of the map used to trace the channels."¹

*The pattern of drainage is one of the most revealing features of landscape and casts light on the rock type, geological structure, stage in drainage evolution."²

The drainage map (Fig. 8) reveals the hierarchy of rivers from the source to its master streams. Rills, rivulets, streams and rivers units to outline a geometrical plan. These streams, in general, do not organize at random. Their hierarchy traces their history to reflect the stage or stages of their development. Rivers cut hard and soft rocks alike over the surfaces and exhibit an organization of drainage lines over granite, gneiss, phyllite and cave surfaces. Over each type of terrain lithology river alignment is guided by Master and Minor joints rock characteristics and epeirogenetic expressions. Drainage patterns are closely adjusted to joints, cleavage, bedding planes and outcrops of weaker strata (Fig.11).

The collective picture of stream carving reflects the drainage arrangements in relation to the geomorphological

¹Miller, A.A. (1953), The skin of the Earth, p.75.

²Zernitz, E.R.(1931), Drainage Pattern and their significance, Jr. Geol. vol. 40, pp.498-521.

history. The common patterns of drainage in the area under study are dendritic, radial, parallel, Rectangular and Trellis.

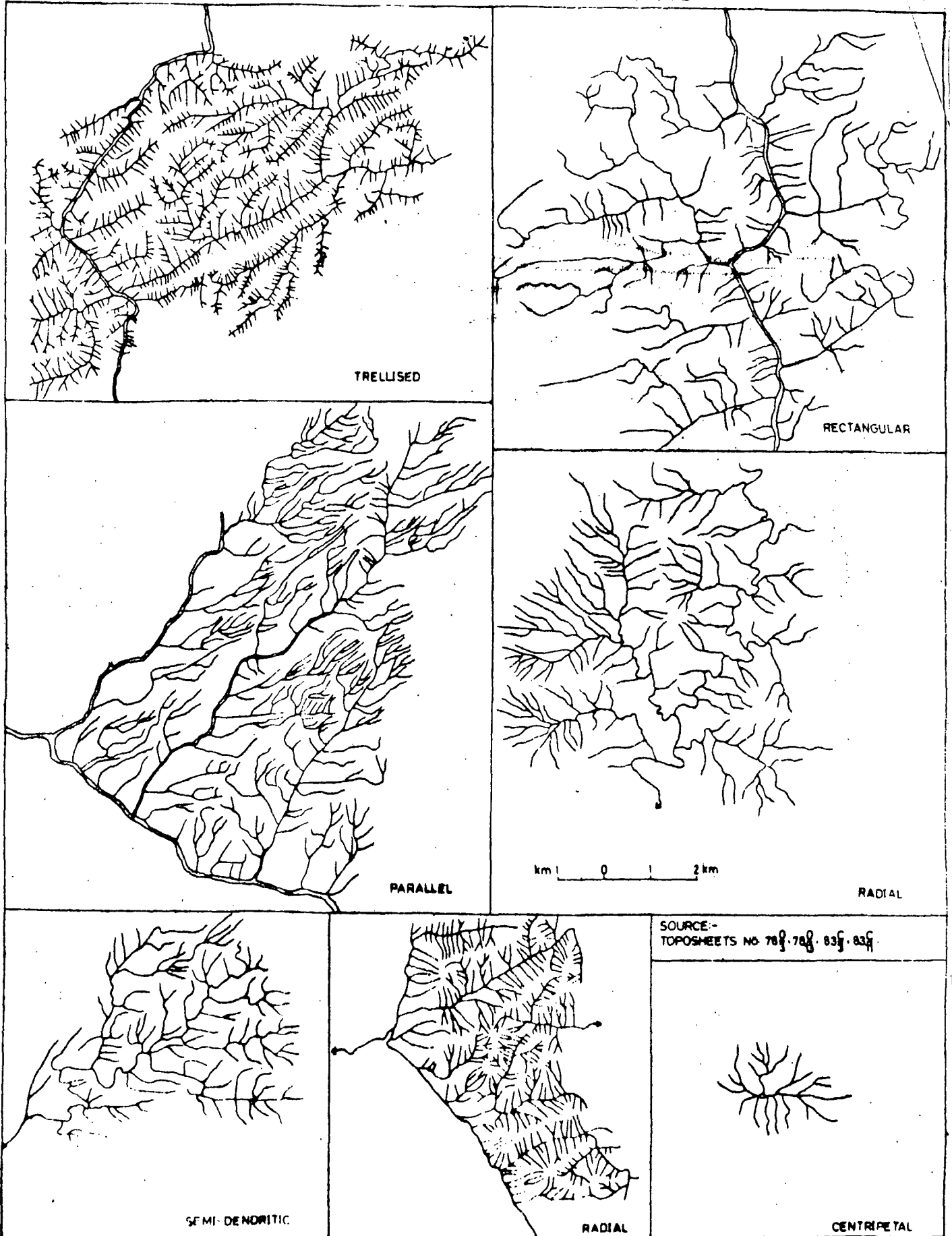
A tracing of the drainage plan from the topographical sheets including the geology of the region viz., granite gneiss, phyllite, Shillong series, Jaintia series, lava terrain reflects the fundamental contrast in their drainage nets. The drainage lines of varying orders seem to set over elevated parts., granite-gneiss domes, plateau and scarps to unravel the organizations and plans.

The drainage map of the Khasi and Jaintia Hills (Fig. 8) reveals the following five types of drainage pattern; viz:

- 1) Dendritic,
- 2) Parallel,
- 3) Radial,
- 4) Rectangular, and
- 5) Trellis pattern.

(1) Dendritic pattern - it refers to the type of drainage produced when a consequent river receives a number of tributaries streams, which in turn are fed by smaller tributaries, the whole forming a dendritic or tree-like pattern.

KHASI AND JAINTIA HILLS DRAINAGE PATTERNS



SOURCE--
TOPOSHEETS NO 78f, 79f, 83f, 83f

FIG 10

It will be seen from the geology map (Fig. 2) of Khasi and Jaintia Hills that the Khasi Hills underlie a very complex geological structure in comparison to that of Jaintia Hills formed mainly of Jaintia series and gneissic complex. It is obvious that with the wide variation in geological structure there is a little chance for the development of dendritic drainage pattern. However, a glance at the drainage map of Khasi and Jaintia Hills (Fig. 8) displays a few areas, where dendritic drainage pattern have developed, particularly in Jaintia Hills. The Umlunar river in the south-eastern part of Jaintia Hills show a clear dendritic pattern. In Khasi Hills, Wahlaw stream and its tributaries flow more or less in a dendritic pattern.

(2) Parallel Pattern - Regional slope plays a significant role and to some extent joints and cracks also help in the development of parallel drainage pattern (Fig.10). The average slope map of Khasi and Jaintia Hills (Fig. 18) show that in the Khasi Hills the variation in regional slope is much and the slope increases from north to south and finally in the south, the slope is very steep forming scarps facing towards Bangladesh plain. A few patches of parallel pattern of drainage are noticed in the southern part which flow parallel to the steep slope. The rivers Umiew and Umshohsingkiew with their tributaries in south

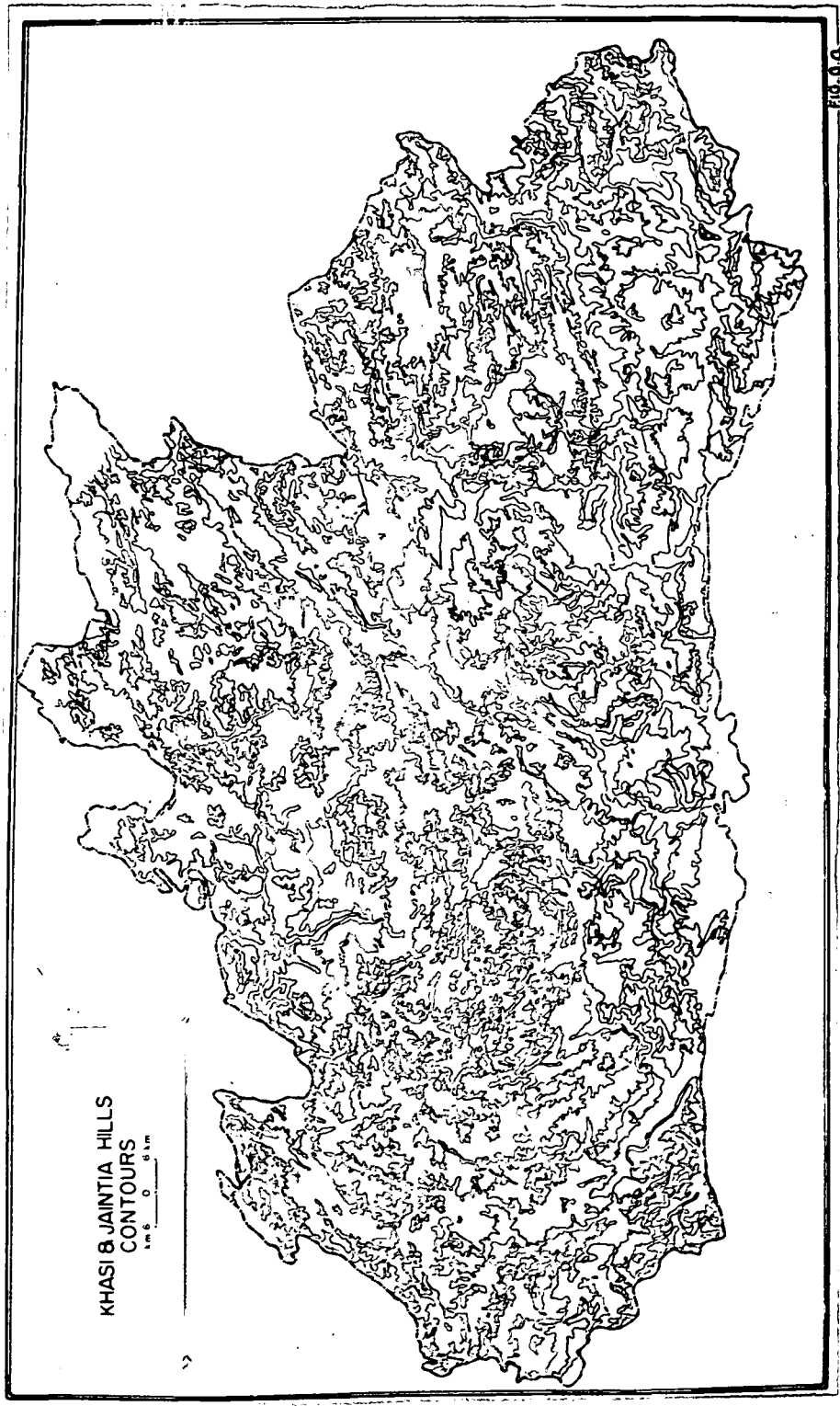
display a typical parallel drainage pattern. In the north of Khasi Hills also there are a few patches where parallel drainage pattern found adjusted to the regional slope.

In Jaintia Hills, the slope is very gentle which varies from 0 to 6 degrees in the northern part and on the south, the slope is comparatively steep. The drainage pattern in this area is not very distinct and a few tributaries run parallel to each other. For the development of parallel drainage pattern the lithology and structural controls have much role to play. The valleys and ridges run parallel to each other in a north-south-east direction, hence the parallel drainage pattern seen in the region have a similar flow direction.

(3) Radial Pattern - It refers to the type of drainage produced when streams flow outwards from a central dome-shaped upland (Fig. 10). "This type of drainage pattern develops on flanks of domes and volcanoes where there is no effect of differing rock resistance."¹

The drainage map (Fig. 8) of Khasi and Jaintia Hills reveals a wide distribution of radial drainage pattern in Khasi Hills and most predominantly in Jaintia Hills. These are due to the presence of isolated hills from which the

¹Schumm, S.A. (1973), Fluvial Gneomorphology in River Mechanics; River Morphology (Ed.).



KHASI & JAINTIA HILLS
CONTOURS
1:50,000

Fig. 9-a

streams are directed to all sides.

In Khasi Hills most prominent areas are situated in the south-west, where the rivers Kynsiang, Rongkhal and their numerous tributaries drain the region. The characteristic of the underlying rocks are uniform and the relief consists of isolated hills of great heights. In the central upland zone and the northern part of Khasi Hills the radial pattern is most prominent (Fig. 8). A glance at the contour map (Fig. 9a) would reveal that Khasi Hills is traversed by a few contours in the central and eastern part. The land rises towards south-west where the contours are many and the topography is very rugged. The drainage system is very complex in the central and eastern part of the Khasi Hills where a few prominent radial patterns are found.

(4) Rectangular pattern - A system of well-developed joints, fracture zones or small faults may give rise to a rectangular drainage pattern with many straight stream segments and sharp-angular changes in stream direction (Fig.10). If we examine the drainage map of Khasi and Jaintia Hills (Fig. 8), the central portion of Jaintia Hills is dominated by well-developed rectangular drainage pattern formed by the rivers Hari and its tributaries and river Kharkor and its tributaries. In Khasi Hills also there are a few examples of rectangular drainage pattern. Geology

and landform plays the most important role in the development of rectangular drainage pattern. It reflects either a regional pattern of intersecting joint systems, or a pronounced set of joints that cross belts of bedrock at a high angle.

(5) Trellis pattern - If an area is tilted upto about 6 to 7 degrees i.e. the dip is upto about 7 degrees (depending on climate) and layers of different rock types are exposed to erosion, the cuesta landform will develop. The gentle dip slope of the cuesta is controlled approximately by the direction and amount of dip. The valley follow the strike of weaker beds, and the cuesta crest follows the outcrop of the more resistant beds. Such cuestaforms may extend for many miles.

The main consequent drainage cuts across the cuestas, the subsequent drainage follows the strike valleys. long tributaries to the subsequent drainage flow down the dip slopes of the cuestas (flowing in the dip direction), and short, steep tributaries flow down the scarp face. The result is the classic trellis drainage pattern. The most important example of this pattern is the Umngot river which flows over a major cuesta landform which separates Jaintia Hills with Khasi Hills on the east. Some other areas are northern and north-eastern part of

Khasi Hills bordering Jaintia Hills.

Adaptation of Streams to Structure

Nearly all landscapes whose form and pattern is due primarily to erosion rather than deposition show the influence of geologic structures to a greater or lesser extent. The structures herein to be considered are assumed to have undergone all or most of their deformation in pre-Quaternary time.

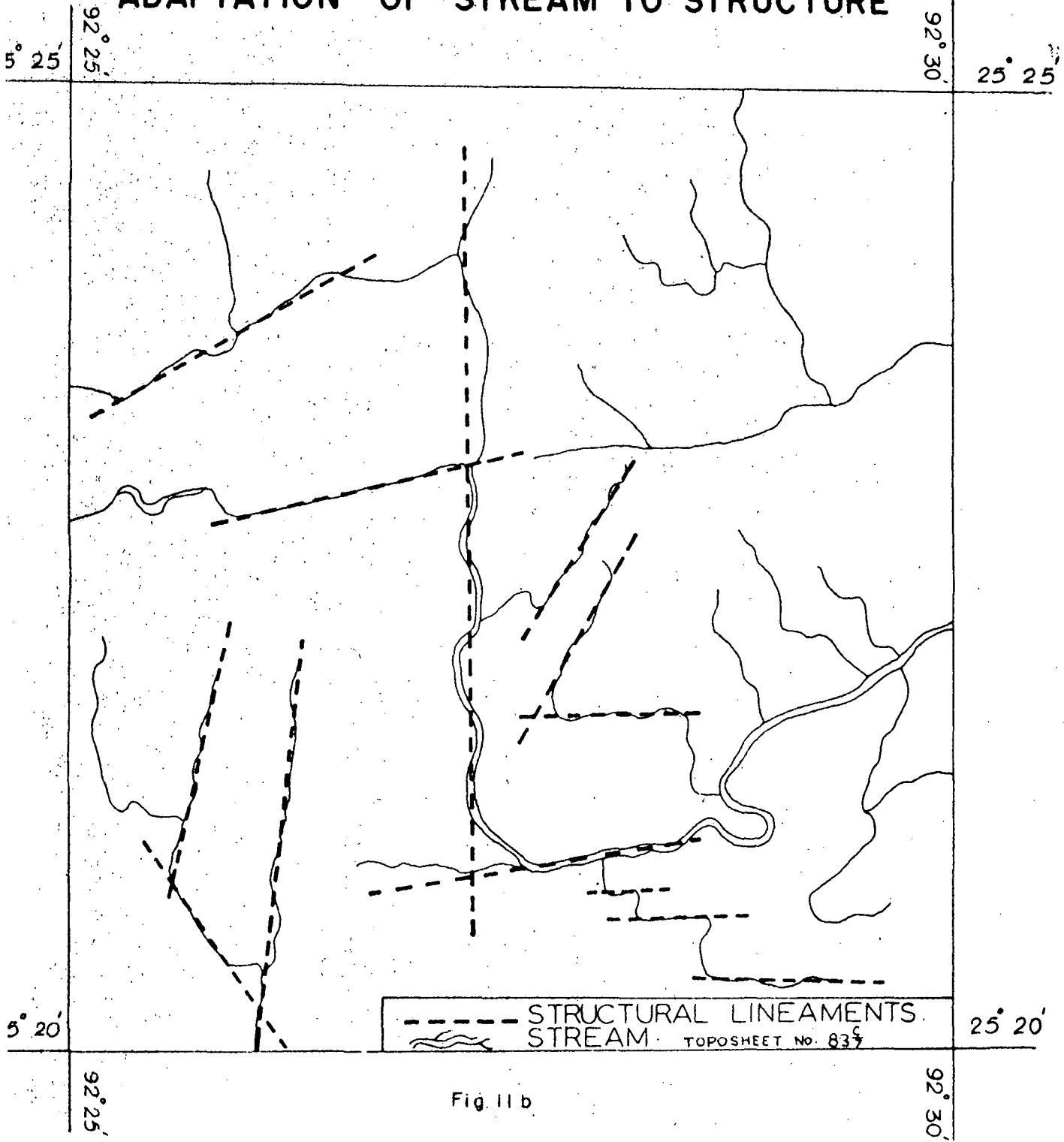
As these landscapes are due primarily to erosion and the structures are inactive today, the basic concept underlying any discussion of the role of such structural influence in geomorphology may be simply stated as follows:

"The influence of inactive geologic structures in erosional landscapes is due to the differential or selective nature of the weathering and erosional processes."¹

Stated in more expanded form, this concept holds that such structural influence is manifest in an erosional landscape because (i) weathering and erosion attack different types of rocks at different rates under various climates, and (2) structural deformation causes a variety of rock types to be present at the topographic surface. It must be borne in

¹Sparks, B.W. (1971), Principles of Geomorphology.

JAINZIA HILLS
ADAPTATION OF STREAM TO STRUCTURE



mind that such structural deformation may range from simple tilting to complex folding.

In this area it is interesting to note that in south-east, south-western and to a maximum - the tributaries of the north and south flowing rivers are very much adjusted to regional structure and master and minor lineaments. The superimposition of lineament maps over the drainage maps of this region gives an interesting picture.

The Laichiki Nadi and the Lamir Nadi are two right bank and left bank tributaries of Myntdu Nadi flowing in the Jaintia Hills are the example of streams adjusted to the lineaments. The Umngot river which is separating Khasi hills from Jaintia Hills is also flowing across a major lineament . Several right bank and left bank tributaries are adjusted to minor joints in the rocks which flow into the Umngot river. In fact, this river seems to be flowing over a dip slope facing towards west and the scarp face towards east. The toposheet No. 83 $\frac{C}{7}$ show some of the areas around Khliehriat of Jaintia Hills (Fig.11b) where the tributaries of Kailaipai Nala are flowing along the joints in a SW-NE direction. It is also important to note here that all the major lineaments are flowing in a SW-NE direction. The tributaries of Mostem Nala are also flowing in a N-E direction along the minor lineaments.

KHASI HILLS ADAPTATION OF STREAM TO STRUCTURE

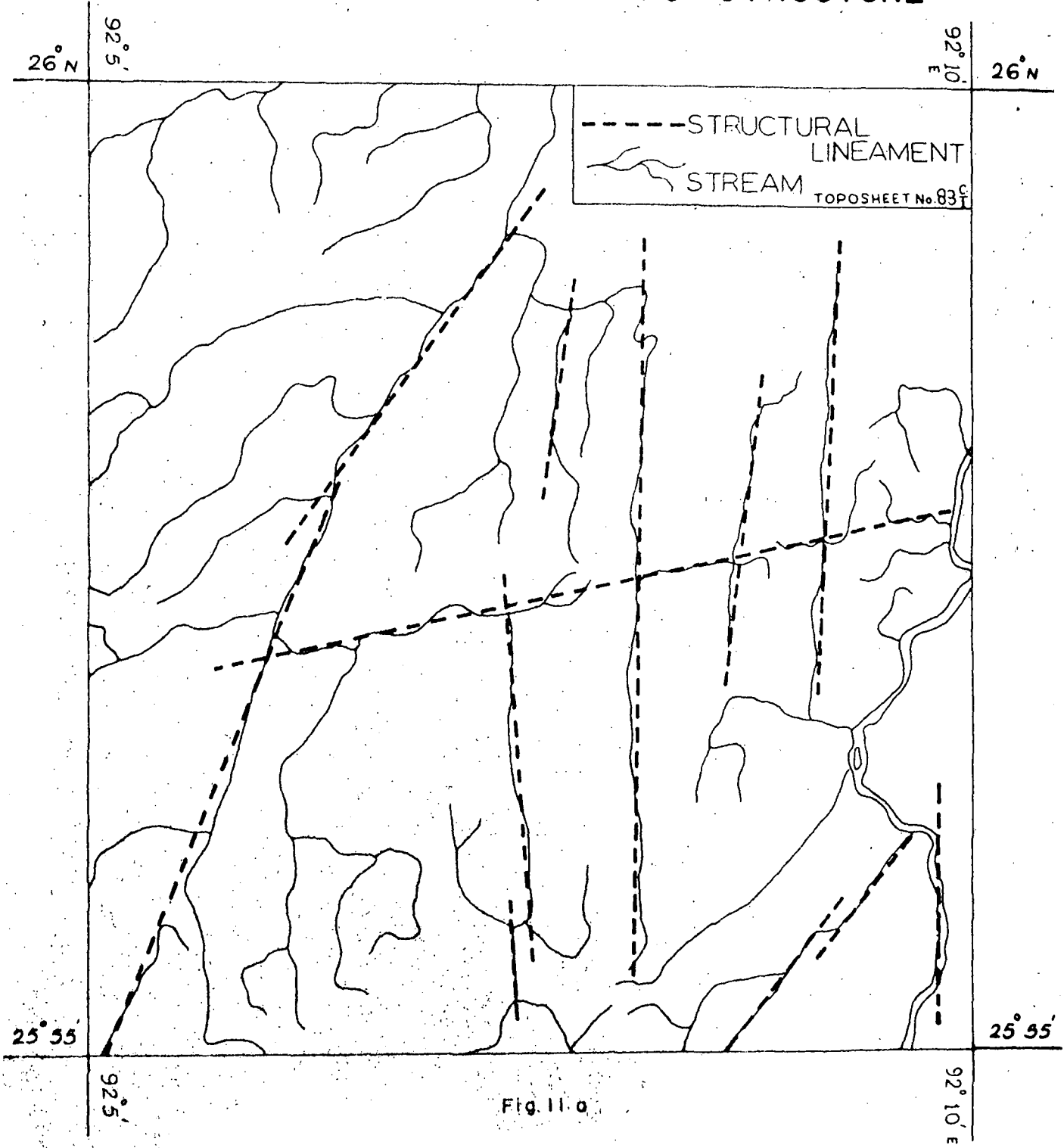


Fig. 11.0

In the eastern part of Khasi Hills the Umseyang river and its tributaries (Fig. 11a) are the example of adjustment to local structure. These small tributaries are flowing along the joints and cracks in a straight course and at places it changes its direction in almost right angle. The tributaries of Mostem Nala are also flowing in a N-E direction along the minor lineaments.

Plate (15) show the Umshirpi Nala near Mahadev Khola (5 km. south of Shillong) an example of adjustment to structure. The toposheet No. 78 $\frac{0}{10}$ reveals certain areas around the central part of Shillong plateau, where a number of small tributaries of Wah Mawlong stream are flowing in a E-W direction depicting their course adjusted to lineaments of the rock structure.

The lineament map of Khasi and Jaintia Hills (Fig. 4b) prepared from the Landsat imageries is superimposed over the drainage map (Fig. 11a). It is found that the above discussed tributaries are acutely adjusted and flowing along the master and minor lineaments.

In the well-known example of the development of scarpland drainage the streams of each class are all at right angles to those of another class and generally conform to the pattern of dip and strike.

The Erosion Surfaces

In the study of geomorphological features of the Khasi and Jaintia Hills, the most significant features are the erosion surfaces. The study and interpretation of the erosion surfaces will help in tracing the geomorphological history of the area under study. The Khasi and Jaintia Hills of Meghalaya display erosion surfaces standing at different levels above the sea. Due to the presence of various rock types in the region and the differences in their resistance to fluvial erosion and weathering, the identification and correlation of erosion surfaces is rather complex. The erosion surfaces of the region have been placed in an order of their development and have been correlated with the geological ages, which seems to be logical and most appropriate for each surface.

It appears that the development of different erosion surfaces has been associated with the Himalayan uplift in different periods. The most important earth movement that is relevant to the formation of the Siwalik Himalaya and the Shillong Plateau in Miocene period, by forming the faults around the plateau (Fig. 5). The plateau is covered by comparatively thin cretaceous and Tertiary strata in the southern parts. The strata forms a monocline dipping steeply in to the Bangladesh plains. Along its axis the monocline is split by the Dawki Fault,

the fault zone being 5 to 6 km. wide. It is nearly vertical in the west and the northern limb is thrust over against the southern limb. Near Haflong at its eastern end, it merges into the Disang Thrust which runs in a north-easterly direction for some 400 km.

According to Wadia (1953)¹, "there appear to have been three important phases of the upheaval of the Himalaya mountain system. The first of these was post-Nummulitic, i.e. towards the end of the Eocene, culminating in the Oligocene, ... It was apparently followed by a movement of greater intensity about the middle of the Miocene, ... The last stage was mainly of post-Pliocene age, later than the deposition of the greater part of the Siwaliks and did not cease till after the middle of the Pleistocene". According to Mithal (1968)² the 'uplift' of the Himalayan chain was initiated during the Cretaceous and continued into the Pleistocene. It is also possible that various phases of crustal movements are responsible for the development of salient relief features in this part, which were caused by the dismemberment of the Gondwana land. Parts of which are submerged under the Tethys sediments. This submerged part was 'uplifted' from the

¹Wadia, D.N. (1953), Geology of India, London, p.306.

²Mithal, R.S. (1968), The Physiographical and Structural evolution of the Himalaya, presented in Rivers and Mountains of India, National Committee, Calcutta.

bed of the sea during mio-pleistocene period (as discussed earlier). This uplifted portion is the present Shillong plateau, and in the process of upliftment its continuity to the Gondwana land was disappeared under the Ganga-Brahmaputra alluvium.

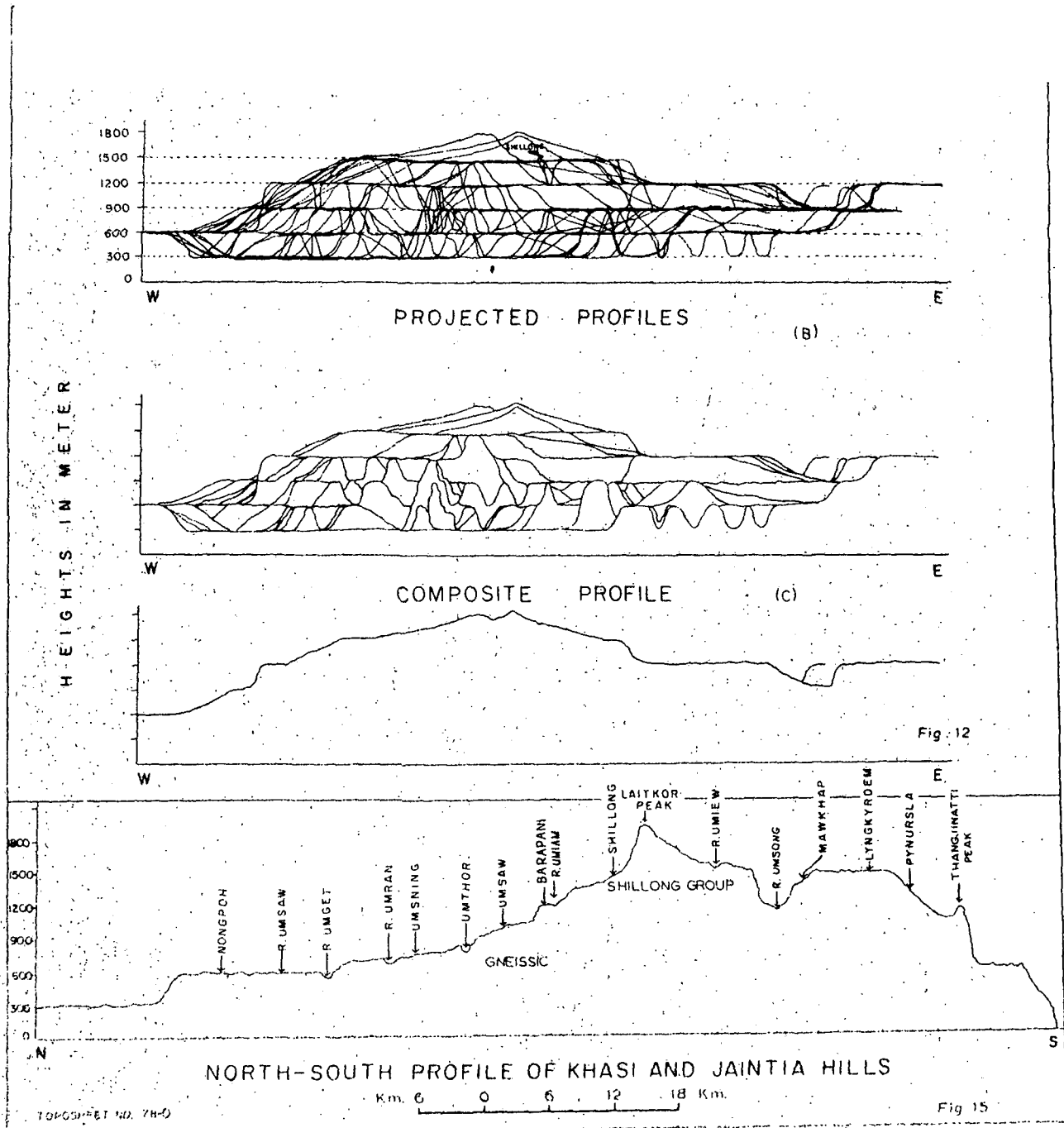
In this light, therefore, it may be stated that the presence of Gandwana surface which was overlain by the newer deposits of Shillong series, are exposed at places because of subsequent erosion, revealing the exhumed Gondwana surface. The present geomorphic features thus, afford the most important clues in identifying the erosion surfaces of the Khasi and Jaintia Hills.

Method of Study

For the identification of the erosion surfaces in the region, different techniques have been applied viz., Superimposed profiles, projected profile, composite profile Longitudinal profiles and Altimatric frequency graph. Subsequently an extensive field work has been done to collect field evidences. During the course of the study relevant literature on the geology of the region has been consulted to understand the geological history of the region. It is emphasized that the ages given to the erosion surfaces are mainly relative and not absolute.

Superimposed, Projected and Composite Profiles

To represent the erosion surfaces of the Khasi and



Jaintia Hills, superimposed, projected and composite profiles have been drawn with due care from quarter-inch toposheets (Fig. 12). Micro-topographical expressions and their agglomerations, and also the isolation at different levels tell the tales of denudational cycles.

A series of profiles have been drawn at half-inch interval with a vertical scale of 2.5 cm to 300 mt. In this manner, the profiles are drawn in east-west direction and all the profiles have been superimposed (Fig. 12a). From the general uniformity of levels of various profiles at different heights, the plains of different erosion surfaces can be identified. The highest summit plains on the profiles are represented at the height of 1500 mt. and the 1200 mt surface occupies the second position. From the profiles, another erosion surface may be recognised at the height of 900 mt. The closeness of profiles show another erosion surface at the height of 600 mt. The recent surface is traced at the height of 300 mt.

Projected profiles (Fig. 12b) have been drawn to relieve the obscurity. These features which are not obscured by higher intervening topographic expressions are accepted to portray a panoramic view. Summit details of various surfaces are outlined. Isolated remnants attaining the elevation as that of the erosion surfaces are also expressed. The undulating terrains visible

through valley mouths of different profiles define themselves as erosion surfaces belonging to pre-Tertiary surface. Composite profile of the area portray the crest line profiles of higher plateau of the central region.

Longitudinal Profiles

Every longitudinal profile is a graph of distance versus elevation. It is a function of discharge load, size of debris, flow resistance, velocity, width, depth and slope. With the valley development these variables become effective in proportion to their capacity. Every variable is inter-related, and from their inter-relation is derived the relation of fall in elevation to distance along the channel, the longitudinal profile."¹

The longitudinal profile of a river is the produced curve of the river course from source to mouth at any stage of its evolution. A break in the longitudinal profile becomes significant, as such break may unfold interruption in the progress of the cycle. It may reflect unick points which have been checked in the field before accepting them as nick points. The youthful features like gorges and waterfalls outline some of the rejuvenated features of its landscape.

¹ Leopold, L.B., et al. (1964) Op.cit., p.251.

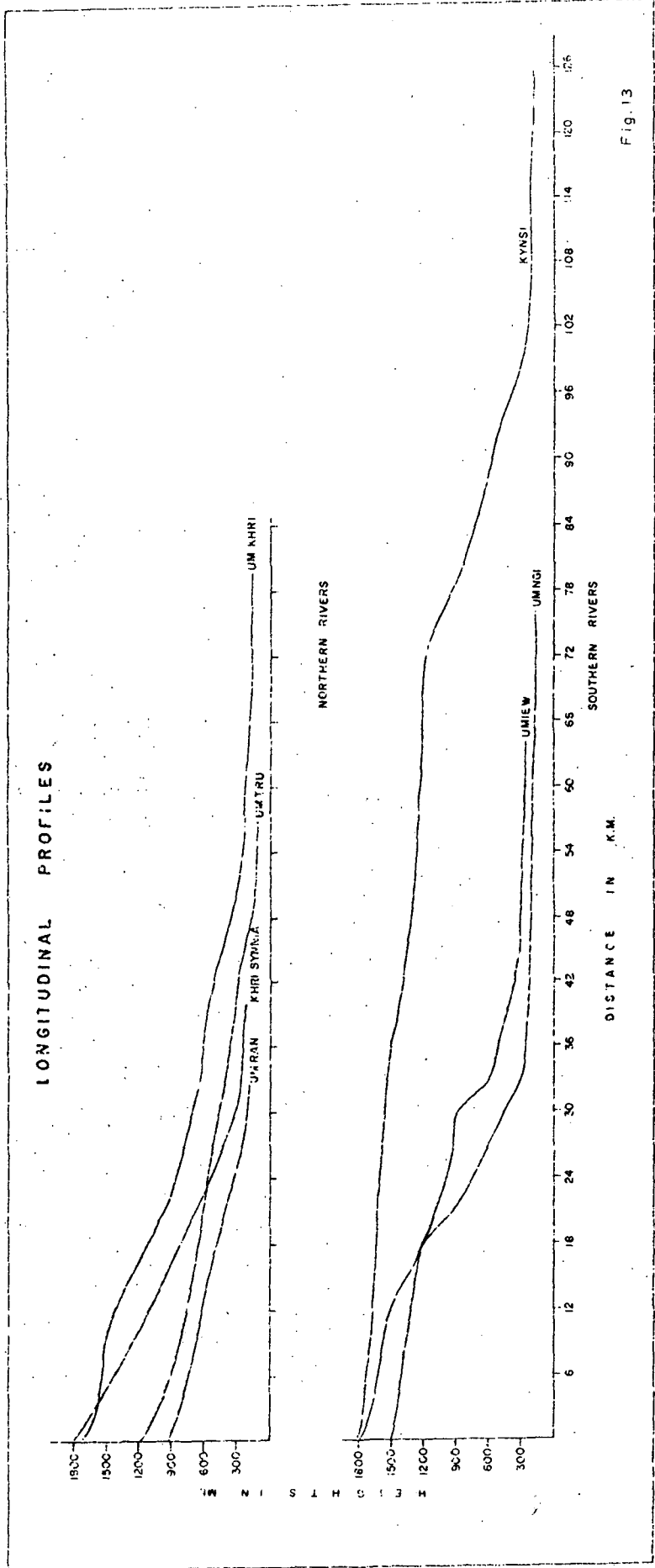


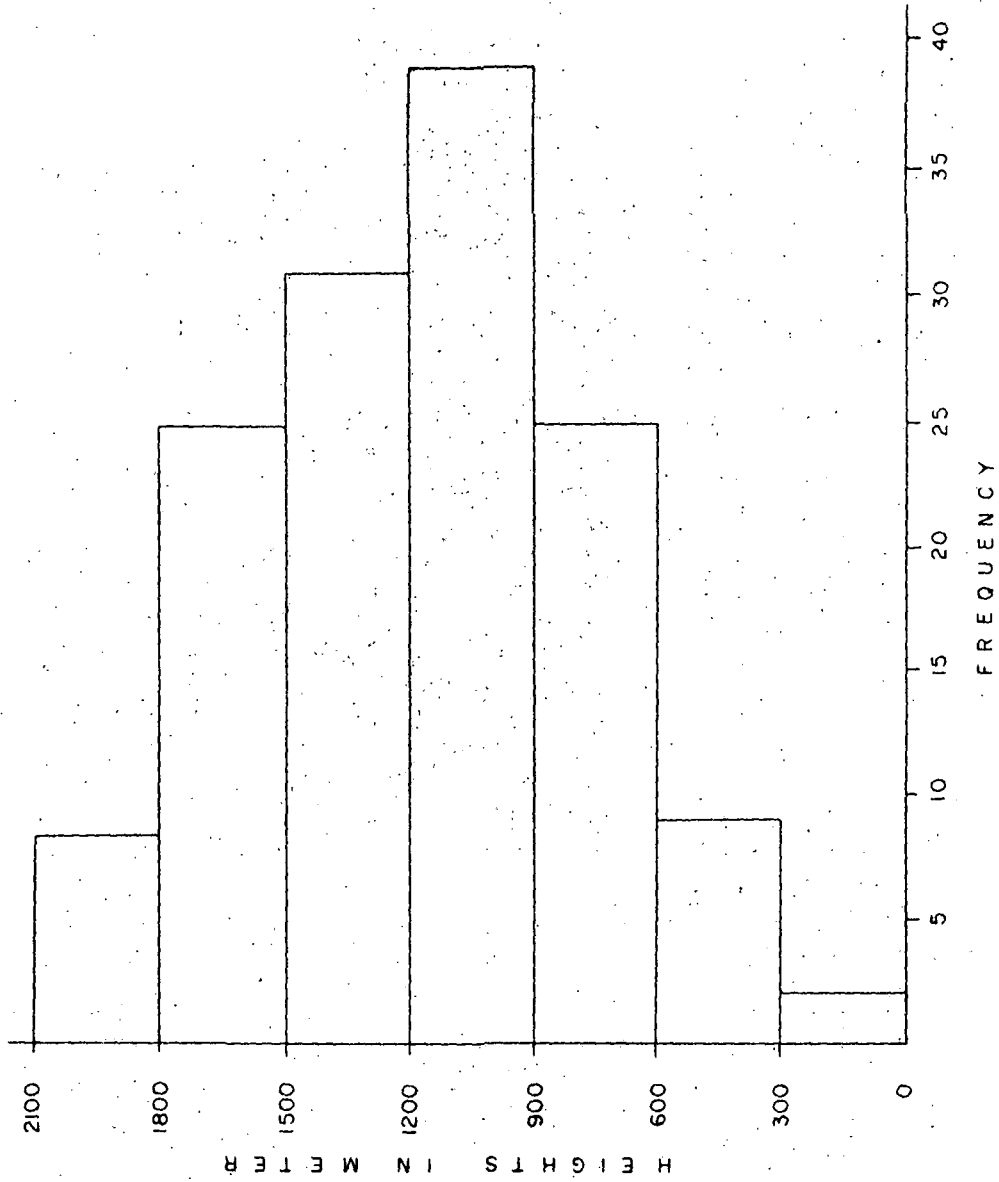
Fig. 13

The longitudinal profile of the Kynshi river (Fig.13), south-west of the Khasi Hills, shows the break-in-slope where there is a gorge marked by a waterfall of 50 mts. height. Roughly 6 km. down slope the river meanders and flows in a S-S-W direction towards Bangladesh plain. The break-in-slope in the Kynshi river distinguished 600 mt. and 300 mt. surfaces. The source of the Kynshi river lies on the 1775 mt. height and after 75 kms. journey shows a break-in-slope of about 300 mts. and is marked by a waterfall of 50 mts. height. From this point the river forms a semi-circular form along deep gorges on the 1200 mt. surface.

The longitudinal profile of Umngi river shows two breaks-in-slope. They define 1200 mts. and 900 mts. surfaces. Again the longitudinal profile of the Umiew river describes one major breaks-in-slope at 1200 mts. surface. with a minor one at 900 mt. surface. These breaks-in-slope indicates the separate surface at 1200 mt. and 900 mt. respectively representing evolution of polycyclic landscape.

The longitudinal profile of Umkhri river shows in general graded profile with a break-in-slope between 35 to 38 kms. of its journey from its source. It is marked by a waterfall of 15 mt. height and enters the 600 mts.

KHASI AND JAINTIA HILLS
ALTIMETRIC FREQUENCY GRAPH



surface. The longitudinal profile of Umtru river show a graded profile. The Umtru river originates from 1140 mt. surface cutting across the Dolerite basic dykes, 9 km. east of Umsning. It defines 600 mt. and 300 mt. surfaces.

Altimetric Frequency Graph

Baulig believes that "the pattern of highest points would define an upper enveloping surface which becomes closer to the real surface as the local relief becomes more gentle."¹ It is also well known that the highest part of the landscape will be the last to loose remnants of the former erosion surface, because the dissection spreads later along the river valleys. The altimetric frequency graph (Fig. 14) for the area has been prepared by taking the frequency distribution of spot heights from a quarter-inch map of the Khasi and Jaintia Hills.* The prepared spot, height frequency graph reveals the nature of topography in the sense that a particular height occupies maximum area and vice-versa.

From the frequency graph it is clear that maximum frequency occurs at the height of 900 mts. to 1200 mts. while the 1500 mts. to 1800 mts. height area restricted

¹Clarke, J.I. (1970), Morphometry from the Maps, Essays in Geomorphology, p.260.

*One-inch toposheets are restricted for certain parts of the region and very few toposheets representing parts of the Khasi and Jaintia Hills are available.

to the central plateau region. The 600 mts. to 900 mts. area occurs on both sides of the Plateau i.e. northern and southern parts. The southern part is capped with cretaceous marine sediments and the northern part is characterized by isolated patches of quartzite residual hills of almost equal heights. In the southern part the Sylhet Trap is exhumed at different river valleys over which the Cretaceous bed is overlain. The streams have developed deep gorges over these surface.

Identification of Erosion Surfaces

The analysis of the superimposed profiles (Fig. 12) Longitudinal profiles (Fig. 13) and Altimetric frequency graph (Fig. 14) and field evidences suggests the presence of at least five erosion surfaces at different heights (against Chatterjee's seven erosion surfaces)¹. These are as follows:

- (i) The Exhumed Gondwana surface (1500-1800 mts.)
- (ii) Cretaceous surface (1200 - 1500 mts.)
- (iii) Eocene surface (900 - 1200 mts.)
- (iv) Pleistocene Surface (600 - 900 mts.)
- (v) Recent Surface (300 - 600 mts.)

(i) The Exhumed Gondwana Surface (1500-1800 mts):
Something exhumed means that it is dug up again, after burial. It is commonly applied to geomorphic

features, particularly ancient relief features, that were burried by such materials as alluvial deposits or transgressive marine sediments. Then at some subsequent date, the former landscape is re-eroded and exhumed. Thornbury (1954)¹ stresses that "little of the earth's topography is older than Tertiary..." and that so-called Pre-cambrian topographic features are most likely exhumed.

The Shillong Plateau comprising the Khasi and Jaintia Hills dips steeply on its southern border. Over the wrinkled faces of the region, intrusion on massive scale resulted. The denudation chronology of the region thus, took a concrete shape in sympathy with the folded structures. The valleys are excavated over its surface. The drainage plain was more or less similar to the drainage organization of the Tertiary fold mountains. The major rivers and their countless tributaries dissected the region removing each folded wrapper. The granites and gneisses were exposed at places. Presence of peneplain ranges in height between 1500 to 1200 mts. above sea level. The central plateau in the vicinity of Shillong presents an undulating surface which might probably be the exhumed Gondwana surface.

¹Thornbury, W.D. (1954), Op.cit., p.26.

(ii) Cretaceous Surface (1200-1500 mts):

The landscape cycle that was initiated since the break up of the Gondwana land obliterated the topography of the region to a considerable degree. Formation of Sylhet Traps also intervened and introduced a change in the landscape. The lower segment of the landscape recorded marine transgression during the cretaceous period. The marine inroad was characterised by the following features :

- (a) the advancing sea extended on either sides of the region.
- (b) The river valleys in the lower reaches were drowned outlining the coastline of that period.
- (c) Marine sediments were gradually recorded in harmony with the extent, depth and lives of the sea. Terrigenous and marine deposits of different orders arranged in relation to the detritus brought by the rivers and marine deposits at varying depths. Marine cretaceous rocks like sandstones and occasional shales and carbonaceous layers attain thickness of one thousand feet to 300 mts or less in the Shillong plateau. The fossil obtained from a place near Therria Ghat is identified as cretaceous deposit.

This chapter of sedimentation has been carved out of the marine chunks of the Jurassic period. Marine sediments lie unconformably over the former eroded landforms. The former Gondwana surface is partially buried beneath them. The story of the Shillong plateau is a complex one, which has recorded various events by establishing and sorting the relict-segments.

The landscape cycle initiated with this change in the base level was marked by the following noted features:

- (i) The former rivers extended their courses over the newly emerged surface.
- (ii) Some consequent streams might have also been initiated.
- (iii) The critical junction between old and new topography was marked by a break-in-slope (as discussed in the longitudinal profiles of southern rivers).
- (iv) The older rivers might have excavated new valleys in the old ones. The juvenile features engraved over the matured topography must have punctuated the new cycle over old ones.
- (v) With the progress of cycle the outstanding features were gradually destroyed.

(iii) Eocene surface (900 - 1200 mts):

The Eocene surface characterised by the Jaintia group overlies the Mahadek formation of Khasi group of cretaceous surface. The rocks consists of calcareous shale, sandy limestone and fine calcareous sandstone. The deposition of these sediments marks the beginning of a table shelf condition which was firmly established later with the deposition of the Shella Formation (600 mt. thick) represented by the alternating limestone and sandstone sequence. The Chengpara formation which appears in the Khasi Hills near Balat an erosional unconformity can be seen. This surface covers the maximum part of Jaintia Hills. The Eocene surface can be traced out over the numerous interfluves present over the Jaintia Hills.

(iv) Pleistocene Surface (600 - 900 mts):

To carve out the story of Pleistocene landscape of Shillong plateau, it is essential to analyse its present morphology in relation to the Tertiary epirogenesis.

- (i) The elevated Shillong plateau ending in scarps unfurls the composite picture of the Khasi & Jaintia Hills.
- (ii) The southern scarp rises steeply and comes under the sway of the summer monsoons recording highest rainfall in Cherrapunji-Mawsynram structural platform on the southern face of the Khasi Hills.
- (iii) Breaks-in-slope between different levels of undulating terrain define surfaces of different cycles.
- (iv) Above and below the deep engravings of the recent periods the undulating peneplains with graded river valleys dominated the landscape.
- (v) The plateau is drained by Jadukata, Umngi, Umiew, Myntdu, Um Ngot etc. in the southern part and Kopili, Umkhem, Umran, Umtru, Umkhri etc. in the northern part.

The Pleistocene landscape cycles explain most of the elements of landscape outlined above. The imposing scarps, step lands, varying levels, juvenile features and bunches of drainage alignment reveal punctuations in the progress of cycles.

The northern part of the region has an undulating topography hills after hills rising to the same height and extending northwards to the Brahmaputra valley. The accordant summits of these hills vary between 170 and

820 mts. The region is characterised by large older alluviums covered depressions as well as deep valleys. The presence of Byrnihat-Nongpoh peneplain is a marked characteristics of this part of Khasi Hills. Remnants of former cycle of erosion can be noticed clearly from the exposed granitic boulders and gneissic complex over which lies a thick layer of laterite and eroded material. The presence of residual hills scattered all over the region also indicates the erosion surface. The geology map (Fig. 2a) of Khasi Hills reveals areas of older alluvium which are deposited during the Pleistocene time on the southern border of the Khasi & Jaintia Hills.

(v) Recent Surface (300 - 600 mts):

From the study of the superimposed profiles (Fig.12) it is clear that in the region especially astride the major rivers, recent surface is in developing stage. The rivers are still deepening their valleys. From the study of superimposed profiles and field observations, it is clear that this surface is developing at the expense of the Pleistocene surface. The old surface has been gradually destroyed along the river valleys and its remnants are only noticeable on northern and southern side of Khasi and Jaintia Hills.

During the study of erosion surfaces of the region,

the researcher has tried to keep in view, the factors such as rock resistance. It may be suggested that the erosion surfaces of this region must have been formed by sub-aerial erosion. From the above discussion it may be said that the Khasi and Jaintia Hills presents a polycyclic landscape which defines peneplains at varying altitudes of 1500 mt - 1800 mt. Shillong and Laitkor Peaks, Shillong and in Laitumkhrach valley, around Barapani and Nongpoh area at the height of 1200 and 900 mts. around Byrnihat at the height of 300 mts. Distribution of different Quaternary recent alluvia in the Brahmaputra valley suggest the persistence of differential movements. The stepped landscape within the massif had formerly been explained in terms of seven cycles of erosion by Chatterjee, (1965)¹, the highest and oldest being the base of the sedimentary capping correlated with the Gondwana surface. It is now seen that scarps separating different topographic levels coincide with traces of fracture faults some of which are very young.

The region has a long geomorphic history in which, from time to time, the cycle of erosion has been interrupted. This along with the structural variations have given rise to varying nature of drainage patterns and slope which are revealed very well in the former and later

¹Chatterjee, S.P. (1965), "Physiography", The Gazetteer of India, vol. I, p.28.

studies in this work. With this background, the present fluvial cycle of erosion in the Khasi and Jaintia Hills may be studied.

Fluvial Cycle of Erosion

Of equal importance in landscape are the erosional features produced by fluvial action. The climate which is characterised by heavy rainfall favours this action of streams to a considerable extent. Hence, during rainy season, the streams flow with high velocity. It is clear in the season, that the weathering and erosion processes on the hill slopes are strengthened by the action of gullies and rills particularly along joint planes and fissures of rocks (Plate- 16). Further it is worth-noting that the periodity of the water-flow is in itself a factor in shaping the local landscape of the area. During rainy season streams and gullies are formed due to erosion. Slopes of the hills are covered by green vegetation during cold seasons and thereby slow down the erosion processes. Only rill action can be noticed on steep slopes (Pl. 17).

Valley formed by the streams are narrow and deep and both sides are bordered by steep slopes, mostly in the southern part of the area (Pl. 18). Steepness of slope gives high velocity to water combined with heavy

rainfall are two main factors which results in the depth and narrowness of the valleys.

According to the cyclic theory the influence of geologic structure on relief is most marked during the stage of maturity. In a youthful relief like Khasi and Jaintia Hills of Meghalaya it is being observed that the streams gradually penetrate and are engaged in deepening their valleys by headward erosion. The east-west running central upland of the Khasi Hills covers about 5000 sq.km. which is demarcated by a 1500 mt. contour line as its outer limit. This zone consists mostly of rolling grassy downs, intersected with river valleys and dotted all over with rounded hills. The upland contains remnant of several peneplained surfaces, ranging in height from 1500 mt. to 1800 mt., thus preserving the several traces of erosional cycles in this part. The Shillong hills contains the highest peneplained surface, trending ESE - WNW, over which streams meander before plunging into the deep valleys of the Umiam and the Umkhen. The region has a youthful topography as is evident by the presence of many rapids and a number of waterfalls in the neighbourhood.

It has been observed in and around Shillong plateau a number of erosional features, (which has been studied by field work as well as with the help of one inch to one mile topographic sheets) showing a large part of this region being an youthful topography.

A careful study of topographic sheets and with the help of field observations a number of erosional features are found in this region, where granitic, sandstones and limestones are available predominantly. Escarpments, faults, plateaus, recession of slopes, bed-load boulders, canyons, dissected plateau, faulted flat area close to plateau top, headward erosion, kinck-point, a number of small and large waterfalls of varying heights, dominate the present landscape of Khasi and Jaintia Hills. These features which show that a large part of the region, yet to attain the maturity stage of the cycle of erosion. Although some parts are seem to be matured. These could be the traces of former erosion surfaces.

A glance at the drainage map of Khasi and Jaintia Hills (Fig. 8) would reveal that the eastern and north-eastern portion of the Khasi Hills is drained more intensively and densely than any other part of the region. The region show, that valley deepening by the rivers is more conspicuous than their widening. The stream divides are generally broad and poorly defined.

In Jaintia Hills most of the area is drained by a number of short tributaries. Most of the valleys are 'v' shaped, and generally lacks in the development of floodplains. Inter-stream areas are extensive and drained only by parallel streams which are rather irregularly drained.

During the field work the researcher has marked some distinct characteristics of the area under study. The erosional relief is characterised by the following features:

A co-existence of steep slopes and wide valleys. The plateau breaks up at its margin into a series of narrow ridges occasionally interrupted by depressions that may be quite deep and may wider into embayments several kilometers wide. The relief is thus very much dissected and deeply hollowed out; the amount of erosion may be judged from the mass removed. Nevertheless, the slopes are steep even though they have retreated quite a distance. Their average gradient is usually more than 30 degrees to 45 degrees. Abrupt escarpments are common; they frequently show up through the vegetation adding a picturesque touch to the landscape. Abrupt slopes are not only located on cuesta fronts; they exist on the flanks of innumerable valleys in the most diverse structural positions.

The above regional picture shows that the general topography of Khasi and Jaintia Hills is in a youthful stage. In places, the study of drainage characteristics and topography reveals the traces of former erosion surfaces which are the result of recent upliftment of the plateau. The region has been uplifted in the recent past, so the streams have again acquired energy to deepen

their valleys. The streams are actively engaged in headward erosion.

It is concluded, in view of the evidences discussed in the preceding paragraphs that after the prolonged denudation of the basement complex the whole area might have submerged beneath a shallow sea in which the sediments were deposited. This sedimentation was accompanied by the intrusions of basic sills and dykes. Because of diastrophism the whole sediments were folded, faulted and metamorphosed and eventually rose from the sea to form land. This might have followed by the intrusion of the Myllem Granite in the form of quartz-tourmaline veins in the area.

After this uplift, the area has never ~~sub~~ subsided below sea level and as such has long experienced sub-aerial erosion. This is supposed by the drainage pattern which is controlled by the structures of the area.

CHAPTER - V

SLOPE ANALYSIS

Introduction

Like other branches of geography, the study and objective of geomorphology have changed considerably since the end of the Second World War. In the modern age of resource consciousness and planning, various disciplines have not only developed their applied aspects but look more and more for providing scientific, analytical and quantitative basis for developmental projects. Morphometric analysis of regions of different scales, shades and grades, is also a field of integrated approach for allied disciplines like geomorphology, geology and hydrology etc. Such studies provide fundamental background for multiple developmental planning.

Since the classic leadership of Davisian concept of fluvial cycle of erosion an attempt of genetic or evolutionary sequence of landform development in terms of structure, process and stages, Penk's (1953)¹ emphasis to work on slope, forms and angles and process through waxing and waning developments leading the stage of pediplanation

¹Penck, W. (1953), Morphological Analysis of Landforms, London.

and the recent quantitative approaches and methods of morphometric evolution of an area evolved and suggested by geomorphologists of various shades and styles like Smith (1933)¹, Kesseli (1946)², Russell (1949)³, Strahler (1956)⁴, Schumm(1966),⁵ Durray (1963)⁶, Young (1971)⁷ and Hammond (1964)⁸ have contributed a great deal in physiographic investigations and researches directed towards the evolution of earth's surface. The insistance is on the inventorying of areas, altitudes, volume, slope profiles, texture of the concerned landforms through morphometric measurements including the evolution, process and stages of developments.

Hillslope Development and Evolution

Slopes have been a favourite subject for research by geomorphologists for many years, but they have also been intensively studied by agricultural and civil engineers

¹Smith, G.H.(1933), "Relative relief of Chio", Geog. Review, Vol. 25, p.272.

²Kesseli, J.E.(1946), A Neglected Field : Geomorphology Annals A.A.G., Vol. 36, p.93.

³Russell, R.J. (1949), Geographical Geomorphology, Annals, A.A.G., Vol. 39, p.10.

⁴Strahler, A.N. (1956), Quantitative Slope analysis, Geol. Soc. Americal Bull., 9, vol. 67, pp.570-96.

⁵Schumm, S.A. (1966), "The Development and Evolution of hillslopes", Jr. Geol.Education, 14(3), pp.98-104.

⁶Durray G.H.(1963), The Face of the earth, Pelican Books, p.39.

⁷Young, A.(1971), "Slope profile analysis - The system of best units". Slopeform and process, Int. Brit. Geog. Sped. Pub. No.3, pp.1-13.

⁸Hammond, E.H. (1964), Classes of landsurface form in the fortyeight states of U.S.A. Map supplement No.4, A.A.A.G. Vol. 54, p.108.

and by soil conservationists.¹ The study of hill slope form and evolution may, under ideal conditions, be a simple process, and this is the situation in rapidly evolving bedlands. However, in most cases lithology, structure, geologic history and climate considerably complicate the interpretation of slopes.

Due to these complications the techniques of soil mechanics, hydraulics and rock mechanics may be invaluable in many situations, but the complexity of the field situation precludes the development of generalizations applicable to all slopes. Hence, the *régour* attained in studies of river morphology, in which many empirical relationships and laws have been discovered, has yet to be achieved in slope studies. At present it also seems unlikely that hill slopes may be the result of operation of different processes at different rates (Schumm, 1966).² In fact, Dylik (1953)³ felt it necessary to define the vocabulary used by students of slopes, because of "the amazing absence of any precise definition of the slope, and the scarcity of opinions concerning the meaning of that term in geomorphology."

It is surprisingly difficult even to describe the geometry of a natural slope. One is commonly provided with

¹Schumm, S.A. and M. Paul Mosley; (1966) *Slope Morphology* (Ed.), p.1.

²Schumm, S.A.(1966), The development of evolution of hillslopes, *J. Geol. Education*, 14(3), pp.98-104.

³Dylik, J. (1953), Op.cit., pp.1-40.

only a profile surveyed down the steepest part of a hillside as a description of the slope, but obviously a profile measured along the crest of a descending ridge will have a significance very different from that of a similarly shaped profile measured along the bed of an adjacent gully. Slopes are irregular surfaces that cannot be described by simple mathematical equations. The best topographic maps are only approximations of the infinite irregularities of hill sides. "We do not yet know what degree of irregularity is significant in the stability of slopes, so we are never sure that we are measuring the correct angles and distances."¹

A slope may be formed by a covering of weathered rock resting on bed rock. Another type of slope consists of bed rock, forming the basal slope, covered by a weathered rock, often including a surface layer of soil. There are three important factors which influence the development of hill slopes :

- (i) The earth surface has relief and hence slopes because a variety of internal & endogenetic forces have raised parts of it to a considerable elevations above sea level. The initial slopes caused by such movement will depend on the rapidity of the uplift and the material which is being raised. Many of the older theories of slope development envisaged separate periods of uplift followed by slope and river development.

¹A.L.Bloom, (1979), Geomorphology, pp.187-88.

- (ii) Both the weathering and transport of materials on slopes are affected by climate. In considering slopes it is important to realise the influence of ages of glaciation and periglaciations.¹ The slopes may be mantled by material deposited there by glaciers and present a form quite unlike the bed rock profile they underlie.
- (iii) The activity of the stream at the base of the slope is important. It removes the material conveyed to it from the surrounding slopes. It sometimes moves around the bottom of the valley and under-cuts its banks. Thus, the slipping of materials on slopes and the removal of sediments from stream banks are but parts of a continuum involved in drainage basin dynamics.
- (iv) Man has had a considerable influence on slope development through agriculture and industrial activities.

There have been two philosophies about studying slopes:

- (A) An older school deduced the systematic changes of slope forms that would accompany long-continued subaerial weathering and erosion. Because landscape evolution is too slow to be witnessed, deductions concerning the changes of slope form with time were based on assumptions that could not be tested until we had isotopic techniques for dating old land surfaces. It is no wonder that the deductive approach to slope analysis has enriched geologic

¹Hauwell, J.D. & Newson, M.D. (1969), Techniques in Physical Geography.

literature with some remarkably opinionated and authoritarian writings. A majority of deductive geomorphologists have held that slopes, especially in humid regions, become lower and more broadly rounded with time. A vocal minority have insisted that slopes are stable forms with angles controlled by rock type and weathering processes, and when a stable slope has evolved, it persists through time, migrating backward parallel to itself unless it is eliminated by the intersection of other slopes. For an excellent review of the classic debate.¹

- (B) Another group of geomorphologists have concerned themselves with the empirical description of slopes. With less regard for theoretical projection into the future, they have studied the processes of slope formation and the geometry of slopes. Innumerable slope profiles and descriptive texts have been published, but empirical study has suffered from the lack of a guiding theory. Only dedicated and persistent workers continue to seramble up and down hills with measuring tapes and levels (Bloom, 1979).²

Thus, the study of slopes in the Khasi and Jaintia

¹Von Engel, O.D.(1942), Geomorphology, The Mac Millan Company, New York, pp. 256-67.

²Ibid.,

Hills of Meghalaya state will bring the nature and characteristics of development of slope profiles. The impact of man in this hilly terrain may clearly be noticed in the modification of slope profiles. The domination of tribal population has its own cultural impact in the practice of agriculture. The practice of (jhum) shifting cultivation in the study area has greater influence in the modification of the slope profiles of the region. Thus, the study of slopes in such a region where practice of shifting (Jhum) cultivation had continued since historical past needs intensive knowledge of the changing nature of relief of the region.

Hillslope Elements

Studies on the nature of formation of hill slope elements, surfacial deposits and landuse in different parts of the country had been very few and even though a few studies have been carried out by a few geographers interested in the field of geomorphology. The North-East Region of India which is mainly a hilly terrain, excepting the plains of Brahmaputra with multicyclic landscapes lacks totally in such studies. In India, it is not yet fully realised by geographers the amount of useful data, one can get from a detailed study of hill slope elements, surface soils and landuse of terrain. Such types of detailed studies could be

formed as a basis for the further planning of the agricultural landuse as well as for horticulture and development of forest resources - and selecting favourable sites for settlements and housing (see Chapter-VII).

In Indian context very few studies on hill slope elements and hill slope profiles have been done. Some of the important studies on this aspect are as follows : Prativa Devi (1970-71),¹ Rai (1970-71)², Rai (1981)³, Rai et al.(1981),⁴ Anilkumar and Devendra Kumar (1981)⁵ are some of the studies on hill slope elements of Chotanagpur plateau, Shillong Plateau and Sagar plateau, Madhya Pradesh. Anil Kumar's book on Geomorphology of Simdega and its adjoining area deals with a separate chapter on the study of hill slope characteristics. Anil Kumar and Pandey (1982, pp.259-270), and Dhinwa (1982, pp.271-282) in Sharma H.S. (Ed. 1981) book "Perspectives in Geomorphology - vol. IV; are some of the distinguished study on hill slope elements. Again Pandey (1968), Sharma and Padmaja (1979), Sharma et. al, (1978) and Subramanyan (1976) have studied on hill slopes of Jodhpur, Mej Basin and Morel Basin of Rajasthan and Sagar (M.P).

¹Devi, P. (1970-71), "The Character of Slopes in the Scarp zone of Chotanagpur", Geog. Outlook Vol. VII.

²Rai, R.K. (1970-71), Op.cit., pp.170-175.

³Rai, R.K. (1981), Op.cit., pp.65-71.

⁴Rai, R.K. and et. al. (1981), Op.cit., pp.359-364.

⁵Anil Kumar & Devendra Kumar, (1981), Slope Morphology of Pre-Cambrian Residual Hills, Monghyr.

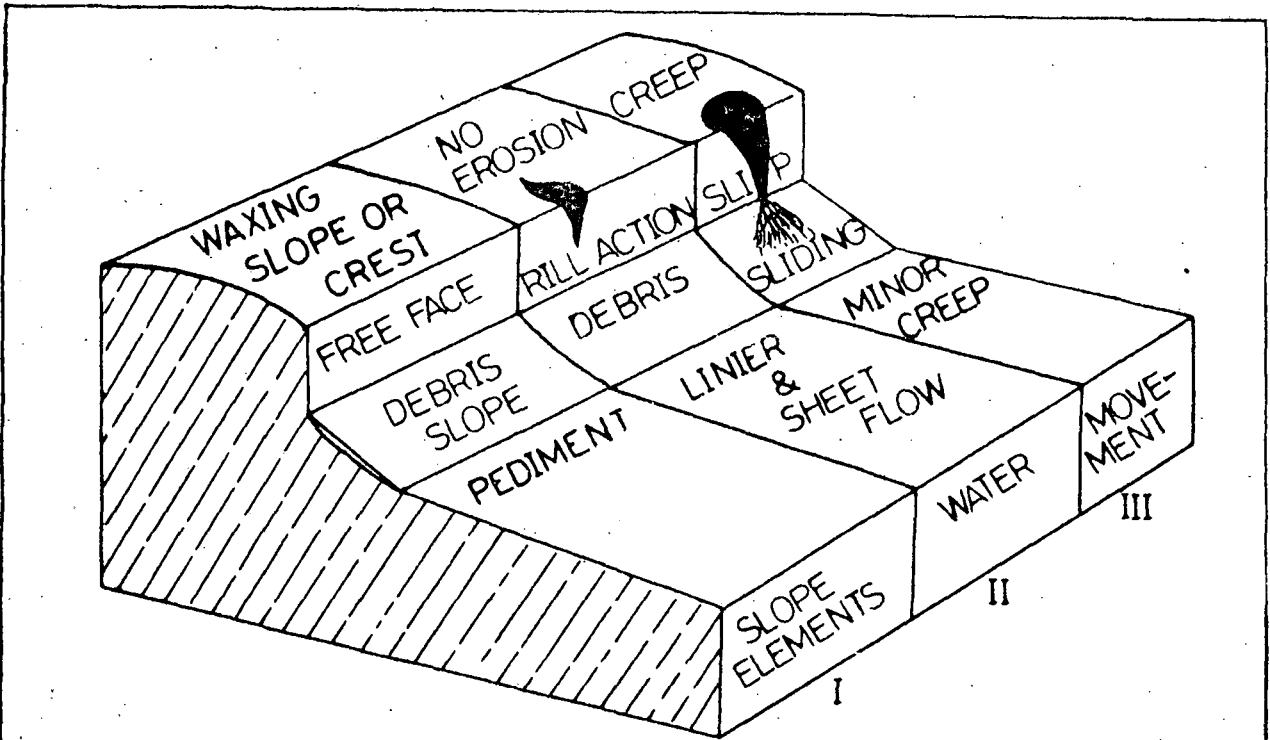


Fig 16a
ELEMENTS OF FULLY DEVELOPED HILLSLOPE (AFTER KING 1962)

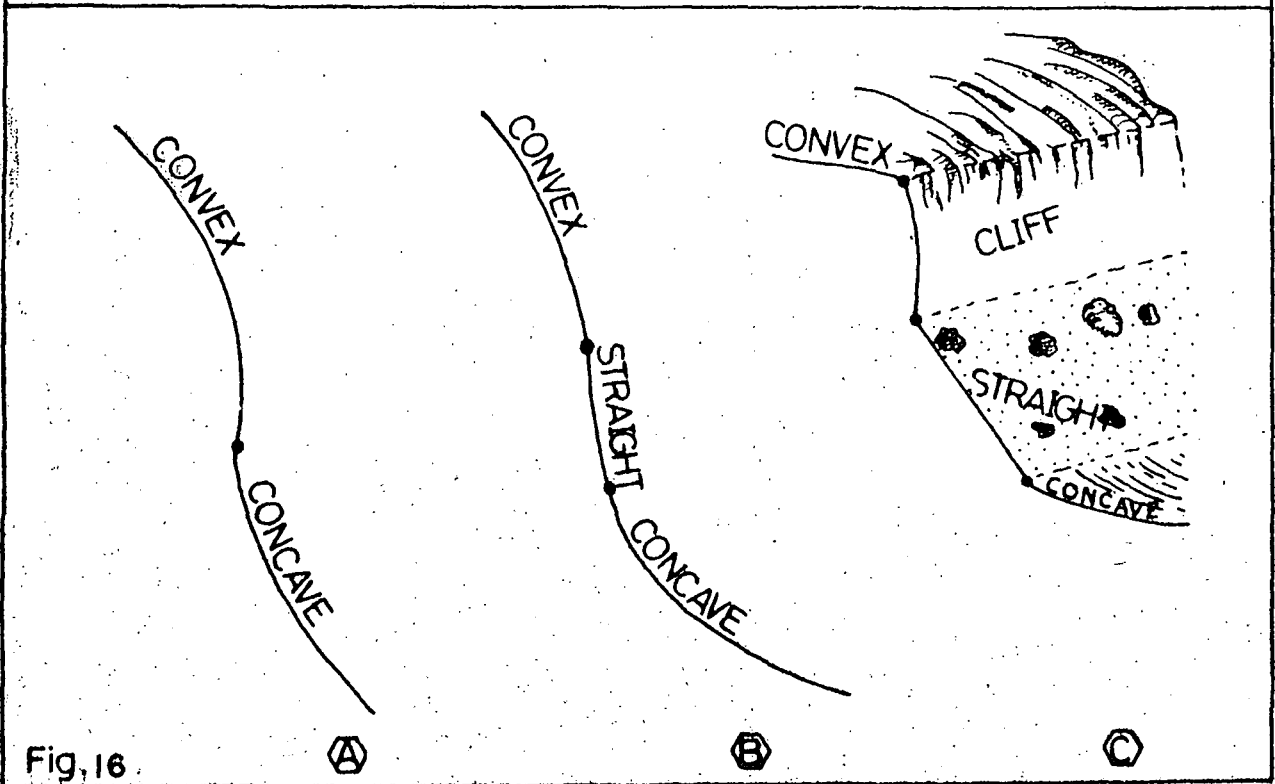


Fig. 16

The starting point for modern hillslope study in the analysis of hillslope form by Wood (1942)¹ who distinguished the four elements that appear in a fully developed slope (Fig. 16). These are from the top :

- (i) the Waxing slope
- (ii) the free-face
- (iii) the debris or talus slope, and
- (iv) the Pediment

Each element undergoes a semi-independent evolution though of course, on a given slope the elements to a greater or lesser extent react upon each other. Any element may be absent from a given slopes profile, which is then not fully developed. Woods (1942)² contribution is sufficiently important as it is basically uniformitarian in character for it applies to hill slopes all over the world, in all stages of development, and indeed of all geological ages.

In this chapter, therefore, an attempt has been made to study the actual characteristics of hill slopes and soil characteristics of some of the important hillslopes of Khasi and Jaintia Hills of Meghalaya state. As a matter of fact, the study area is very big for the study of detailed and extensive hillslope elements, therefore, the researcher has choosen a small area 'in and around

¹Wood, A. (1942), The development of hillside slopes, *Proc. Geol. Assoc.* 53, 128-40.

²Ibid., p.130.

HILL SLOPE PROFILES

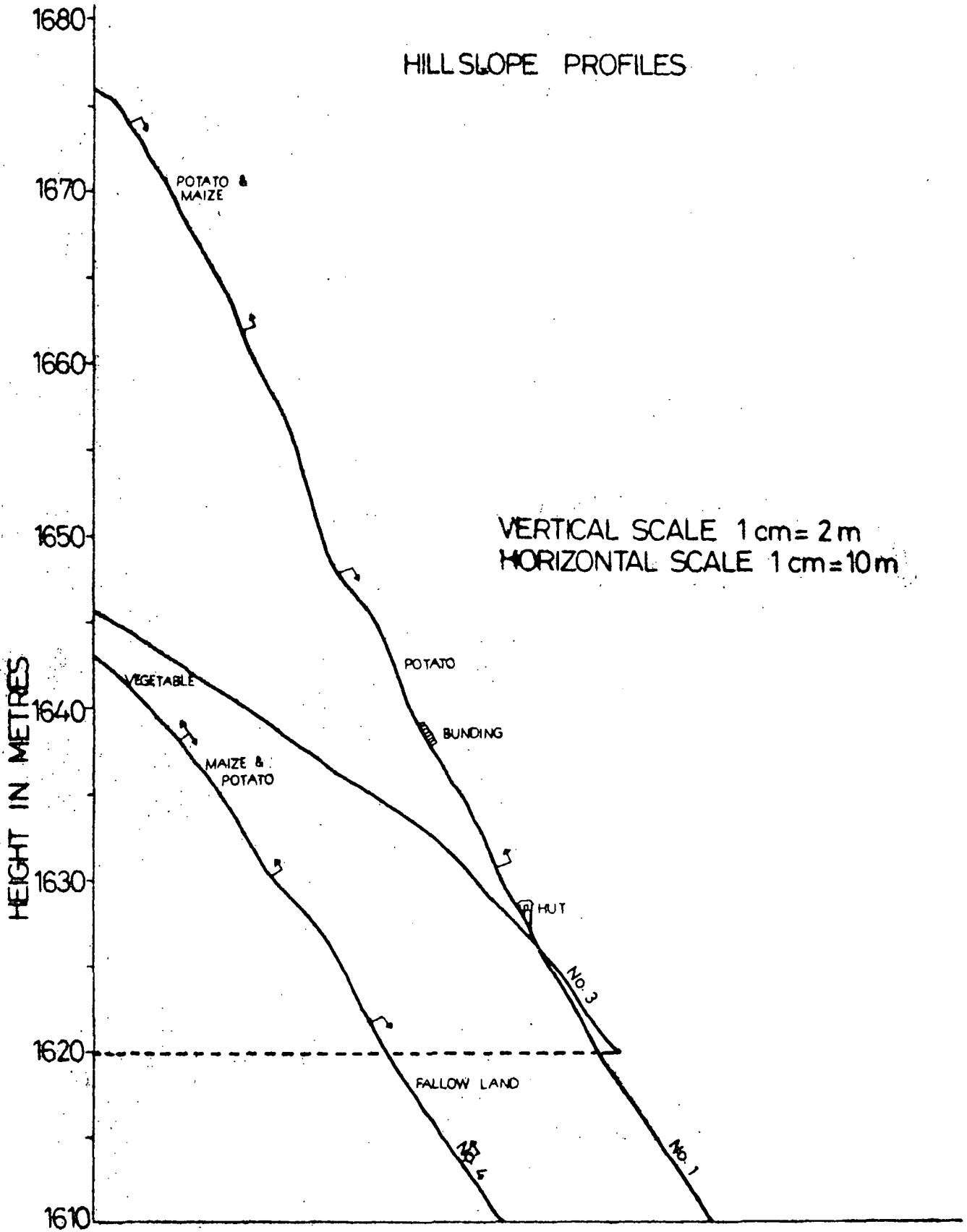


Fig. 17a

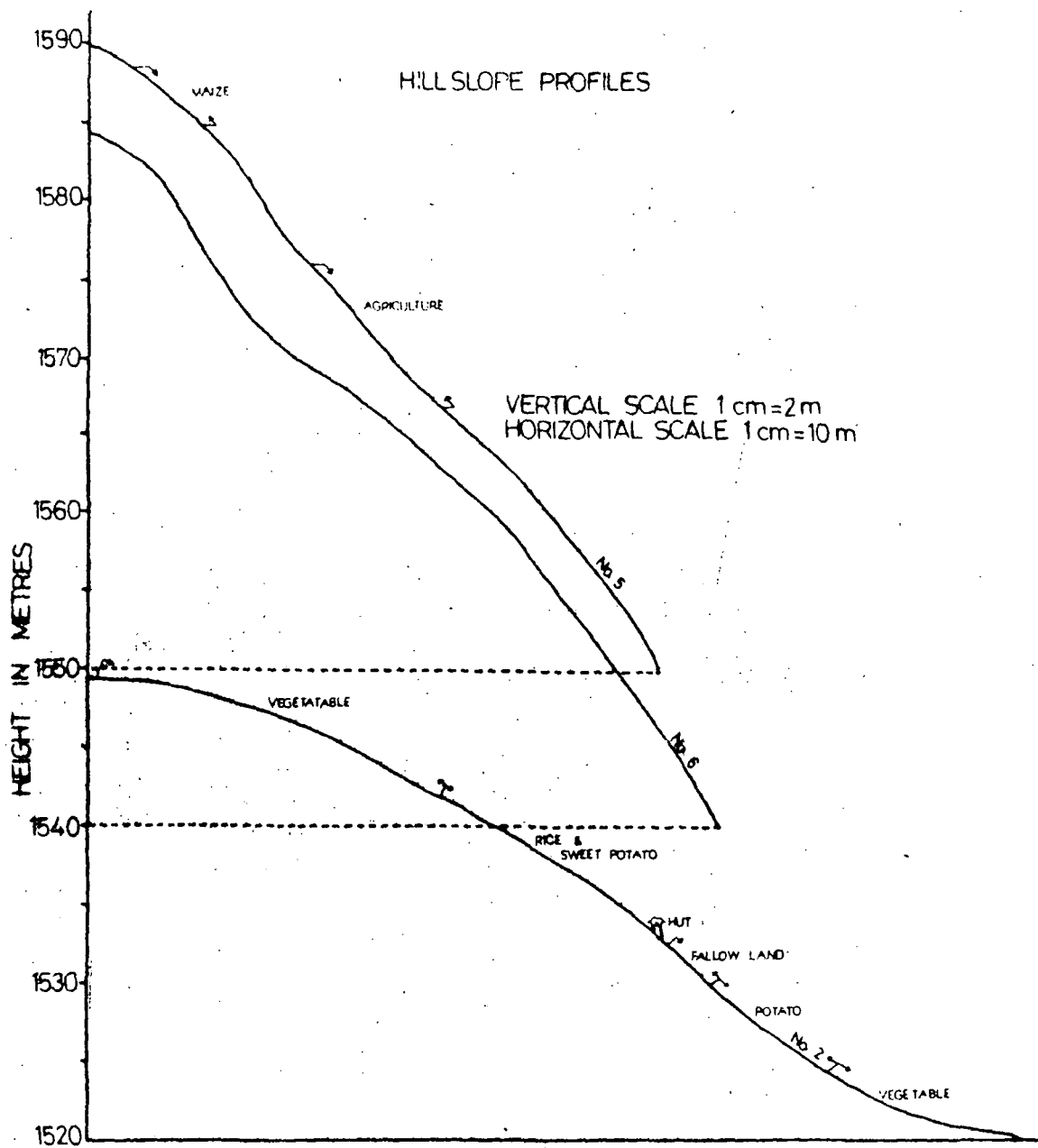


Fig. 17b

Shillong' for the said study. Due to long geological history of the region, the topographic and structural characteristics of landforms are quite complex. The region exhibits the multicyclic landscape of isolated rounded hills varying in height and deep narrow 'V' shaped valleys. The rock formations are covered along hill slopes with thick weathered lateritic soil. The big rock boulders are exposed at some places on the surface. For the analysis part of hill slope elements, the researcher has surveyed six hill-slopes and drawn profiles for them (Fig. 17 a & b), although this work was quite tedious, labourious and time-taking. Due to steep slopes in some of the hills, sometimes it was very difficult to move from one place to another with the theodolite and staff. It has been observed that "the nature of slope profiles around Shillong is quite different from the Vindhyan country."¹ In some hill slopes the scarp or free-face is missing and the whole surface is covered by thick debris slope, in other words the scarp or free-face is not fully developed or it has disappeared through time or has been covered by debris and ultimately the free-face is now totally missing.

(i) The Waxing slope or the Crest

This part of the hill slope is the convex crest of a hill scarp, usually related to the zone of weathering.

¹Rai, R.K. and et. al. (1981), op.cit., p.2.

It is usually longest where the depth of surficial debris is greatest, e.g. where streams have not yet fully developed.

The profiles that have been discussed here show, the crest slightly convex and is less extensive in nature. The top surface exhibiting a slight slope towards its edge. The surface is covered with thick weathered reddish lateritic soil. The thickness of the surface soil is more than one metre in profile No.1 whereas in profile No.2 it is less than one metre. Interestingly enough, it is found that the thickness of the soil within the same hill varies from place to place, i.e. it varies from one slope element to another. The crest of the profile No.3 is covered with thick pine forest, while in other hills the vegetation is totally destroyed and shifting (jhum) cultivation is practised extensively. Due to loose surface soil and heavy rainfall, the rills descending down the slope are flooded with the weathered material in the form of solution or suspension. In those profiles (except No.3) due to the practice of (jhum) shifting cultivation, the tribals cut the trees and clear the land for cultivation, which gradually accelerates the process of soil erosion. Heavy rainfall cause intensive gullying and transportation of large volumes of debris in the form of lateritic soil.

(ii) Debris Slope

The debris slope consists of detritus slipped or fallen from the free face are resting at its angle of repose against the lower part of the scarp face. As this debris is weathered to finer detrital grades, it is removed under erosion and so the debris slope retreats in essential conformity with the free-face above. Clearly, if the free-face retreats more rapidly the quality of waste supplied will build up the debris slope to bury the lower scarp face so that a balance is generally struck between these two elements.

In this case, immediately below the crest the slope gradually is covered by debris and continues to a long distance. The angle of slope varies from 30 to maximum upto 70 degrees. It is an extensive zone of slope profiles. Around Shillong, the hill slope profiles which have been prepared show that along those hills the debris surface is most active zone from farming point of view. Although the degree of slopes in profile No.1 is to a maximum of 70 degrees at the height of 1955 metres, while in profile No.2 the maximum slope is 42 degrees at the height of 1530 metres. In profile No.3 maximum slope is 50 degrees at the height of 1625 metres. In profile No.4 the maximum angle of slope is 62 degrees at the height of 1625 metres.

In profile No.5 maximum angle is 52 degrees, while in profile No.6 maximum angle is 53 degrees at the height of 1575 metres. Thus in all the profiles the angle of the debris slope is under active agricultural practice. The angle of debris slope depends upon the rate of erosion and the accumulation of the material coming down from the crest. Except in profile No. 3 above, the other profiles are devoid of vegetation. The profile No.3 shows the thick cover of pine trees. In other hills due to putting the land under cultivation, the trees have been cut. It is noticed that even upto slope of 70 degrees the parallel narrow strips along the slopes are prepared. Thus, the land on the slope is divided into strips and channels. To check the soil erosion at a particular distance the position of strip and channels are changed. The most important crops grown on these slopes are maize, potato, sweet potato and infrequently high altitude paddy. The tribal people have the traditional background of farming along such steep slopes. Although they do not have the modern scientific knowhow about improved agricultural techniques, but then, they are following the traditional techniques from their long experience.

(iii) Pediment

The pediment is a broad concave ramp extending from the base of the other slope elements down to the bank or

alluvial plain of an adjacent stream. Frequently its profile approximates to a hydraulic curve and it is unquestionably fashioned under the action of running water, though the cut rock surface may often be mantled with surficial deposit.

In profile No.1 and No.2 the pediment surface is noticed at the height of 1620 metres and 1525 metres, while in other profiles the pediment surfaces are not well marked. In most of the profiles the pediment surface is quite important from landuse and settlement point of view. In profile No.1 along pediment surface the land is put under Maize and potato cultivation and settlements are also seen on this surface. The thickness of soil is also between 3 to less than 1 metre. The pediment surfaces in this area are over Archaean granites. These seem to have formed by sheet wash and gradual recession of the debris slope. In the present study area, the pediment surface is not well marked and the minimum slope angle reaches even upto 15 degrees. The angle of slope indicates that they hills have more angle of slope than it is to be noticed on pediment surface. It appears that due to intermittent upliftment of the region the topography has very much dissected into steep slopes and deep narrow valleys. Thus the process of recession of slope is not well marked and it could not develop the well marked pediment surface.

In comparison to the Vindhyan country and the Deccan Traps¹ the pediment surface is not well developed. Slight irregularities in profiles are noticed on this surface. The sheet erosion is a main process of surface wash. The soil contents in the form of material also vary from one profile to another. This surface generally consists of heterogeneous materials of varying particles which accumulate on the lower parts of the hill slopes. The rock pieces and particles which have been transported by gravity and running water have deposited on this surface.

The study of slope profiles around Shillong indicates the intimate association of soils and terrain. Therefore, it is relevant to inquire in details the mechanism of this relationship. The association of particular soil with distinct slopes will demarcate different zones of landuse. It is also noticed that the agricultural practice around Shillong displays striking variety which has been developed under the influence of rapidly changing socio-economic forces operating in the context of limitations and potentialities of physical environment.

The production of Maize and potatoes per hectare is quite low in comparison to plain areas. But due to limited availability of plain land, they are forced to carry

¹Rai, (1970-71), Op.cit., p.170.

on farming along steep slopes. There are marked differences in the intensity of farming and crop types. The potato cultivation along hillslopes has become a very common practice because it is more attractive to farmers as they get more money in terms of yield per hectare in comparison to any other crops grown in this area.¹ But on the other hand the potato cultivation has created a serious problem of soil erosion. As potato grows below the surface, so the surface soil becomes loose and during rainy season huge amount of this loose surface soil is washed away by rain water in the form of surface run off. It has been noticed that the areas which are under potato cultivation the yield of potato per hectare has gradually gone down, even though farmers are using fertilizers. The reason is very clear, due to potato cultivation the top soil is washed away and the hillslopes have become more or less a barren surfaces. Thus, to check such serious soil erosion one has to think to develop some scientific methods so the soil erosion would be minimised and the yield of potato and other crops may be increased. Otherwise in the long run potato cultivation may cause serious consequences in the region.

Previously, in some hillslopes the pediment surfaces were also used for vegetable growing, but due to the expansion of Shillong town, now these pediment surfaces are

¹Rai and Panda (1982), Environmental Framework and Landuse on hillslope, Meghalaya.

seen dotted with houses. In profile No.1 the zone between pediment slope and debris slope a few houses are present.

The surface deposits vary within certain range in size and usually are confined to certain pockets controlled by topography and action of geomorphic agents. In this region heavy rains cause intensive gullying and transportation of large volumes of debris in the form of laterite soil. The soil texture varies from coarse to medium fine in the upper horizon to fine in lower horizons. The soil pH generally is between 4 and 6 but may be as low as 3.5 in pine forests.¹

Average Slope

Methods of Study - There are different methods suggested by many geographers for the study of average slope. Some methods are tedious and time-taking and results obtained are also not satisfactory. So, in the present study the method suggested by C.K. Wentworth (1930)² to determine the average slope of the region has been used. This method is simple and the results obtained are also encouraging to get the general picture of the region. The formula proposed by Wentworth is as follows :

¹Ramakrishna, et al, 1980, Op.cit., p.10.

²Wentworth, C.K. (1930), A Simplified Method of determining the average slope of land surfaces, Americal Journal of Science, Series 5, vol. 20, New Haven, Conn.

$$\text{Average Slope} = \text{Tan } \phi = \frac{N \times I}{3361}$$

$$\text{Angle} = \phi = \text{Tan}^{-1} \frac{N \times I}{3361}$$

where 'N' = Average Number of contour crossings in an area of 1 sq Mile.

'I' = Contour Interval in feet.

3361 = a constant figure

For the purpose of an average slope map, first of all the researcher has taken contour map from one inch to four miles (1" = 4 miles) topographic sheets of Khasi and Jaintia Hills. Then grids of one inch north-south and east-west line have been drawn over the contour map. After that the total number of contour crossings have been counted in each grid and that has been divided by 16* to get the average number of contour crossings per mile. Then applying the formula

$$\text{Average Slope} = \text{Tan } \phi = \frac{N \times I}{3361}$$

(I = 250 feet)

the researcher obtained the values of Tan ϕ for each grid. Using the natural tangent values for ϕ have been obtained for each grid and the values have been plotted at the centre of each grid. After that a category of slope

*the total number of contour crossing have been divided by 16 because the toposheet used is of 1" = 4 miles scale.

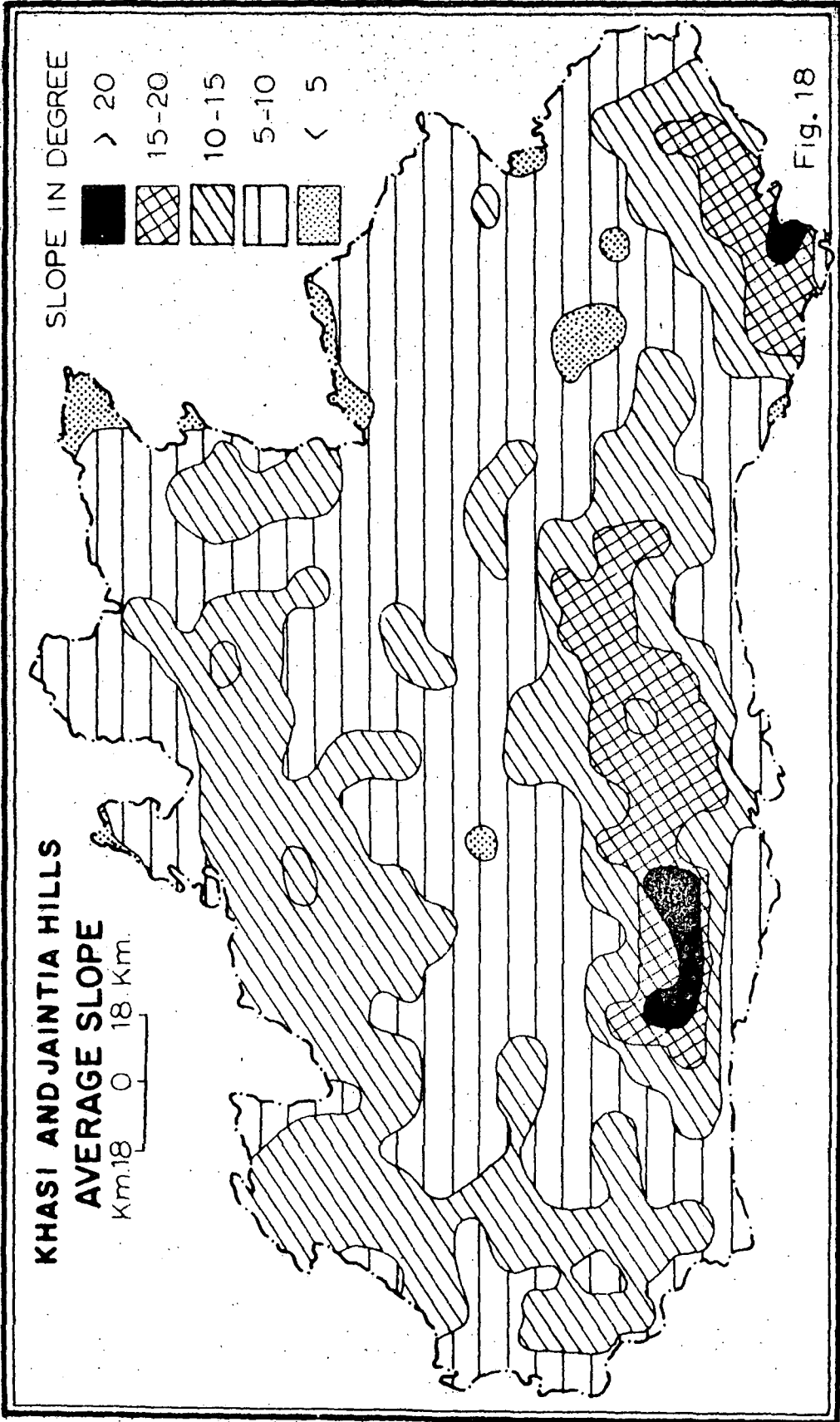


Fig. 18

(degree) has been formed and isolines of 5 degrees interval have been drawn to complete the map (Fig. 18).

Analysis:- For the analysis of the study of the average slope the author has taken five categories of slope as follows :

TABLE - V(i)
Extent of Slope Units

Sl. No.	Categories of Slope	Degree	Area in Km ²	%
1.	Gentle	0-5	219.42	1.52
2.	Moderate	5-10	10531.94	72.82
3.	Moderately Steep	10-15	2797.72	19.34
4.	Steep	15-20	695.10	4.80
5.	Very Steep	20 >	219.42	1.52
Total			14,463.6	100.00

(i) Gentle Slope: (0-5 degrees):

This slope category is found between 0 to 5 degrees. Interestingly enough this category of slope is found mainly near the mouths of the rivers those flow out of the region in a north and east directions. The area concentration of gentle slope are found mainly in Jaintia Hills; viz., south-east of Jowai covering the important villages of Bapung, Pammura, Dlehiah, Khliehriat, Sutanga, Umia and Paler, Sumera, and eastern part of Jaintia Hills covering Mawlashah,

Rakbah, Kdiap, Mynsngat and Moosharam etc. villages.

In Khasi Hills there are four patches of area those come under gentle slope category with a higher concentration at the northern boundary. The areas covered by this slope category are as follows : Umsantang, and Ranigadam village on the northern fringe of Khasi Hills bordering Kamrup district of Assam. A small patch of gentle slope is also found near the Langtar village of Khasi Hills.

The total area covered by this category is only 219.42 sq. km. (1.52 % of the total area), Table-V(i). The soil in such areas is lateritic. The slopes having 0 to 5 degrees are suitable for cultivation and encourage permanent settlements. This category of slope also found along the river valleys such as the mouth of river Myntdu and Kopili river in Jaintia Hills, and Umiam river in Khasi Hills. These areas are utilized for agriculture, but being barren surfaces are often seriously affected by soil erosion.

(ii) Moderate Slope (5 - 10 degrees) :-

These slope surfaces indicate undulating uplands. Walking in this gradient requires considerable efforts. These areas are well drained by small and large streams with its numerous tributaries. It has been observed that

this slope category is covered with patches of shifting as well as sedentary cultivation. This slope category is also considered to be a good site for housing purposes. At this gradient, the slope is essentially a steep one where roads are risky for modern vehicles, tractors can not be used in the field and ploughing is quite arduous.¹

Area-wise it occupies the maximum area of Khasi and Jaintia Hills. The total area covered by this slope category is 10,531.94 sq. kms. and is 72.82 per cent of the total area of Khasi and Jaintia Hills (Table-V(i)). A large number of rural settlements as well as the three towns of Shillong, Jowai and Cherrapunjee are situated in this slope zone. A large areas south of Shillong near the village Mylkiem, Mylkiem 12 miles, Laithyngkot and towards North of Shillong around Nongpoh are covered with patches of paddy fields.

(iii) and (iv) Moderately Steep to Steep (10-20 degrees)

The third category of slope varies generally from 10 to 20 degrees. The slopes are fairly steep and walking in this region requires much efforts. This part is generally thickly forested. Some forest settlements exists such as hill-slope settlements found in Cherrapunjee area of south

¹Mcgregor, D.R. (1957), Op.cit., p.168.

Khasi Hills (Plate-16). Due to steep gradient of slope people in this region generally practised contour ploughing. It is to be noted here that such slopes are generally the limit for ploughing but interestingly enough, during field-work the author has observed some peculiar sights of agriculture being practised in some hill slopes where the gradient of slope varies between 50 to 60 degrees. In these areas mixed type of cultivation is practised viz., Maize , potato and high altitude paddy etc.

The steep gradient is a formidable obstacle for the road traffic. This is reckoned as a maximum slope site where the levelling of the ground for habitation is possible. In such slopes the run off water generally destroys the field banks and temporary village paths. This also affected by intense soil erosion. The areal extent of this category of slope is found to be 2797.71 sq.kms. (19.34%) of 10 to 15 degrees and 695.10 sq. kms. (4.80%) of 15 to 20 degrees of slopes (Table-V(i)).

A glance at the average slope map (Fig.18) would reveal that both in Khasi and Jaintia Hills, at some places, the moderately steep and steep slope zone broadens and at other it narrows down. The broad zone of moderately steep slope is highly dissected towards west as well as to a certain extent towards south of Khasi Hills. During field

work the researcher observed that towards south of Shillong and farther south-west of Myllem granite area towards Cherrapunjee, the terrain is highly dissected with average slope gradient ranging from 15 degrees and above. This part of Khasi Hills is very often witnessed by landslides and debris flow. One could find while travelling towards Cherrapunjee, minor landslides are frequent. Towards the north of Khasi Hills before and after Nongpoh and around Umran, Umsning villages. Deformed debris fall, soil wash etc. are more active. At places large to medium granite boulders roll down the slope along with huge vegetative cover due to landslide. These in turn stage obstruction to regular transport system. During rainy season road blockade due to landslide is a common phenomenon on Gauhati-Shillong National Highway. Mass-washing and landslides have been discussed in detail in the last chapter.

(v) Very Steep Slope (20 degrees and above):

The fifth and the last category of slope unit having 20 degrees and above gradient has been categorised as very steep slope. A slope of this order makes a straight descent hard but one can walk up to a desired goal with difficulty in a round about circuit. Such slopes are generally covered with thick vegetation, and are not at all suitable for agricultural purposes. The run-off is very fast and cause destructive gullying. The physical

environment i.e. slope, soil moisture of the area, however, encourage natural forest growth.

There are certain areas east and north-east of Cherrapunjee, the researcher noticed during field work, that the slope in deep gorges are covered with scanty shrubs and other little bushes often come to little relief in direct ascent on such slopes. Large-scale felling of trees has turned these areas in to barren surfaces. Then weathered rocks are slipping and rolling down resulting in some sort of accumulation on the foot of such scarps. Owing to the difficult access the areas having such slopes cannot be utilized for agricultural and settlement purposes, though very few settlements have been located during field work.

The angle of slope is a fact of geomorphic and economic significance. The nature of lithology, process of erosion, nature of tectonic movement, climate of the region and the time factor play an important role in determining slopes into straight, concave or convex surfaces. Debris accumulation are common features at the base of the steep slopes.

The relationship between slopes and the flowing water is significant. A steep gradient allows a greater speed of flow, this in turn helps the stream to scour its course deeply. A zig zag course seldom occurs on such steep gradients except when it is produced by excessive

over loading or due to the physical obstructions in the stream. The steep slopes provide the velocity required for the transportation of all the load supplied to the streams from upper courses. The areas without vegetation cover suffer from erosion the most. However, on the slope zones the erosional changes are continuous.

The slope units selected to express geographical significance are not rigidly true to angular scale. It is a generalised picture. As for example, a slope instead of being uniform may be concave or convex or it may be marked by knicks associated with rock junctions, falls, and rapids etc.. Such irregularities have been overlooked in drawing the full map of the average slope (Fig. 18). The slopes have great influence on landuse. The five slope categories may further be scrutinised and useful information may be gathered on the basis of slope sub-units for micro-regional studies.

A knowledge of slope gradients is indispensable for the construction of metalled roads and rail tracks. In fact, slopes play an important role in determining how far and how fast development can be proceed.¹ The intimate acquaintance with slopes and awareness of their importance can, however, only be acquired through persist and field observation.

¹ Miller, O.R. & Summerson, C.H., (1960), Op.cit., pp.194-202.

CHAPTER - VI

QUANTITATIVE ANALYSIS OF TEN SMALL
DRAINAGE BASINS

"Although the river and the hill-side waste sheet do not resemble each other at first sight, they are only the extreme members of a continuous series, and when this generalization is appreciated, one may fairly extend the 'river' all over its basin and upto its very divides. Ordinarily treated, the river is like the veins of a leaf; broadly viewed, it is like the entire leaf."

- W M DAVIS
(1899)

Introduction

Under the impetus supplied by R.E. Horton (1945)¹, the description of drainage basins and channel net work was transformed from a purely qualitative and deductive study to a rigorous quantitative science capable of providing hydrologists with numerical data of practical value. Horton's work was further developed in detail by Strahler (1950, 1952, 1956 and 1958) and his Columbia University Associates (Melton, 1957; Morisawa, 1959 and Schumm, 1956).

This chapter treats quantitative landform analysis as it applied to normally developed watersheds in which

¹Horton, R.E. (1945), Erosional development of streams and their drainage basins: Hydro-physical approach to quantitative Morphology; Bulletin of the Geological Society of America 56, pp.275-370.

running water and associated mass gravity movements, acting over long periods of time, are the chief agents in developing surface geometry. Emphasis is upon the geometry itself, rather than upon the dynamic processes of erosion and transportation which shape the forms.

The application of principles of Mathematical statistics to quantitative geomorphology is essential if meaningful conclusions are to be achieved. A systematic description of the geometry of a drainage basin and its stream channel system requires measurements of linear aspects of the drainage network, arial aspects of the drainage basin and relief aspect of channel network and contributing ground slopes. Whereas the first two categories of measurements are planimetric (i.e., treat properties projected upon a horizontal datum plane), the third category treats the vertical inequalities of the drainage basin forms. In this chapter, the above first two aspects have been discussed in detail by selecting ten small drainage basins such as five fifth order and five fourth order (five each from Khasi and Jaintia Hills respectively).

Linear Aspects of the Basins

Linear aspect of the drainage basin includes the study of the channel patterns of the drainage network in terms of open links wherein the topological properties of

the stream segments are analysed. The drainage network which includes all the stream segments of a particular river, is studied in graphic terms where stream junctions are considered as points and streams are regarded as the lines which connects them. For this purpose, the numbers (Nu) of all stream segments are counted, their hierarchical orders are determined, the length of stream segments are measured and various inter-relationships are analysed. The sinuosity of the stream is also included in the linear aspect of the drainage basins includes the analysis and interpretation of stream order (u), stream number (Nu), bifurcation ratio (\bar{R}_b), stream lengths (Lu), mean stream lengths (\bar{L}_u) and sinosity indices.

The drainage basin is bounded by its perimeter which is determined by its watershed. The length of the master stream (L) from the mouth of the source is called 'mesh length'. The distance from the mouth of the trunk stream to the 'centre of the gravity' of the drainage basin is "usually measured up the main stream to a point where one-half of the drainage basin area lies headward of it, but for most basins 'Lea' (distance from the mouth to the centre of gravity = 0.5 L) is a good approximation."¹ The straight line horizontal distance from the mouth of the master stream

¹Chorley, R.J. (1969), Fluvial Processes, p.38.

to the most distant point on the perimeter (L_c) is significant in determining the shape of the basins. In the present study, the data of various attributes of linear aspects of the basins have been derived and calculated from the available toposheets of one inch to one mile and two cms to one kilometre and results drawn so far have been verified by intensive field work.

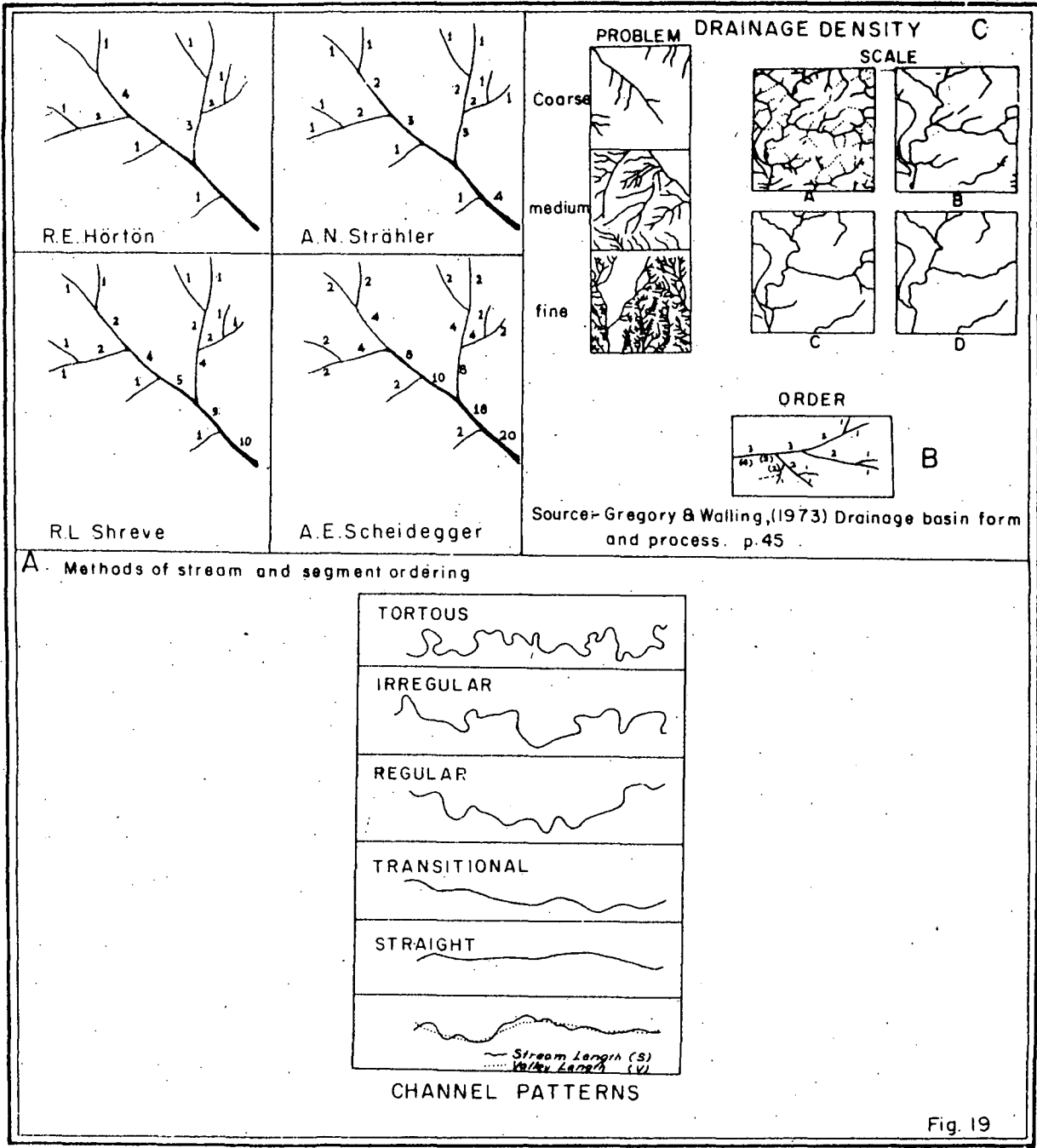
Concepts of Hierarchical Order of the Basins

Different stream segments of a drainage basin have their definite positions in the domain of a drainage basin. They have their distinct morphometric characteristics which necessitate the determination of their relative positions on the hierarchical scale of stream segments. "This has required the assignment of a level of relative order of magnitude to each segment in a stream segment-hierarchy, determined by sequential arrangement of tributaries with respect to the main trunk."¹ Thus, stream order is defined as a measure of the position of a stream in the hierarchy of tributaries.²

Playfair was the first geomorphologist who recognised the unitary features of the geometry and process presented by the erosional drainage basin. Later on Davis (1899) described the drainage basin as a leaf and the streams as the veins of that leaf. It was Gravelius (1914) who

¹Gregory and Walling, (1973), Drainage basin forms and processes, p.46.

²Leopold et. al. (1969), Fluvial Processes in Geomorphology, p.134.



made the first systematic attempt to decide the hierarchical orders of the streams of a drainage basin by tracing the streams from the mouth to the source. He tried to recognise the trunk stream through greatest width, discharge, headward branching and junction angle which he allotted the position of first order. He assigned the second order to those rivers which joined the main river of 1st order and so on. Gravelius's scheme was based on subjective decision of the worker at each bifurcation and hierarchical orders, thus determined, were not symmetrically related to the Magnitude of a given segment or link (Woldenberg, 1967, p.107 and Hagget-Chorley, 1969, p.13)

order by Gravelius.

Horton (1945) presented his scheme of stream ordering just opposite to Gravelius' scheme. As defined by Horton (1945) "the stream-ordering is a measure of the position of a stream in the hierarchy of tributaries". According to Horton (Fig. 19a) in a given map of a certain scale, the first order streams are those which have no tributaries, and second order streams are those which have as tributaries only first-order and second order streams, and so on. Horton's original system is somewhat more complex than this, in that the streams of maximum order in the drainage basin is determined and it then extended back to its furthest sources; in other words, the largest

stream of the basin will be given the number of highest order. When both the streams of the 1st order have the same length, the extension is arbitrarily decided by the choice of the worker. In this process of renumbering only, the fingertip streams of the first order are unaffected by their position.

Horton's scheme of ordering of rivers is difficult, tedious and time consuming because it involves double phases of classification and reclassification at several times. During the second phase of renumbering some fingertip tributaries are upgraded and others are left. Strahler (1952)¹ modified the limitations of Horton's (1945) ordering scheme. Strahler proposed a simple scheme out of Horton's method. In his method, Strahler retained the original definition of 1st order, 2nd order etc. streams as suggested by Horton. This method by Strahler simplifies the computation but it reduces the length of the main trunk, because the method of giving order number is restricted to stream segments only. While originally intended to order streams, the Strahler's method actually orders basin. The seemingly arbitrary way of ordering streams actually is an accurate and easy way to order basins.

According to Strahler, "each finger-tip channel

¹Strahler, A.N. (1952): Dynamic Basis of Geomorphology, Bull. Geol. Soc. Ame., vol. 63, pp.923-38.

is designated as a segment of the first order. At the junction of any two 1st order segments, a channel of 2nd order is produced and extends down to the point where it joins another 2nd order segment whereupon a segment of 3rd order results and so forth."¹ The limitation of Strahler's segment ordering system is that, the lower order segments do not increase the order of the streams of the higher order in lower reaches whereas in the upper reaches of the basin, a single fingertip 1st order segment can upgrade the trunk stream (Fig. 19b).

Shreve (1966, 67)² presented his scheme of 'stream link-magnitude' based on the 'interval-scale' of stream ordering wherein each exterior link or 1st order segment is given a magnitude (M) of 1, and "each successive link a magnitude equal to the sum of all the 1st order segments, which ultimately feed it". Thus combination* of links M_1 and M_2 gives a down stream link magnitude of $M_1 + M_2$

$$M_1 * M_2 = M_1 + M_2$$

Thus, in Shreve's scheme of stream ordering, each segment contributes in increasing the magnitude (order) of the segment which it joins (Fig. 19).

¹ Strahler, A.N., (1964), Quantitative Geomorphology of Drainage Basins and Channel Networks, in Chaw, V.T.(ed), Handbook of Applied Hydrology, McGraw Hill, Sec. 411, p.41.

² Shreve, R.L., (1966), Statistical Law of Stream numbers, Jr. Geol.74, pp.17-37.; _____ (1967), Infinite Topologically random channel networks, Jr. Geol. 75, pp.178-86

Lewin (1970)¹ has drawn attention to the fact that the Shreve system is based only upon the outer segments and neglects the fact that the inner links gather water as well. Thus, a modification of Shreve's method could be proposed and alternative ordering methods can be based either upon junctions (nodes) or paths.

Scheidegger (1965)² proposed his scheme of 'consistent Law of stream ordering' based on 'ratio-scale measures' and presented for postulates defining an algebra of combination of stream segments which is commutative as well as associative.

Woldenberg (1967) used Scheidegger's index to desire a new order magnitude (W) which, unlike Scheidegger's 'G' gives an increase in geometrical progression downstream in :

$$W = \frac{\text{Log } M}{\text{Log } R_b} + 1$$

where $M = \frac{1}{2}$ and the order magnitude (W) conforms to the geometric progression $Q_u = Q_1 (R_b)^{u-1}$

Thus, it becomes clear from the critical analysis of different stream ordering that Strahler's scheme of

¹Lewin, J. (1970), A note on stream ordering. Area 2, pp. 32-5.

²Scheidegger, A.E. (1965), The algebra of Stream-order numbers, U.S. Geol. Survey Prof. Paper 525B, B187-9.

modification of Horton's method has been used most extensively, particularly in conjunction with the 'laws of drainage composition'. Geomorphologists have frequently used Strahler's scheme for the morphometric analysis of drainage basins because it is the modified form of Horton's scheme and is best suited for the explanation of different laws of stream network which were postulated by Horton and verified by Strahler himself. The researcher has applied this method in the present study, but Horton's laws are also used for the analysis of networks of the small basins.

Ordering of the Selected Basins

Scale of the maps used in the ordering of the drainage network plays a vital role in deciding the accuracy of the orders of stream segments. Large scale maps like 1:24,000 or 1:25,000 may produce more accurate results than the small scale maps because finger-tip tributaries and rills are correctly depicted on such maps but in the region of very high drainage density and in the areas of closely spaced rivers, it becomes very difficult to differentiate finger-tip channels, rills and rivulets. Some geomorphologists have suggested to use contour maps for the determination of streams. In such cases, contour crenulations are used to determine the streams but at certain occasions

STREAM ORDERING

KHASI HILLS
km 0 km

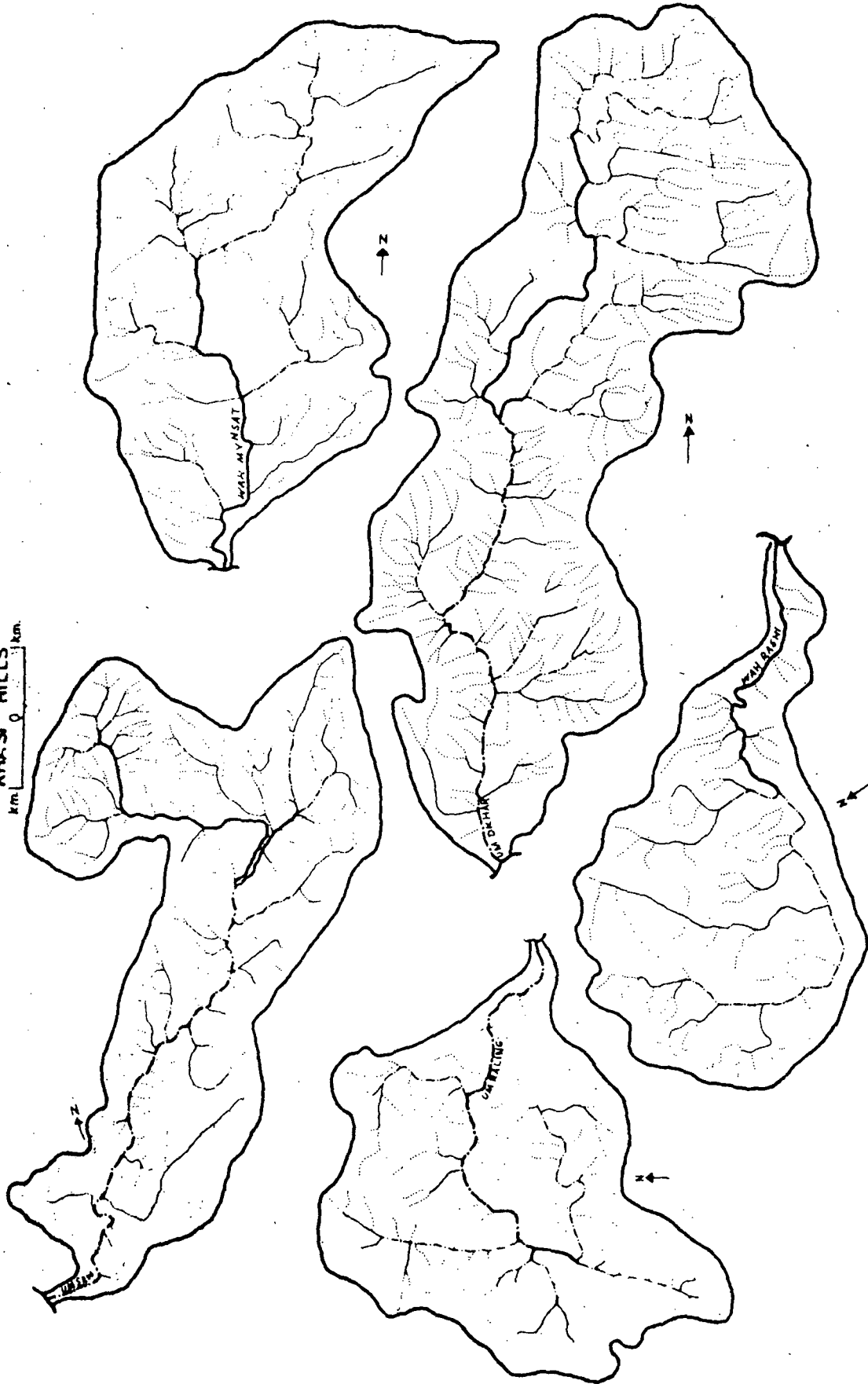


Fig. 2b

STREAM ORDERING

JAINTIA HILLS

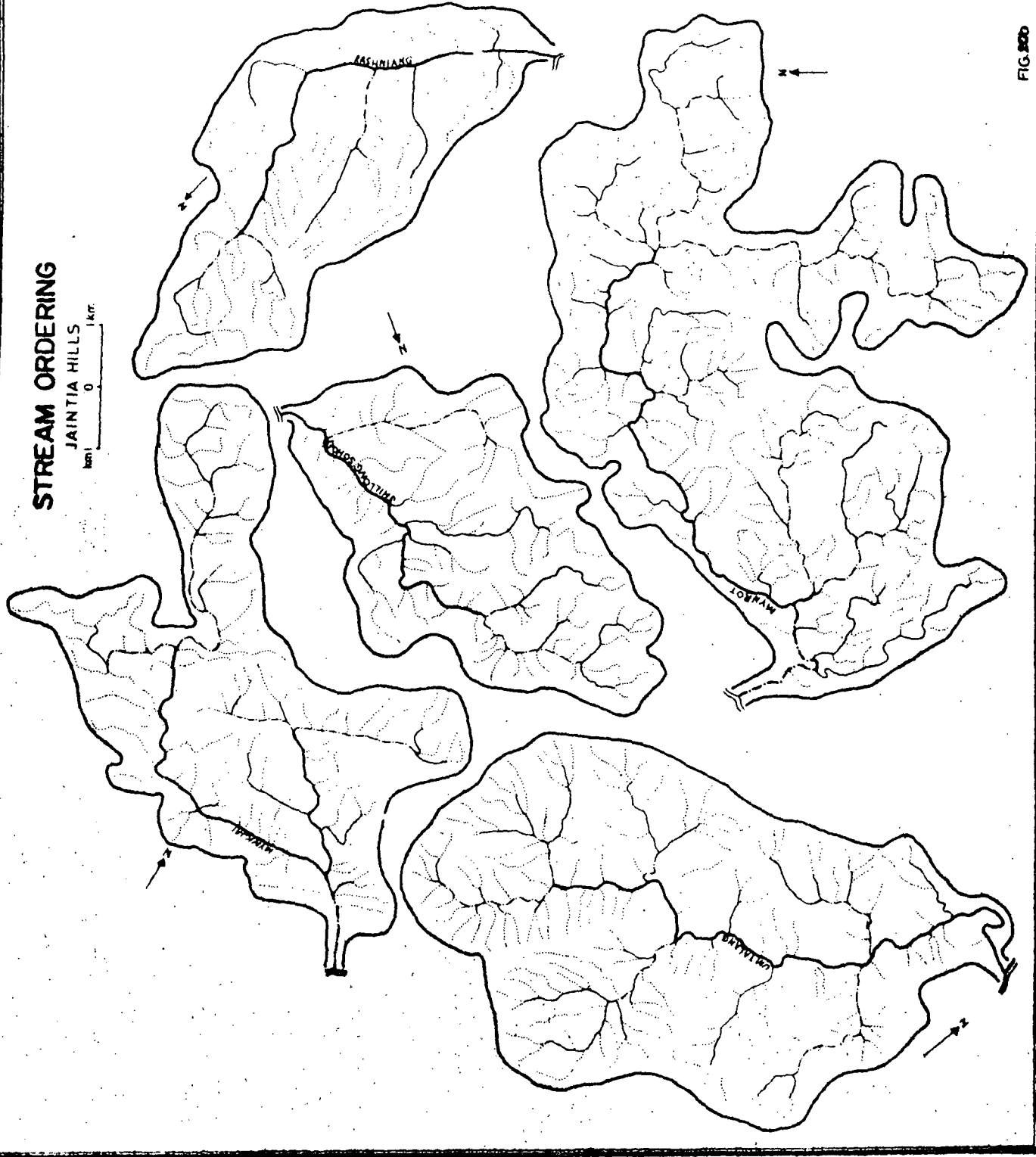


FIG. 800

contour crenulations becomes helpless because they do not depict stream lines, but merely topographic irregularities. The problem of stream ordering is more severely felt in India because the largest scale maps, so far available are on the scale of 1:50,000 and 1:25,000 but such maps are not available for a whole region.* The sample-field work may be helpful in the verification of smaller streams but the lack of necessary facilities for field mapping presents a serious difficulty in this task. Owing to the above problems, the researcher used one inch to one mile and two cm. to one kilometre maps (1:63,360 and 1:50,000) in his scheme of stream ordering. Chance variations as well as scale variations may register departures from the different laws of drainage network postulated by Horton and Strahler.

All the selected small drainage basins have been traced from one inch to one mile (1:63,360) and two cm to one km. (1:50,000) toposheets of the Survey of India. The selected ten small basins have been ordered according to Strahler's scheme of ordinal scale of stream ordering and stream segments of different orders are represented in Fig. (20 a & b). Out of the ten small drainage basins, five basins viz., Umdkhar (1)*, Umsaw(2), Wah Mynsat (3),

*Air photographs may be used for the verification of stream orders but unfortunately, air photographs are restricted for this region.

*Numbers in the parenthesis against the basins indicate their serial numbers as presented in all the table in the text.

Wah Rashi (4), Um Raling (5) from Khasi Hills and Mynrot (6), Umtalang (7), Shillong Sohoet (8), Rashniang (9), and Mynkjai (10) from Jaintia Hills. Umdkhar, Umsaw, Um Raling and Mynrot, Mynkjai are fifth order basins from Khasi Hills and Jaintia Hills respectively. Rest five basins Wah Mynsat, Wah Rashi and Um Talang Shillong Sohoet, and Rashniang are fourth order basins from Khasi Hills and Jaintia Hills respectively.

After the completion of the ordering of the basins the numbers of all the segments of each order have been counted and the same have been represented in Table VI(i). It is clear from the table that Umsaw basin (Khasi Hills) and Mynrot basin (Jaintia Hills) tops the list each having the largest number of stream segments (245), whereas, the bottom position is occupied by Wah Rashi (Khasi Hills) basin with only 70 stream segments.

It is apparent from Table-VI(i) that there is no direct relationship between the area of the basin and number of stream segments. The Mynrot river of Jaintia Hills occupies the first position by area and also occupies the second position by number of stream segments along with the Umsaw river of Khasi Hills, but this river's position by area is far below than that of Mynrot. But interestingly enough, these two rivers Mynrot and Umsaw have got similar

TABLE - VI-(i)

Number of Stream Segments Nu

Sl. No.	Basins	Area in Sq.km	Order (U)					Total Number of Stream segments
			Nu ₁	Nu ₂	Nu ₃	Nu ₄	Nu ₅	
<u>Mhasi Hills</u>								
1.	Umdkhar	30.25	105	45	9	2	1	162
2.	Umsaw	23.25	194	40	8	2	1	245
3.	Wah Mynsat	22.50	80	22	5	1	-	108
4.	Wah Rashi	17.50	53	13	3	1	-	70
5.	Um Raling	14.25	93	19	6	2	1	121
<u>Jaintia Hills</u>								
6.	Mynrot	50.00	188	46	8	2	1	245
7.	Um Talang	38.75	143	28	6	1	-	178
8.	Shillong Sohoet	20.25	78	11	2	1	-	92
9.	Rashniang	19.75	61	11	3	1	-	76
10.	Mynkjai	15.50	88	17	4	2	1	112

number of stream segments as well as similar bifurcation ratios (3.96). Um Raling basin of Khasi Hills is the smallest by area but it has more number of stream segments (121) than the following basins which are larger by area Mynkjai (112), Rashniang (76), and Shillong-Sohoet (92) of Jaintia Hills and Wah Mynsat (108) and Wah Rashi (70) of Khasi Hills. It is, therefore, clear from the table VI(i) that the number of stream segments of any given order will be fewer than for the next lower order but more numerous than for the next higher order.

Law of Stream Number

Some definite relationship exists between the orders of the basins and numbers of stream segments. Horton and Strahler have propounded an inverse geometric series of the numbers of stream segments and orders and have stated "that the number of stream segments of successively lower orders in a given basin tends to form a geometric series beginning with the single segment of the highest order and increasing according to constant bifurcation ratio." They have recommended the following equation of stream number:

$$N_u = R_b^{(K-u)}$$

where, N_u = Number of Stream segments of a given order.

R_b = Constant bifurcation ratio

K = Highest order of the basin.

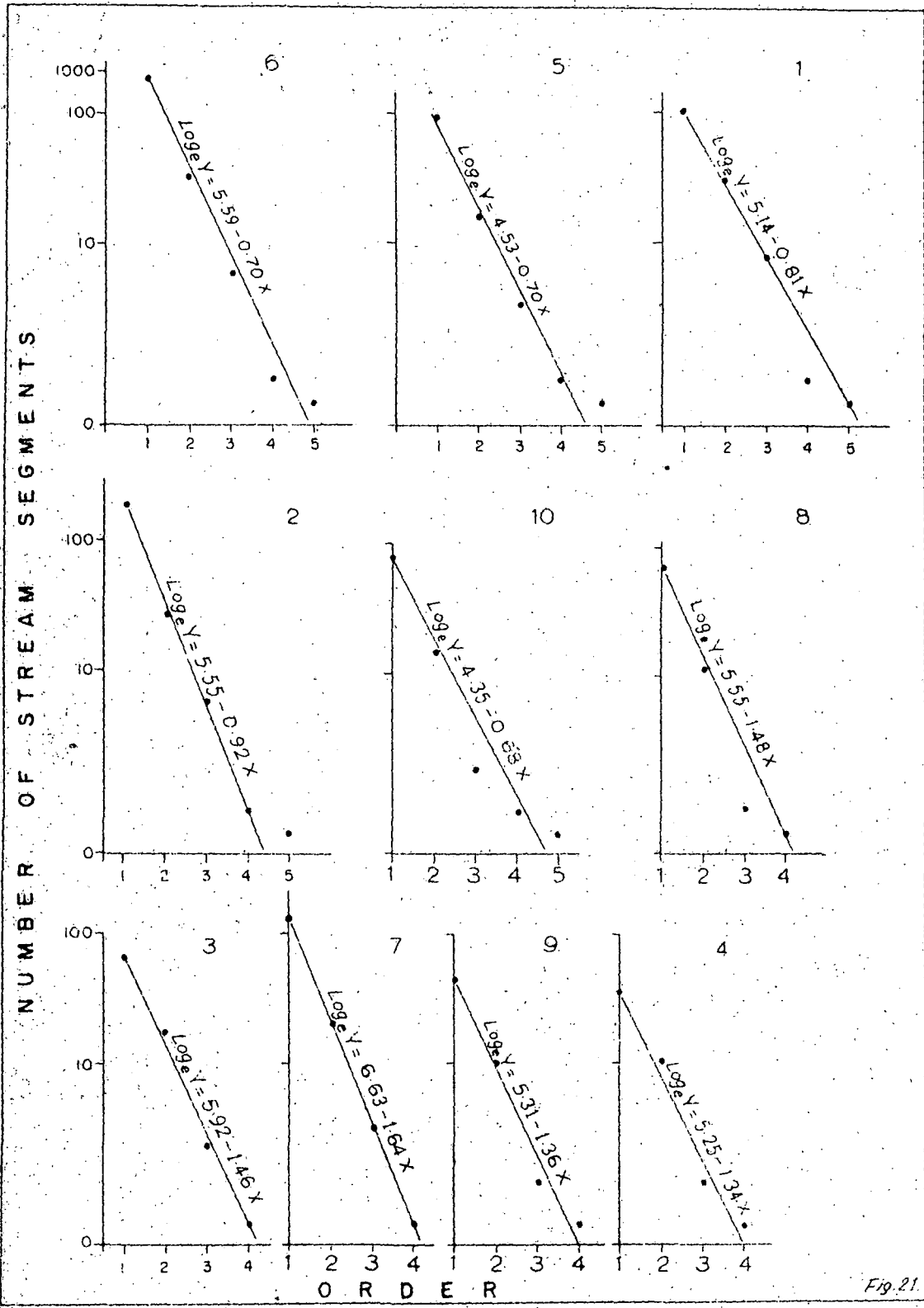


Fig. 21

Horton further worked out the following formula (using constant R_b) to find out the total number of stream segments of whole drainage basin :

$$\sum_{u=1}^K Nu = \frac{R_b^k - 1}{R_b - 1}$$

where, K = highest order of the basin.

Horton has used constant R_b in his equation which is not possible in reality, therefore, the practical application of this rule becomes doubtful. When the numbers of stream segments of different orders are plotted on a semi-logarithmic graph paper, a straight line of regression representing negative exponential function model is obtained. Though Strahler's ordinal scale of stream ordering differs significantly from the Horton's scheme of ordering, yet, Strahler's system also produces the same inverse geometric series of numbers of stream segments.

In the present study, stream numbers (Nu) have been plotted against orders on a semi-logarithmic graph using the following equation of negative exponential function model as suggested by Strahler. The regression coefficients (b) for each plot have been calculated and the same have been represented on the graphs (Fig. 21) :

$$Y = a e^{-bx}$$

$$\text{Log}_e Y = \text{Log}_e a - bx + 1 \text{ (Episton)}$$

where, Y = number of stream segments

x = stream order (u)

a = constant, and

b = regression co-efficient.

Explanation

The Fig. 21 reveals that, when the number of stream segments are plotted against successive orders of that streams, the graphs for the 5th order basins show that the Umdkhar and Umsaw basins have indicated almost a straight line except the deviation of the 4th and 5th order's stream number. In other words, the number of stream segments of the various orders are proportional to the orders except the 4th and 5th order of these two basins of Khasi Hills district. The same case also noticed in the Um Raling basin of Khasi Hills.

The five fourth order basins show that, except for the Wah Mynsat and Umtalang basin and to a lesser extent the Shillong Sohoet basin, other two have shown deviation of all the stream numbers as the points are not coming on a straight line.

The deviation of the stream numbers from the straight line indicates the affect of various factors which

caused this deviation. This, in a way is due to the underlying rock structure and unfavourable conditions for the development of the stream network. The surface drainage system is not well developed due to the lack of relief and relatively low rainfall over these basins. Hence, the number of streams are not developed in proportion to the orders. Therefore, Mynrot, Mynkjai, Wah Rashi etc. basins show a linear relationship, but with small deviation from a straight line.

Stream Lengths (Lu)

The stream length is a significant morphometric parameter of the drainage basin as it helps in the calculation of drainage density. The stream lengths of different orders of all the selected 10 drainage basins have been measured in kilometres and represented in Table-VI(ii). The total length of various orders has no significance because they may not be compared. Therefore, mean lengths (Lu) of each order have been calculated and arranged in Table-VI(iii). Generally, the 1st order stream segments have shortest mean length but the mean length increases with the increase in order. All the stream follow this postulation except some departures in certain orders of a few streams viz., Um Raling, Umdkhar of Khasi Hills and Mynrot and Mynkjai basins of Jaintia

TABLE - VI(ii)
Stream Length (Km.) (Lu)

Sl. No.	Basins	Stream length				
		L ₁	L ₂	L ₃	L ₄	L ₅
<u>Khasi Hills</u>						
1.	Umdkhar	110	28	14	6	7
2.	Umsaw	65	25	5.5	5	5.5
3.	Wah Mynsat	44	17	8	5	-
4.	Wah Rashi	60	21	12	9	-
5.	Um Raling	46.4	9	9	0.6	5
<u>Jaintia Hills</u>						
6.	Mynrot	97	35	17.5	9	2.5
7.	Um Talang	85	19	8.5	10	-
8.	Shillong Sohoet	85	20	10	5	-
9.	Rashniang	80	19	6	13	-
10.	Mynkjai	50	10	7.5	8	1.5

Hills exhibit departure in certain orders.

TABLE - VI(iii)
Mean Stream Length(Lu) of Stream Segments(Kms.)

Sl. No.	Basins	L ₁	L ₂	L ₃	L ₄	L ₅
<u>Khasi Hills</u>						
1.	Umdkhar	1.04	0.62	1.50	3.00	7.00
2.	Umsaw	0.34	0.62	0.70	2.50	5.50
3.	Wah Mynsat	0.55	0.77	1.60	5.00	-
4.	Wah Rashi	1.13	1.61	4.00	9.00	-
5.	Um Raling	0.50	0.47	1.50	0.30	5.00
<u>Jaintia Hills</u>						
6.	Mynrot	0.52	0.76	2.20	4.50	2.50
7.	Um Talang	0.52	0.67	1.40	10.00	-
8.	Shillong Sohoet	1.08	1.81	5.00	5.00	-
9.	Rashniang	1.31	1.72	2.00	13.00	-
10.	Mynkjai	0.57	0.58	1.90	4.00	1.50

Except Umsaw basin of Khasi Hills all other 5th order basins exhibit departure in certain orders. Umdkhar basin shows mean length of 1st order, higher than 2nd order and Um Raling shows the mean length of 3rd order more than 4th order. Again, Mynrot and Mynkjai basin of Jaintia Hills shows the mean length of 5th order is less than 4th order segments.

Law of Stream Lengths

Horton (1945) has postulated a law of positive geometric progression between cumulative mean lengths and stream orders wherein the cumulative mean lengths of stream segments increase geometrically with successive increase in stream orders with constant length ratio. The model of law of stream length is called positive exponential function model and is expressed through the following equation :

$$L_u = L_1 R_L^{(u-1)}$$

Where, L_1 = The mean length of the 1st order

$$R_L = \frac{L_u}{L_{u-1}} = \text{constant length ratio}$$

This theoretical model may not be applicable to the natural stream system in its totality because constant length ratio seldom exists, as is evident from Table-VI(iii) wherein significant variations in length ratios may be noted in all the 10 small drainage basins.

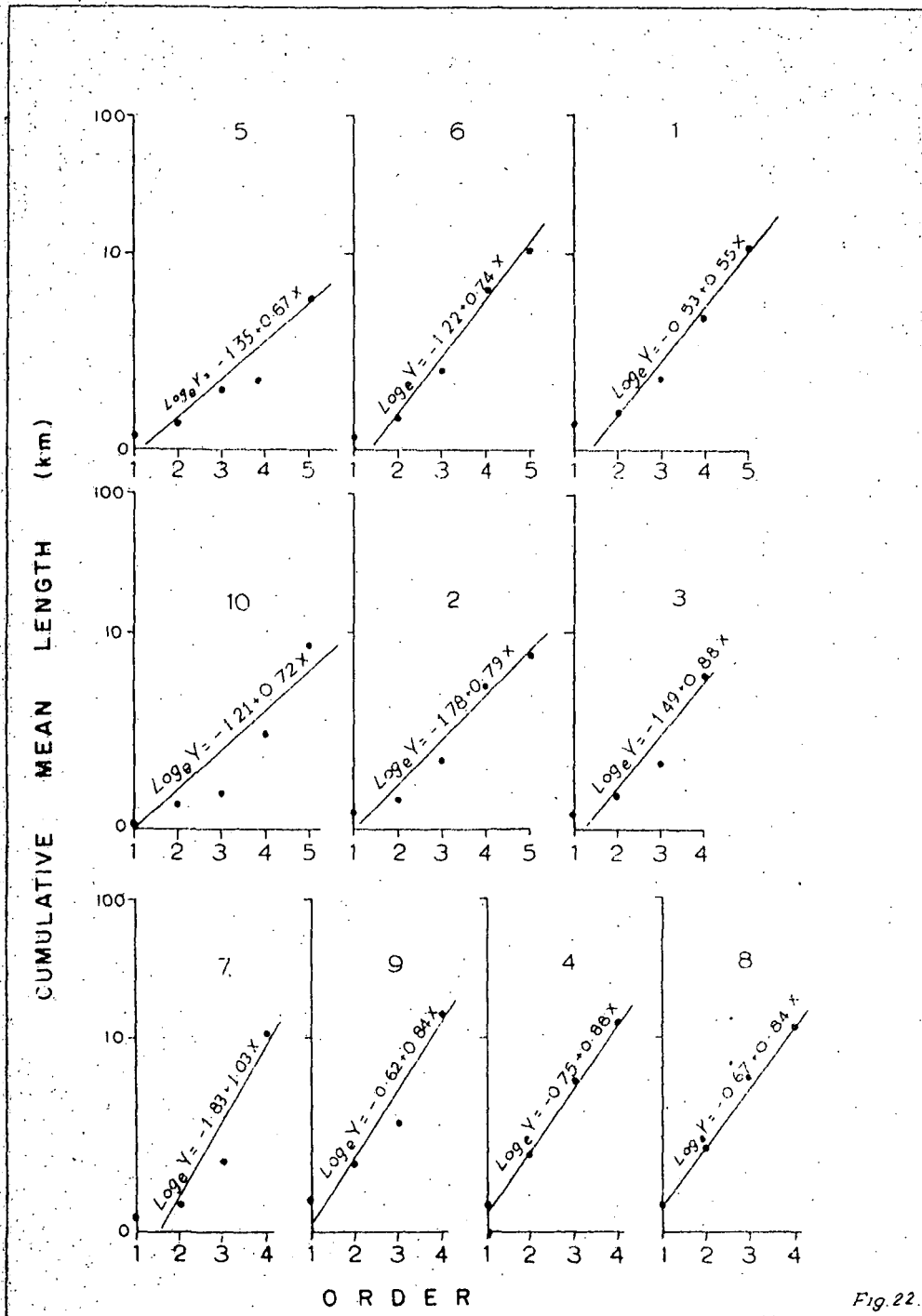


Fig. 22.

When cumulative mean lengths of stream segments (Table-VK(iii)) are plotted on the ordinate against the orders on the abscissa on a semi-logarithmic graph a straight line of positive exponential function is derived (Fig. 22). The regression lines for all the 10 basins have been drawn on the basis of the following regression equation :

$$Y = a e^{bx}$$

$$\text{Log}_e Y = \text{Log}_e a + bx + u$$

where, 'Y' stands for cumulative mean length

'X' denotes order (u)

'b' is the coefficient of regression, and

'a' is the constant

TABLE - VI (iv)
Cumulative Mean Lengths (kms)

Sl. No.	Basins	Order (u)				
		1	2	4	3	5
<u>Khasi Hills</u>						
1.	Umdkhar	1.04	1.66	3.16	6.16	13.16
2.	Umsaw	0.34	0.96	1.66	4.16	9.66
3.	Wah Mynsat	0.55	1.32	2.92	7.92	-
4.	Wah Rashi	1.13	2.74	6.74	15.74	-
5.	Um Raling	0.50	0.97	2.47	2.77	7.77
<u>Jaintia Hills</u>						
6.	Mynrot	0.52	1.28	3.48	7.98	10.48
7.	Um Talang	0.52	1.19	2.59	12.59	-
8.	Shillong Schoet	1.08	2.89	7.89	12.89	-
9.	Rashniang	1.31	3.03	5.03	18.03	-
10.	Mynkjai	0.57	1.15	3.05	7.05	8.55

Explanation

The Fig. 22 reveals that, when the cumulative mean stream lengths are plotted against successive orders of the streams, the graphs for 5th order basins of Khasi and Jaintia Hills show that Umdkhar and Mynrot basin indicate almost a straight line except the deviation of 3rd and 4th orders. Rest three basins - Um Raling, Umsaw and Mynkjai show the points are much deviated from the straight line.

The five 4th order basins also indicate the same pattern. Except Wah Rashi basin of Khasi Hills and Shillong Sohoet basin of Jaintia Hills, rest three basins Wah Mynsat Um Talang and Rashniang show their 1st, and 3rd order lengths deviated much from the straight line.

The deviation of the cumulative stream lengths from the straight line indicate the effect of various factors. Stream length data from all these ten basins illustrate that, like the first "law" of drainage composition, geometric regularity is not maintained perfectly. The deviation from the straight line show that, the valley network is not fully developed. The organization of fluvial hierarchies, as manifested in the laws of stream numbers is not maintained properly due to differences in geologic structure and variation in rainfall. Moreover,

the stream lengths from the toposheets are measured as if projected on to a horizontal plane. This technical factor hinders the researcher to get exact lengths of various orders of stream segments.

Bifurcation Ratio (R_b)

Bifurcation ratio (R_b) is related to the branching pattern of the drainage network. The bifurcation ratio, for a given density of drainage lines, is very much controlled by basin shape and shows very little variation (ranging between 3 and 5) in homogeneous bedrock from one area to another. Where structural effects cause basin elongation, however, this value may increase appreciably. Besides influencing the landscape morphometry, the bifurcation ratio is an important control over the 'Peakedness' of the run off hydrograph.¹ The bifurcation ratio is defined as the ratio of number of segments of a given order Nu to the number of segments of the higher order Nu + 1 is termed the bifurcation ratio R_b , and is expressed in terms of the following equation :

$$R_b = \frac{Nu}{Nu+1}$$

Where, Nu = Number of streams of a given order

Nu+1 = Number of streams of the next higher order

¹Chorley, R.J.(1969), "The drainage basin as the Fundamental Geomorphic Unit" in Fluvial Processes(Ed.), R.J. Chorley (1969), p.34.

Norton (1945) recognised bifurcation ratio as one of the most important characteristic of the drainage basin. The bifurcation ratio will not be precisely the same from one order to the next because of chance variations in watershed geometry, but will tend to be a constant throughout the series. This observation is the basis of Horton's 'Law of stream numbers' which states that the numbers of stream segments of each order form an inverse geometric sequence with order number, or

$$Nu = R_b^{K-u}$$

where, K is the order of the trunk segment and the other terms are as previously defined.

Bifurcation ratio has been studied by a number of eminent geomorphologists (Maxwell-1960¹, Schumm-1956², Chorley-1957³, Strahler-1957⁴, Strahler in Chow-1964⁵, Milton-1966⁶ and Horton-1945⁷) in different regions having

¹Maxwell, J.C.(1960), Quantitative Geomorphology of the San Dimas Experimental Forest, California, office of Naval Research, Geography Branch, Project NR 389-042: Technical Report-19.

²Schumm, S.A.(1956), The evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey, Geol. Soc. Amer. Bull. 67, pp.597-646.

³Chorley, R.J. (1957), Climate and Morphometry, Jr. Geol. 65, pp.628-68.

⁴Strahler, A.N.(1957), Quantitative Analysis of Watershed geomorphology, Trans. Amer. Geophys. Union 38, pp.913-20.

⁵Strahler, A.N.(1964), Quantitative Geomorphology of drainage basins and channel networks. In Chow, V.T.(ed.), Handbook of Applied Hydrology, KV, p.39 and IV, p.76.

⁶Milton, L.E.(1966), The geomorphic irrelevance of some drainage net laws. Australian Geographical Studies, 4, pp.89-95.

⁷Horton, R.E.(1945), Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology, Geol. Soc. Amer. Bull 56, pp.275-370.

varied geological formations and relief characteristics. These studies clearly indicated marked regional variation in bifurcation ratios due to differences in climatic conditions, geological and structural characteristics of rocks, relief features and stage of basin development. Horton (1945) has postulated that bifurcation ratio varies from 2.00 in the flat or rolling basins to 3.00 to 4.00 in the mountainous highly dissected basins. Strahler (1964) has observed that "because the bifurcation ratio is a dimensionless property and because drainage systems in homogeneous materials tend to display geometrical similarity, it is not surprising that the ratio shows only a small variation from region to region."

The bifurcation ratios of all the 10 selected basins have been calculated and the same have been represented in Table-VI(v). The average bifurcation ratios (R_b) of 9 basins confirm the observation of the above geomorphologists. The calculated bifurcation ratios of all the 9 basins range between 3.00 and 5.00. The only exception is the river Um Talang of Jaintia Hills which is a left bank tributary of Kopili river has the mean bifurcation ratio of 5.25. This departure is the result of elongated shape of the basin, because of the parallel ranges that guide the courses of the tributaries of the stream.

TABLE VI(v)
Bifurcation Ratio(R_b)

Sl. No.	Basins	N_1/N_2	N_2/N_3	N_3/N_4	N_4/N_5	R_b
<u>Khasi Hills</u>						
1.	Umdkhar	2.33	5.00	4.50	2.00	3.46
2.	Umsaw	4.85	5.00	4.00	2.00	3.96
3.	Wah Mynsat	3.64	4.40	5.00	-	4.35
4.	Wah Rashi	4.08	4.33	3.00	-	3.80
5.	Um Raling	4.89	3.17	3.00	2.00	3.26
<u>Jaintia Hills</u>						
6.	Mynrot	4.09	5.75	4.00	2.00	3.96
7.	Um Talang	5.10	4.66	6.00	-	5.25
8.	Shillong Schoet	7.09	5.50	2.00	-	4.86
9.	Rashniang	5.55	3.67	3.00	-	4.16
10.	Mynkjai	5.18	4.25	2.00	2.00	3.36

Giusti and Schneider (1965)¹ have advocated that bifurcation ratios within a region decrease with the increasing order.

$$R_{b_1} > R_{b_k}$$

K stands for successive increasing orders.

The general trend of the bifurcation ratios confirms with the above hypothesis because there is a general trend of decrease in the bifurcation ratios. Um Raling (3.26) Umdkhar (3.46), Umsaw (3.96) of Khasi Hills and Mynrot (3.96)

¹Giusti, E.V. and Schneider, W.J.(1965), The Distribution of branches in river networks. U.S. Geol. Survey. Prof. paper 422 G.

Mynkjai (3.36) of Jaintia Hills show decreasing bifurcation ratio with increase in orders. In other words, the five 5th order basins have less bifurcation ratios in comparison to the five 4th order basins. But, the following basins confirm the above hypothesis in respect of successive increase in orders viz., Um Raling (4.89, 3.17, 3.0 and 2.0), Mynkjai (5.18, 4.25, 2.0 and 2.0), Rashniang (5.55, 3.67 and 3.0) and Shillong-Sohoet (7.09, 5.5 and 2.0). Rest six basins show departure from the general trend and it may be due to the effect of geology and relief condition of the basins.

Giusti and Schneider (1965)¹ have further propounded that "basins of equal order but variable areas tend to have the smallest bifurcation ratios in the smallest areas; the ratio increases with increasing areas upto a certain size beyond which the bifurcation ratios tend to become constant". This hypothesis can be applied to these 10 basins. The five basins from Khasi Hills show that Um Raling basin has smallest area (14.25 sq. km.) as well as smallest bifurcation ratio (3.26). The other five basins from Jaintia Hills reveal that Mynkjai basin has the smallest area (15.5 sq.km) as well as smallest bifurcation ratio(3.36). If one sees according to their order also, the hypothesis is confirmed

¹Giusti, E.V. and Schneider, W.J.(1965), Op.cit., Prof. Paper, 422 G.

The five 5th order basin show that Um Raling basin has smallest area (14.25 sq. km) and smallest bifurcation ratio (3.26) while, Mynrot basin has largest area (50.00 sq.km.) and largest bifurcation ratio (3.96). In five 4th order basin also show the same tendency, the Wah Rashi basin has the smallest area (17.50 sq.km.) and smallest bifurcation ratio (3.80), while the Umtalang basin has the largest area (38.75 sq.km) and largest bifurcation ratio(5.25).

The only exception is in 5th order basin, the Umdkhar basin of Khasi Hills has the second largest area (30.25 sq.km) but the bifurcation ratio is less than that of Umsaw basin (Table-VI(v) which occupies 3rd place by area (23.25 sq.km). This is because of not only the area, but also other factors like structural characteristics of rocks, slopes, stages of basin development etc. play dominant role in deciding the branching of streams. The coefficient of correlation between mean bifurcation ratio (R_b) and basin area stands at 0.35. Multiple correlation among seventeen morphometric variables are discussed in the end of this chapter.

Sinuosity Indices

The shape of the open link in terms of geomorphic structure of drainage lines involves the calculation of departure of observed path (O_L) from the expected path(E_L) of a stream from its source to its mouth. It is supposed

that the expected path of the river will be in a straight line. The calculation of such deviations presents a great problem because "it is not always clear where the terminating points for the observation should be located."¹ Practically, the straight line path of a stream is never possible because it is affected by a number of causative factors which force the drainage line to deviate from its straight line expected path. These factors include geological and hydrological controls, dip angles, slopes, absolute relief, relative relief, degree of dissection, stage of valley development, etc.. Sinuosity indices of the drainage lines help in studying the effect of terrain over river course and vice-versa.

The sinuosity indices of streams have been very much in use in understanding the geomorphological character of a region. The usual approach is to derive the index as a ratio between the channel length (CL) of a reach and its valley length (VL), thus, limiting the use of streams which have developed flood-plains. This restricts the analysis to speaking of hydraulic action as the sole performer of sinuosity limited to matured and old streams. As a result, the young streams whose valleys and channels

¹Hagget and Chorley, (1969), *Fluvial Processes in Geography*, p.59.

are coincident, give the sinuosity index as unity thereby suggesting complete topographic control of the streams, which is an obvious flaw in interpreting topography in relation to the character of drainage, because we know that some amount of hydraulic action, also exists in most of the youthful streams owing to structural controls, rejuvenation and greater amount of precipitation in the catchment area. Another important drawback in this type of index is that this suggests that all streams with a value of unity are not sinuous, (i.e. straight) which is not true because all streams have some amount of departure from a straight line course in what-so-ever stage and reach they are.¹

Smart and Surken (1967)² measured the unsystematic deviations from a straight line paths and curves of considerable symmetry, whose dimensions were proportional to the size of the channel and they recognized two types of shapes of a drainage line viz., (i) Wandering and (ii) Meandering. The wandering path may be calculated by relating the length of the observed path (O_L) to the length of the expected path (EL). Schumm (1956)³ after measuring the deviations from a straight line path presented 5 categories

¹Davis, W.M.(1913), "Meandering valleys and underfit Rivers", A.A.A.G. Vol. 3, pp.4-5.

²Smart and Surken, (1967), Op.cit., pp.965-66.

³Schumm, S.A.(1956), Fluvial Geomorphology in River Mechanics, River Morphology (Ed.)

of channel sinuosity viz., (i) Straight = (OL/EL = 1.00) (ii) Transitional, (iii) Regular, (iv) Irregular and (v) Tortous = (OL/EL = > 2.00) (Fig. 19c).

Müller (1968)¹ modified the difficulties found in Schumm's method and presented his model of sinuosity index. This model explains the effect of hydraulic and topographic controls on the courses of the streams. He measured the length of the channel (CL), the length of the valley between the base of the valley walls (VL) and the shortest distance between the source and mouth of the river (Air L) and presented his model in the form of the following equations -

$$(i) \quad CI = \frac{CL}{\text{Air L}}$$

where CI = Channel Index

$$(ii) \quad VI = \frac{VL}{\text{Air L}} \quad \text{where VI = Valley Index}$$

$$(iii) \quad \text{H.SI} = \% \text{ equivalent of } \frac{CI - VI}{CI - 1}$$

where HSI = Hydraulic Sinuosity Index.

$$(iv) \quad \text{TSI} = \% \text{ equivalent of } \frac{VI - 1}{CI - 1}$$

where TSI = Topographic sinuosity Index.

$$(v) \quad \text{SSI} = \frac{CL}{VL}$$

where SSI = Standard Sinuosity Index

¹Müller, J.E. (1968), "An Introduction to the Hydraulic and Topographic Sinuosity Index", A.A.A.G., Vol. 58, No.2

The present study aims at the application of Muller's model of sinuosity indices for the 10 small drainage basins of Khasi and Jaintia Hills of Meghalaya. The river courses are classified into three categories on the basis of the standard sinuosity index viz., (i) Straight course (SSI=1.00), (ii) Sinuous course (SSI=1.00-1.50) and (iii) Meandering course (SSI = > 1.50)

TABLE - VI(vi)
Sinuosity Indices

Sl. No.	Basins	CI	VI	HSI (%)	TSI (%)	SSI
<u>Khasi Hills</u>						
1.	Umdkhar	1.20	1.08	0.60	0.40	1.11
2.	Umsaw	1.20	1.10	0.50	0.50	1.09
3.	Wah Mynsat	1.47	1.33	0.30	0.70	1.10
4.	Wah Rashi	1.47	1.33	0.30	0.70	1.10
5.	Um Raling	1.25	1.25	0.25	1.00	1.00
<u>Jaintia Hills</u>						
6.	Mynrot	1.54	1.31	0.42	0.57	1.20
7.	Um Talang	1.36	1.16	0.55	0.44	1.20
8.	Shillong Sohoet	1.20	1.06	0.70	0.30	1.12
9.	Rashniang	1.25	1.25	0.25	1.00	1.00
10.	Mynkjai	1.39	1.33	0.15	0.85	1.04
Average		1.33	1.22	0.40	0.64	1.09

It is apparent from the table VI(vi) that the channel Index (CI) and Valley Index (VI) are having same figures for two basins i.e. Um Raling basin of Khasi Hills (CI = 1.25 and VI = 1.25) and Rashniang basin of Jaintia Hills (CI = 1.25 and VI = 1.25). Further it is clear from

the above table that the figures for Standard sinuosity index are also same for these two basins (SSI = 1.00) which indicates the straight river course.

The rest eight basins have differences in channel index and valley index and their standard sinuosity index ranges between 1.04 to 1.20. These we can put in the second category of the standard sinuosity index which ranges between 1.00 - 1.50 indicating sinuous course of the streams.

The hydraulic and topographic sinuosity indices (HSI and TSI) are the valuable morphometric tools which help in determining the controlling factors of sinuosity. The following basins show high Topographic sinuosity Index (TSI) : Um Raling (1.00 %), Wah Mynsat (0.70 %) and Wah Rashi (0.70 %) of Khasi Hills and Mynkjai (0.85 %) Rashniang (1.00 %) and Mynrot (0.57 %) of Jaintia Hills. This indicates that these six basins are in their early stage of basin development. While the basins Umkhar (0.60 %) from Khasi Hills and Um Talang (0.55 %) and Shillong sohoet (0.70 %) from Jaintia Hills show high percentage of Hydraulic sinuosity Index (HSI). This indicate that these three basins are in their mature stage of basin development.

Areal Aspects of the Basins

Drainage Density (Dd) - Density of the stream network has long been recognised as a topographic characteristic

of fundamental significance. This arises from the fact that network density is a sensitive parameter which in many ways provides the link between the form attributes of the basin and the processes operating along the stream course. If drainage basins were uniform in every aspect, stream flow would be proportional to the length of water course in a basin, because channel flow is much more rapid than the alternative flow on, or beneath slopes. As the extent and density of the network reflect topographic, lithological, pedological and vegetational controls, and because they also incorporate the influence of man, network density promises to be a valuable index.

Use of maps of varying scales and degree of detail, or aerial photographs taken at different seasons, produce widely divergent results, especially in areas where seasonal stream flow is marked characteristic and the definition of drainage lines not always without ambiguity (Fig. 19d). Thus, figures such as those given by Selbey (1967-a)¹ show that measures of drainage density may vary by a factor of 10^3 , and are very difficult to compare. Lithology and relief development as well as climate and vegetation cover, are major controls. Thus, in semi-arid areas drainage density over poorly consolidated shales may rise into hundreds

¹See, Doornkamp and King (1971), Numerical Analysis in Geomorphology, An Introduction.

of kilometer of terrain, whilst in humid temperate areas with a forest or woodland vegetation cover, figures tend to vary from 1.8 - 5.6 km/km² (Selbey 1968).¹

Infiltration capacity is also a major factor which is directly affected by lithology, and all are closely related to climate. Chorley (1957)² and Chorley and Morgan (1962)³ compared three lithologically similar areas from Britain and confirmed a close relationship between drainage density and rainfall. Carlston (1966)⁴ has also studied the effect of climate on drainage density.

It is perhaps significant that figures from areas of low relief in the humid tropics generally exhibit a range below those just quoted. Doornkamp and King (1971)⁵ analysed more than one hundred third-order basins from Uganda and found drainage densities ranged from 0.62 - 6.25 km/km².

For the present study, the drainage density for

¹Selbey, M.J. (1968), Morphometry of drainage basins in areas of pumice lithology, Proc. Fifth New Zealand Geog. Conference, pp.169-74.

²Chorley, R.J. (1957), Illustrating the laws of Morphometry, Geol. Mag. Vol. 94, pp.140-50.

³Chorley, R.J. and Morgan, M.A. (1962), Comparison of Morphometric features, Unaka Mountains Tennessee and North Caroline and Dartmoor, England. Geol. Soc. Amer. Bull 73, pp. 17-34.

⁴Carlston, C.W., (1966), The effect of climate on drainage density and stream flow; Bull. of the Intern. Assc. of Sci. Hydrology, II, pp.62-9.

⁵Doornkamp and King; (1971), Numerical Analysis in Geomorphology, London, Arnold. 372 pp.

10 selected small drainage basins have been calculated by using the following formula as suggested by Horton (1945)¹:

$$Dd = \frac{\sum_{i=1}^K \sum_{j=1}^N Lu}{Au}$$

Where Dd = Drainage density,

Lu = Length of the stream

Au = Total area of the basin

Thus, Dd is simply the ratio of total channel segment lengths cumulative for all orders within a basin to the basin area (projected to the horizontal). After calculating the drainage density figures for all the 10 small basins, the values have been represented in Table-VI(vii).

TABLE - VI(vii)
Drainage density (Dd) Km/Km²

Sl.No.	Basins	Drainage density
<u>Khasi Hills</u>		
1.	Umdkhar	5.45
2.	Umsaw	4.56
3.	Wah Mynsat	3.29
4.	Wah Rashi	5.83
5.	Um Raling	4.91
<u>Jaintia Hills</u>		
6.	Mynrot	3.22
7.	Um Talang	3.16
8.	Shillong sohoet	6.08
9.	Rashniang	5.83
10.	Mynkjai	5.92
Average		4.82

¹ Horton R.E., (1945), Op.cit., p.283.

The above table-VI(vii) shows clearly that the drainage densities of 10 small drainage basins ranges between 3.16 to 6.08 km/km². The lowest drainage density value is shown by Um Talang basin of Jaintia Hills, while the highest drainage density value is shown by Shillong Sohoet basin of Jaintia Hills. The low drainage densities of Um Talang (3.16), Mynrot (3.22) of Jaintia Hills and Wah Mynsat (3.29) of Khasi Hills are due to the fact that these basins are located in regions of highly permeable subsoil, under dense vegetation cover, and where relief is low. While the high drainage densities shows by Shillong sohoet (6.08), Mynkjai (5.92), Rashniang (5.83), from Jaintia Hills and Wah Rashi (5.83), Umdkhar (5.45), Um Raling (4.91) and Umsaw (4.56) from Khasi Hills are due to the location of these basins in regions of impermeable subsurface materials, sparse, vegetation and mountain relief. This fact is clear from this study that an increase in drainage density occurs, with increasing relief. It is interesting that Peltier (1962)¹ in a pilot study undertaken from the analysis of large numbers of topographic maps, found that there was a much steeper rise in drainage density with increasing mean slope in tropical areas than any other climatic zone. Since increasing mean slope will usually be accompanied by increase in absolute altitude, local relief

¹Peltier, L.C. (1962), Area sampling for terrain analysis, Prof. Geographer, 14, pp.24-28.

and valley side slopes, it is likely that total precipitation amount and regolith type and depth will be major factors accounting for these figures.

In the present study also the impact of above elements are clearly noticed. The contour map (Fig. 9a) of Khasi and Jaintia Hills reveals that the relief increases from east towards central plateau and decreases towards west. Out of the ten selected small drainage basins 5 of them viz.; Umdkhar, Wah Rashi, Rashniang, Shillong sohoet, Mynkjai are situated on the central plateau zone of Khasi and Jaintia Hills. This is the fact that these basins represent high drainage density in comparison to the rest. The basins, such as Um Raling and Umsaw of Khasi Hills are located on the fringe of the high relief and low relief zone, hence, represent medium drainage densities. Rest three basins viz., Mynrot, Wah Mynsat and Um Talang show lowest drainage densities because of their location and low relief.

Again, the geology map of (fig. 2) Khasi and Jaintia Hills reveals the regional variation in geological and structural characteristics of the region. It has been examined that geomorphic parameter most strongly influenced by geological factors is the drainage density. In an area of relatively homogeneous rocks, the drainage density will be fairly constant. From the Table-VI(vii) it is apparent

that the following basins show more or less similar drainage density figure, viz., Rashniang (5.83 km/km^2), Wah Rashi (5.83 km/km^2); and Um Talang (3.16 km/km^2); Mynrot (3.22 km/km^2) and Wah Mynsat (3.29 km/km^2). These basins show relatively very simple geology. The selected 10 small basins have the following geological characteristics, Um Raling (Gneiss and Shillong series), Mynrot (gneiss), Umdkhar (Cherra sandstone), Umsaw (Shillong-series), Mynkjai (Shillong series), Wah Mynsat (Shillong series), Um Talang (Jaintia series), Rashmiang (gneiss and Jaintia series), Wah Rashi (Jaintia series) and Shillong sohoet (gneiss and Jaintia series).

With relation to texture ratio, Smith (1950)¹ and Strahler (1957)² described drainage density values (i) less than 5.00 as coarse, (ii) between 5.00 and 13.7 as medium, (iii) between 13.7 and 155.3 as fine, and (iv) greater than 155.3 as ultra-fine - (Fig. 19d). As texture may also be represented by the relative closeness of the drainage network, i.e. drainage density (Dd). Thus, a high drainage density results in fine texture and a low density in coarse texture. The Table-VI(vii) reveals that 5 out of 10 basins show less than 5.00 drainage density representing coarse

¹Smith K.G.(1950), Standards for grading texture of erosional topography: Am. Journ. Sci., Vol.248, pp.655-668.

²Strahler, A.N.(1957), Quantitative analysis of Watershed Geomorphology, Am. Geophys. Union Trans. Vol. 38, pp. 913-920.

texture. These are Umsaw (4.56), Wah Mynsat (3.29) and Um Raling (4.91) from Khasi Hills and Mynrot (3.22), Um Talang (3.16) from Jaintia Hills. Rest 5 basins viz., Umdkhar (5.45) and Wah Rashi (5.83) from Khasi Hills and Shillong sohoet (6.08), Rashniang (5.83) and Mynkjai (5.92) from Jaintia Hills show more than 5.00 km/km² drainage density indicating medium texture.

Constant of Channel Maintenance (CCM)

Schumm (1956)¹ used the inverse of drainage density as a property termed constant of channel maintenance (CCM). Thus :

$$CCM = \frac{1}{Dd} = \frac{Au}{\sum_{i=1}^K \sum_{i=1}^N Lu}$$

Specifically, the constant CCM tells the number of sq. miles or kms. of watershed surface required to sustain 1 linear mile or km of channel. For the present study, the constant of channel Maintenance for all the 10 selected small drainage basins have been calculated and represented in Table-VI(viii).

It is apparent from the Table-VI(viii) that the Um Talang basin of Jaintia Hills requires 0.32 sq. km. to maintain 1 km. length of stream, is the highest and the Shillong sohoet basin of Jaintia Hills requires the lowest

¹Schumm, S.A. (1956), Op.cit., pp.597-646.

TABLE - VI(viii)
Constant of Channel Maintenance (CCM)

Sl. No.	Basins	CCM (sq. km/km.)
<u>Khasi Hills</u>		
1.	Umdkhar	0.18
2.	Umsaw	0.22
3.	Wah Mynsat	0.30
4.	Wah Rashi	0.17
5.	Um Raling	0.20
<u>Jaintia Hills</u>		
6.	Mynrot	0.31
7.	Um Talang	0.32
8.	Shillong sohoet	0.16
9.	Rashniang	0.17
10.	Mynkjai	0.17

amount of area i.e. 0.16 sq. km. to maintain 1 km. length of stream. It is interesting to note that these exist an inverse relationship between Drainage density (Dd) and constant of channel maintenance (CCM). The basins which represent the highest drainage density figure are seen showing lowest CCM values. This can be stated in a different way, while it is the relief which controls drainage density i.e. higher the relief higher is the drainage density. In this case, higher the relief, lower is the CCM value and vice-versa. Therefore, it is confirmed that Schumm's formula for $CCM = \frac{1}{Dd}$ is applicable for this study. The correlation coefficient between Dd and CCM is calculated. It is found that there is a high negative correlation between Dd and CCM (-0.99).

Stream Frequency (Fs)

Horton (1945)¹ introduced stream frequency (or channel frequency) F_s , as the number of stream segments per unit area. Melton (1958)² analysed in detail the relationship between drainage density and stream frequency, both of which measure the texture of the drainage net, but each of which treats a distinct aspect. He derived the dimensionally correct equation.

$$F = 0.694 D^2$$

And from this the dimensionless number F/D^2 , which tends to approach the constant value 0.694 despite as variations in linear scale. It is now clear that stream frequency is calculated by the total number of streams in a drainage basin divided by the area of the basin or the stream frequency is calculated by the total number of stream in an unit area in a given drainage basin.

$$F_s = \frac{N}{A}$$

where, 'Fs' is the stream frequency,

'N' is the total number of streams in an unit area,

and 'A' is the unit area.

¹Ibid., p.285.

²Melton, M.A. (1958), Geometric Properties of Mature Drainage Systems and their representation in an E_4 phase space, Journ. Geol., Vol. 66, pp.35-54.

**KHASI HILLS
STREAM FREQUENCY**

km. 1
0 1 km.

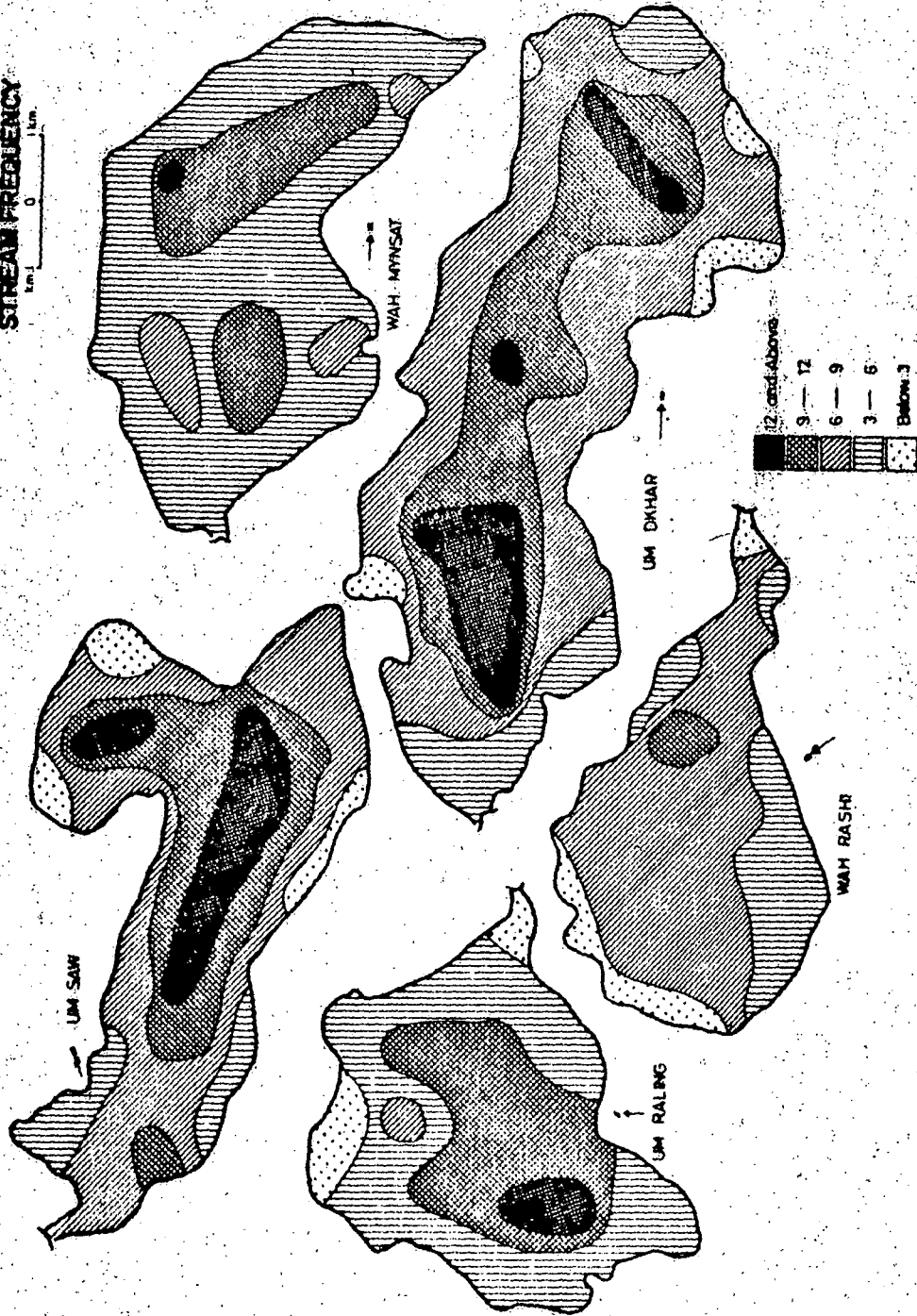


FIG. 23a

Method of Study

In the present study the later method has been applied. The drainage maps of all the 10 selected small drainage basins on the scale two cm. to one km., were first divided into two cm. grids, thereby making each grid to represent 1 sq. km. The total number of streams crossing to each grid was calculated and then put in the centre of the grids. By counting the maximum and minimum number of streams in each grid the isopleths of 3 stream interval have been drawn in all the 10 selected drainage basins. The resulting maps of stream frequency bring out the regional or spatial variations very clearly (Fig. 23 a & b).

The drainage frequency of all the ten basins have been put in certain category of 3 streams interval. Then the different categories have been termed as coarse, moderate, moderately high, high and very high. The areas for all these five categories have been measured for all the 10 basins and their percentage to the total area have been calculated and represented in the Table-VI(ix).

Analysis

Spatial distribution of Stream

Khasi Hills - The stream frequency map (Fig. 23a) for five small drainage basins from Khasi Hills show clearly

TABLE - VI(ix)

Stream Frequency (Area in Sq. km)

Sl. No.	Basins	Total Area	0 - 3 (Coarse)	3 - 6 (Moderate)	6 - 9 (Mod. high)	9 - 12 (High)	12 (V. High)
<u>Khasi Hills</u>							
1.	Umdkhar	30.25	2.125 (7.02%)	4.75 (15.70%)	8.375 (27.68%)	10.75 (35.54%)	4.25 (14.05%)
2.	Umsaw	23.25	1.375 (5.91%)	5.625 (24.20%)	7.25 (31.18%)	5.00 (21.5%)	4.00 (17.2%)
3.	Wah Mynsat	22.50	-	15.375 (68.33%)	1.75 (7.78%)	5.25 (23.33%)	0.125 (0.55%)
4.	Wah Rashi	17.50	1.5 (8.57%)	4.375 (25.00%)	11.125 (63.57%)	0.5 (2.86%)	-
5.	Um Raling	14.25	1.75 (12.28%)	4.50 (31.58%)	0.25 (1.75%)	6.25 (43.85%)	1.50 (10.52%)
<u>Jaintia Hills</u>							
6.	Mynrot	50.00	6.625 (13.25%)	5.875 (11.75%)	21.25 (42.50%)	14.25 (28.50%)	2.00 (4.00%)
7.	Um Talang	38.75	1.45 (3.74%)	9.30 (24.00%)	18.50 (47.74%)	9.25 (23.88%)	0.25 (0.64%)
8.	Shillong Sohoet	20.25	5.875 (29.01%)	5.875 (29.01%)	0.25 (1.23%)	7.5 (37.03%)	0.75 (3.70%)
9.	Rashniang	19.75					
10.	Mynkjai	15.50	4.375 (28.22%)	4.125 (26.61%)	1.625 (10.48%)	5.00 (32.25%)	0.375 (2.42%)

Figures in parenthesis indicate percentage to the total area.

the regional variation on space.

(i) Coarse Frequency (less than 3):

This category of frequency can be noticed in all but one basin that is Wah Mynsat. Fig. 23(a) reveals that in all the five basins this category of stream frequency is found only near the watershed areas of the basins. In Umsaw basin two patches of coarse stream frequency are found on the north-western part and a small area on the western part. In Wah Rashi basin, the only two patches of coarse stream frequency are found on the north and south of the basin. Um Raling basin shows two small patches of coarse stream frequency on the southern and western margins respectively. In Umdkhar basin also, this category of stream frequency found in small patches on the northern, north-eastern and south-western margins respectively.

(ii) Moderate Frequency (3-6):

Fig. 23(a) reveals that this category of stream frequency is found extensively in Wah Mynsat basin and Um Raling basin. Others have shown fewer areas under this category. Moderate frequency covers whole of Wah Mynsat basin except a few patches in the centre. In Umsaw basin, it covers the areas south-west and south-east portion, while Wah Rashi and Umdkhar basin it occupies the southern, northern and a little area east of Wah Rashi basin.

(iii) Moderately High Frequency (6-9):

This category of stream frequency is found in large areas in the Umsaw, Wah Rashi and Umdkhar basins, while in Wah Mynsat and Um Raling basin, this category occupies only a few areas.

(iv) High and very High Frequency (9-12 & above):

Interestingly high stream frequency occupies in the centre of all the five basins, and is seen in two patches only in the Wah Mynsat and Umsaw basins. In a way, it is due to the narrow valley and that too steep in character receives a large number of stream from all sources, hence, high and very high frequency of stream of 9 to 12 and above 12 streams per sq. km. found in the central part of all the basins.

JAINTIA HILLS
STREAM FREQUENCY

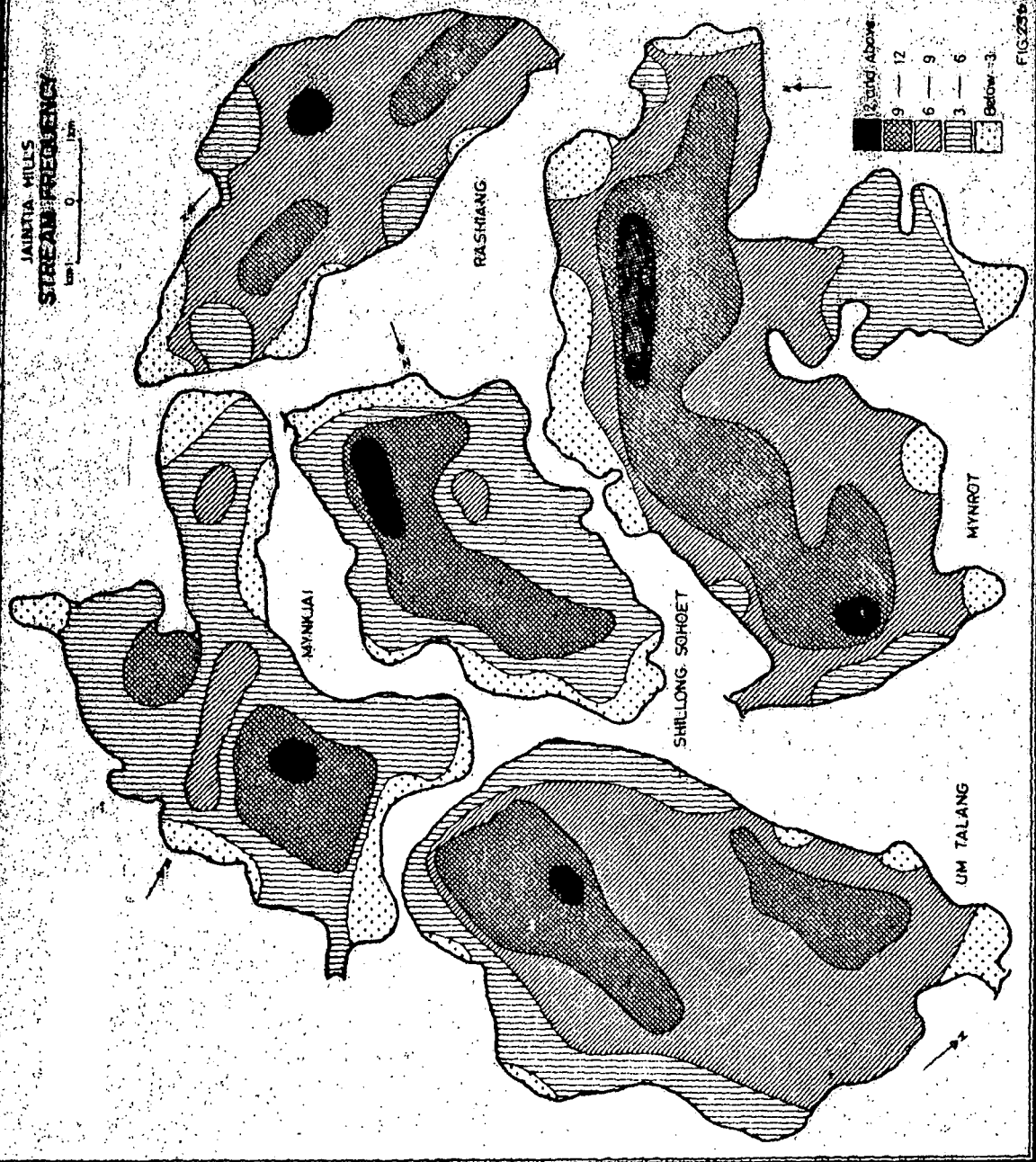
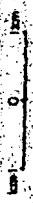


FIG. 258b

Jaintia Hills(i) Coarse Frequency (Less than 3):

The stream frequency map (Fig. 23(b)) of five basins from Jaintia Hills reveal that, all the basins are surrounded by coarse stream frequency. These are the areas of 1st order basins and are the areas of higher altitudes.

(ii) Moderate Frequency (3-6):

The second category of stream frequency is the areas drained by 3 to 6 streams per sq. km. Unlike the coarse frequency this category also covers the basins from almost all sides. The basins of Mynkjai and Shillong sohoet show extensive areal coverage under this category.

(iii) Moderately High Frequency (6-9):

Moderately high stream frequency is the areas drained by 6 to 9 streams per sq. km. Fig. 23(b) reveals that except the Mynkjai and Shillong sohoet basins, rest three basins have the majority of their areas under this category.

(iv) High and very High Frequency ((9-12 & above):

The stream frequency map Fig. 23(b) of five selected drainage basins of Jaintia Hills reveal that, unlike those of Khasi Hills, the basins of Jaintia Hills also show high and very high stream frequency in the central part of the basins. This is due to the fact that these are the areas where all the streams both large and small flows in. In other words, the valleys of all the five basins show the areas of high and very high stream frequency.

From the above analysis of stream frequency of different categories it is clear that, the stream frequency is in a way controlled by the altitude of the basins. As the altitude decreases the number of streams per sq. km. increases. In other words, high altitude areas of the basins are having less developed surface drainage systems,

whereas the lower altitude areas i.e. the river valleys, where the main nodes of the streams are present show relatively higher number of streams per sq. km. Because these areas are having well-developed surface drainage systems which results in high and very high stream frequency.

Areal Aspect of Stream Frequency

(i) Coarse Frequency (less than 3):

Table-VI(ix) reveals that the only basin Wah Mynsat, does not have this category of stream frequency. Areawise, the Mynrot basin occupies the highest position comprising 6.625 sq. km. i.e. 13.25 per cent of the total area of the basin and the lowest place goes to the Umsaw basin comprising an area of 1.327 sq. km. i.e. 5.91 per cent to the total area of the basin. But, if one sees the percentage distribution of stream frequency of different category, the Shillong sohoet basin occupies 29.01 per cent to the total area of the basin. It is interesting to note that this category of stream frequency is found only at the watershed zone of the basins.

(ii) Moderate Frequency (3-6):

The second category of stream frequency is 3 to 6 streams per sq. km. Table-VI(ix) reveals that the largest area covered by this category is found in the Wah Mynsat basin (15.375 sq. km) followed by Um Talang basin (9.30 sq. km.) of Jaintia Hills. The lowest area covered by moderate frequency is found in the Mynkjai basin (4.125 sq. km.) of Jaintia Hills. The percentage to the total area is highest in the Wah Mynsat basin (68.33%) of Khasi Hills and followed by Um Raling basin (31.58%) of Khasi Hills. The lowest percentage is noted from the Mynrot basin (11.78%) from Jaintia Hills.

(iii) Moderately High Frequency (6-9):

Moderately high frequency of streams indicates the areas drained by six to nine streams

per sq. km. Table-VI(ix) reveals that the largest area covered by this category is found in the Mynrot basin (21.25 sq. km.) followed by Umtalang basin (18.50 sq. km.) both are from Jaintia Hills. The lowest area under this category is found in the Shillong sohoet basin (0.25 sq. km.) and Um Raling basin (0.25 sq. km.) from Jaintia Hills and Khasi Hills respectively. Percentage-wise the Wah Rashi basin (63.57%) from Khasi Hills covers the maximum percentage of area to the total area of the basin, while the second position goes to Um Talang basin (47.7%) and lowest percentage of area under this category is noted from the Shillong sohoet basin (1.23%) from Jaintia Hills.

(iv) High Frequency (9-12):

Table-VI(ix) reveals, that the Mynrot basin (14.25 sq. km.) has the largest area under this category from Jaintia Hills followed by Umdkhar basin (10.75 sq. km.) from Khasi Hills. The lowest area under this category is found in the Wah Rashi basin (0.5 sq. km.) from Khasi Hills. Percentage-wise the Um Raling basin (43.85%) from Khasi Hills covers the highest percentage of area under this category followed by Shillong sohoet basin (37.03%) from Jaintia Hills. While the lowest percentage of area under high frequency is found in the Wah Rashi basin (2.86%) of Khasi Hills.

(v) Very High Frequency (12 and above):

The last category of stream frequency is the area drained by more than 12 streams per sq. km. This stream frequency is found in a few patches in all the 10 selected basins. The largest area covered by high frequency of streams is found in the Umdkhar basin (4.25 sq. km.) from Khasi Hills and the lowest area under this category is found in the Um Talang basin (0.25 sq. km.) from Jaintia Hills. This is due to the lack of relief and unfavourable underlying rock structure that results few areas of high frequency and more areas under coarse to moderate stream frequency.

Factors Affecting Stream Frequency

The study of the stream frequency maps of the ten

selected small drainage basins of Khasi and Jaintia Hills reveals that the frequency of streams in these basins depends upon a number of variable factors, which may be divided into two categories :

1. Natural Factors, and
2. Map factors.

Natural Factors: The important factors which might have affected the drainage frequency of these basins are as follows and the relative significance of these factors varies from place to place and basins to basins :

- (a) Climate,
- (b) Structural Characteristics of rocks,
- (c) Relief,
- (d) Infiltration capacity; and
- (e) Vegetation

From the spatial analysis of the ten small basins of Khasi and Jaintia Hills, it is apparent that the coarse and moderate stream frequencies are due to the lack of relief and the absence of impermeable rocks on the surface. Being the plateau like character of the Wah Mynsat, Um Raling and Wah Rashi basins of Khasi Hills and the limited relief except along the scarp face gave rise to coarse to moderate stream frequency. It is also noticed from the rainfall data that these basins receive less rainfall in comparison to the other two basins of Umdkhar and Umsaw. The location of

the Wah Mynsat, Um Raling, and Wah Rashi basins are towards the eastern boundary of the Khasi Hills. As the rainfall decreases from west to east, it is apparent that these basins receive less rainfall, hence low frequency of streams is noticed in these basins.

It is also noticed that the regions of high and very high frequency have the relief of dissected hills. Such areas also have favourable lithology. The two basins Umdkhar and Umsaw from Khasi Hills are located on the western part of the central plateau region and receive high rainfall resulting high and very high frequency of streams per sq.km.

According to Thornbury (1954) "Horton (1945) has called infiltration capacity, or what is more commonly referred to as the permeability of the mantle rock and bed rock, is probably the most important single factor influencing the drainage texture."¹ These ten basins which underlain by sandstones have shown relatively less permeability and this results the moderately high frequency of streams.

Climate indirectly affects stream frequency by its control upon the amount and type of vegetation through their influence upon the amount and rate of surface runoff.

¹ Thornbury, W.D.(1954), Principles of Geomorphology, p.126.

Climate affects the capacity of the soil to absorb rain-water by determining whether the soil is frozen and whether it is nearly saturated with moisture. "It is probably true that with similar conditions of lithology and geologic structure in semiarid regions have finer drainage texture than humid regions, although major streams may be more widely spaced in semiarid than humid regions. The reason for this lies chiefly in the less extensive vegetal covering in dry regions and the larger percentage of runoff."¹

Map Factor: In the study of drainage frequency, the affect of the Map factor is also of a great significance. In the map, the most important factor determining the frequency of drainage is the scale of the map. Needless to mention with large scale maps one will get a more accurate picture of drainage frequency than from small-scale maps. In small-scale maps the 1st order and the second order streams are not given clearly. In this study the researcher has used the topographic sheets of 1:50,000 due to the lack of larger scale toposheets and areal photographs.

Interrelation of Selected Morphometric Variables

The fluviially eroded landscapes are composed of drainage basins, and these provide convenient units into

¹Thornbury, W.D.(1954), Op.cit., p.126.

which an area can be subdivided. The development of a landscape is equal to the sum total of the development of each individual drainage basins of which it is composed.¹

There are varying degree of complexity associated with geomorphological data. The simplest way is to analyse a single characteristic of certain landforms as analysed earlier. They were measured and their proportions analysed through univariate statistics. In many instances, however, the geomorphologist needs to know the relation between two variables. This requires the use of bivariate statistics. But when these are more than two variables to be analysed, it requires the use of multivariate statistics. In the present study an attempt has been made to study the relationship between the morphometric properties of 10 selected drainage basins. Since it is not possible to measure the morphometric variables of all the drainage basins of Khasi and Jaintia Hills (because of non-availability of toposheets) the analysis was made to be based on a sample study.

The data which have been used for the present analysis fall into two distinct groups. Some of them are obtained directly by measuring from the map viz., N_1 , N_2 , N_3 , N_4 , L_1 , L_2 , L_3 , L_4 and Area. Other variables are

¹Doornkam, J.C. and King, C.A.M. (1971), Numerical Analysis in Geomorphology; An Introduction, p.3.

TABLE-VI(x)
Data Matrix

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
93	19	6	2	3.26	46.4	9	9	0.6	1.25	1.25	0.25	1.0	1.0	4.91	0.2	14.25
188	46	8	2	3.96	97	35	17.5	9	1.54	1.31	0.42	0.57	1.2	3.22	0.31	50.0
105	45	9	2	3.46	110	28	14	6	1.2	1.08	0.6	0.4	1.11	5.45	0.18	30.25
104	40	8	2	3.96	65	25	5.5	5	1.2	1.1	0.5	0.5	1.09	4.56	0.22	23.25
88	17	4	2	3.36	50	10	7.5	8	1.39	1.33	0.15	0.85	1.04	5.92	0.17	15.5
80	22	5	1	4.35	44	17	8	5	1.47	1.33	0.3	0.7	1.1	3.29	0.3	22.5
143	28	6	1	5.25	85	19	8.5	10	1.36	1.16	0.55	0.44	1.2	3.16	0.32	38.75
61	11	3	1	4.16	80	19	6	13	1.25	1.25	0.25	1.0	1.0	5.87	0.17	19.75
53	13	3	1	3.8	60	21	12	9	1.47	1.33	0.3	0.7	1.1	5.87	0.17	17.5
78	11	2	1	4.86	85	20	10	5	1.5	1.06	0.7	0.3	1.12	6.08	0.16	20.25

Key to the Data Matrix

- | | | |
|------------------------------------|--|---|
| 1. U_1 = No. of 1st Order stream | 7. L_2 = No. of 2nd order length | 13. T.S.I = Topographic Sinuosity Index |
| 2. U_2 = 2nd Order Stream | 8. L_3 = 3rd order length | 14. SSI = Standard Sinuosity Index |
| 3. U_3 = 3rd order stream | 9. L_4 = 4th order length | 15. Dd = Drainage density |
| 4. U_4 = 4th order stream | 10. CI = Channel Index | 16. CCM = Constant of Channel maintenance |
| 5. R_b = Bifurcation ratio | 11. VI = Valley Index | 17. Area = Area of the Basin. |
| 6. L_1 = 1st order Length | 12. H.S.I = Hydraulic Sinuosity Index. | |

TABLE - VI(xi)
Correlation Matrix

	U ₁	U ₂	U ₃	U ₄	R _b	L ₁	L ₂	L ₃	L ₄	CI	VI	HSI	TSI	SSI	Dd	CCM	Area
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.	1.0	0.82	0.75	0.53	0.10	0.32	0.57	0.21	-0.07	0.05	-0.27	0.35	-0.40	0.55	-0.61	0.58	0.69
2.		1.0	0.95	0.63	-0.15	0.53	0.73	0.49	-0.10	0.05	-0.28	0.39	-0.46	0.54	-0.53	0.47	0.72
3.			1.0	0.70	-0.28	0.37	0.52	0.37	-0.25	-0.05	-0.25	0.26	-0.28	-0.35	-0.52	0.44	0.58
4.				1.0	-0.72	0.07	0.15	0.25	-0.41	-0.14	-0.06	-0.11	-0.08	-0.12	-0.02	-0.07	0.13
5.					1.0	0.25	0.15	-0.16	0.32	0.03	-0.32	0.54	-0.52	-0.57	-0.37	0.45	0.35
6.						1.0	0.76	0.57	0.37	-0.21	-0.56	0.70	-0.60	0.53	-0.03	0.06	0.67
7.							1.0	0.66	0.29	0.17	-0.26	0.54	-0.58	0.66	-0.31	-0.31	0.77
8.								1.0	0.03	0.42	0.09	0.27	-0.35	0.56	-0.19	0.21	0.63
9.									1.0	0.31	0.23	-0.13	0.07	0.21	0.03	0.08	0.33
10.										1.0	0.81	-0.42	-0.21	0.50	-0.22	0.31	0.39
11.											1.0	-0.86	0.69	-0.19	-0.17	0.20	-0.09
12.												1.0	-0.92	0.61	-0.10	0.10	0.42
13.													1.0	-0.77	0.19	-0.21	-0.49
14.														1.0	-0.62	0.67	0.84
15.															1.0	-0.99	-0.70
16.																1.0	0.73
17.																	1.0

1.00 = Positive 'r' values
-1.00 = Negative 'r' values.

calculated out of these measured variables, includes, CI, VI, HSI, TSI, SSI, CCM, Dd, Rb vide Table-VI(x). Attempts have been made to calculate the product-moment correlation coefficient with the formula :

$$r = \frac{\sum (X - \bar{X}) (Y - \bar{Y})}{\sqrt{\sum (X - \bar{X})^2 \sum (Y - \bar{Y})^2}} = \frac{\sum x y}{\sqrt{\sum x^2 \sum y^2}}$$

The coefficients have been worked out for 17 morphometric variables drawn from 10 selected drainage basins. Their level of significance at 0.05 level of significance has been assessed from t-table. The results have been arranged in the correlation Matrix Table-VI-(xi).

Analysis

(i) Basin Area and Number of Stream:

The study of Table-VI-(xi) shows that Basin Area is highly correlated with Number of 1st order, 2nd order and 3rd order streams (0.69, 0.72 and 0.58). Another interesting significant positive correlation exists between the number of 1st order with Number of second order (0.82), number of 1st order with number of 3rd order (0.75), number of 2nd order with number of 3rd order (0.95) and number of 3rd order with number of 4th order (0.70). It means that every increase in 2nd order stream will increase the number of 3rd order stream and this is an established fact. In this study the correlation between number of 2nd order streams with number of 3rd order is the highest (0.95) and is

significant at 0.05 level of significance. There is a high correlation between number of 2nd order stream and length of 3rd order stream. It means that when number of 2nd order stream will increase, number of 3rd order stream will increase and subsequently the length of 3rd order stream will also increase.

(ii) Basin Area and Stream Lengths:

The correlation between basin area and the length variables of the stream are significant at 0.05 level of significance. The study aims also at the revelation of the magnitude of fluvial erosion system and its relation to the basin area and the length of streams. The rate of increase of Area of the basin with the values of stream length increases as the order of the streams increases.¹ In other words, an increase in the length of second order stream is associated with a large increase in basin area than is an increase in the total length of the first order streams. This does not mean, for example, that an increase in the length at first-order streams, does not bring about an increase in basin area. From the table-VI(xi) it is apparent that the correlation coefficient between Basin area with length of 1st order stream (+0.67), length of 2nd order stream (+0.77) length of 3rd order stream (+0.63) and length of 4th order stream is (+0.33). It is interesting to note that number of second-order stream is highly correlated with length of 2nd order stream (+0.73) and length of 2nd order stream is highly correlated with Basin area (+0.77).

¹Doornkamp, J.C. and C.A.M. King, (1971), Op.cit., p.67.

(iii) Area and Constant of channel maintenance:

The correlation matrix table-VI(xi) reveals that there is a high positive correlation between area and CCM(+0.73). It means that an increase in the basin area is associated with an increase in constant of channel maintenance. In other words, when area of the basin increases the area required to maintain an unit length of stream will certainly increase, with length of streams remaining constant.

(iv) Interrelation among sinuosity indices and other variables :

Table-VI(xi) reveals that there exists a high negative correlation between valley Index and Hydraulic sinuosity Index (-0.86), and is significant at 0.05 level of significance. The VI is positively correlated with TSI (Topographic Sinuosity Index) (0.69). The HSI is negatively correlated with TSI (-0.92) but with SSI (Standard Sinuosity Index) it has a high positive correlation (+0.61). CI is highly correlated with Vi with a high positive correlation (+0.81). The Rb, L₁ and L₂ are positively correlated with H.S.I. and the same are negatively correlated with T.S.I., and L₁, L₂ and L₃ are high positively correlated with S.S.I. (0.53, 0.66 and 0.56).

A glance at the table-VI(xi) shows that the area of the basin is negatively correlated with the drainage density (-0.70) at 0.05 level of significance. It means that when the area increases the drainage density decreases in a particular proportion. It is interesting to see that there

is a high negative correlation exists between drainage density and CCM (-0.99). This conforms the established fact that drainage density is inversely related to constant of channel maintenance, that means high drainage density is generally associated with low constant of channel maintenance value. Because, high HSI value indicates mature stage of basin development and high TSI value indicates youth stage of basin development. In general the drainage density variable is negatively correlated with almost all the variables excepts with topographic sinuosity index and length of 4th order stream, although the 'r' values are insignificant (0.19 and 0.03). Likewise Topographic Sinuosity Index is negatively correlated with almost all the variables except with almost all the variables except with number of fourth order (0.08), Length of 4th order stream (0.07) and a high positive correlation with valley index (0.69).

The analysis thus, provides a better understanding of the interrelated morphometric variables. Areas of the basin increases with increase in length. Drainage density is inversely correlated with constant of channel maintenance and area of the basin is highly correlated with constant of channel maintenance. Number of second order stream is highly correlated with length of second order streams and R_b is negatively correlated with number of fourth-order stream.

CHAPTER - V I I

DISTRIBUTION AND LOCATION OF RURAL SETTLEMENTS
(KHASI & JAINTIA HILLS)

"The evolution of the various types of settlements noticeable in a particular region is attributable to a host of factors of the cultural and physical environment of the region"for they are the synthesis, the crystallization of the civilization of the region, the complex of natural and man-made phenomena of land."

- Hans Wilson Ahlmann
(1928).

Unlike many other fields of geographical investigations, the study of rural settlement has, with few exceptions, received relatively little attention in recent years. Geographers have approached the study of rural settlements in many ways. For example in the 1952 the French Geographer, Jean Brunhes¹, concentrated on such detailed aspects as regional variations in house design, building methods and materials and the influence of the physical environment on those features. Others have attempted to clarify the historical development of rural settlement patterns by a study of place names and a variety of documentary evidence. Obviously, such an approach is closely allied to the field of historical geography, and as such, lies outside the scope of this study. At the present

¹Brunhes, J. (1952), Human Geography, pp.39-40.

time, it is probably true to say that the changing social and demographic structure of village settlements is attracting much attention.

During last few years, various scholars have paid their attention to analyse the morphogenesis of rural settlements from different angles. Hudson (1970)¹ correlated the Christaller's and Losch's central place network on the basis of algebraic equations. In Germany, Jager(1968)², studied the distribution of deserted settlements. Hudson (1969)³ presented quadrat sampling method for the analysis of the distributional pattern of rural settlements on empirical maps. The same pattern was formerly used by Olsson (1968)⁴ also by trend and cell counting analysis of the settlements distribution in northern Sweden. He concludes that the spatial distribution of settlements may be described as an undulating economic surface generated by a two-stage diffusion process. Losyakova (1969)⁵ has developed a technique for mapping the settling process, while Baker(1969)⁶ has taken rank-size rule

¹Hudson, F.S. (1970), *Geography of Settlement* (2nd Ed.) Great Britain.

²Jager, H. (1968), *Op.cit.*, pp.165-80.

³Hudson, J.C. (1969), "A Location Theory for Rural Settlement", *A.A.A.G.* (59), pp.365-381.

⁴Olsson, G. (1968), "Complementary Models, A Study in colonization Maps," pp.115-31.

⁵Losyakova, K.M. (1969), "On the mapping of the settling process", pp.618-23.

⁶Baker, A.R.H. (1969), *Op.cit.*, pp.386-92.

to analyse the rural settlement sizes in France. Conzen (1969)¹ has taken spatial data from the nineteenth century manuscript - censuses for the analysis of rural settlements and landuse.

In Indian context, a number of studies relating to rural settlements have been done. Kaushic² in his 'Human settlements in the Western Central Himalaya' - pointed out that "although the types and patterns of settlements are related to both the physical and socio-cultural processes, and the agro-pastoral economy and tempo of life yet the predominantly governing factors of settlement ecology are the (i) relief, (ii) gradient of slope, (iii) climate, and (iv) soil". Tamaskar (1958)³, has discussed the "Jabera basin : its geomorphology and settlements". In this study he shows the influence of various geomorphic factors on settlements. Singh (1958)⁴ has traced the evolution of rural settlement pattern and their characteristics in the middle Ganga valley. Enayat Ahmad (1952)⁵ in his paper "Rural Settlement Types in Uttar Pradesh", has discussed the

¹Conzen, M.P. (1969), Op.cit., pp.337-43.

²Kaushic, S.D., Human Settlements in the Western Central Himalaya, pp.329-32.

³Tamaskar, B.G. (1958), "The Jabura basin : Its Geomorphology and Human Settlements", National Geographer, Vol.II pp.53-60.

⁴Singh, L.R. (1958), Rural Settlement in the Terai Region. National Geographer, Vol. II, Special Number, p.8.

⁵Ahmed, E. (1952), "Rural settlement type in Uttar Pradesh, (United provinces of Agra and Oudh)", A.A.A.G.(42) pp.223-246.

different house types and the impact of building materials on them. Sharma (1972)¹ has discussed the different types of rural settlements, use of building materials in Rajasthan. Singh (1958)², in his paper 'Rural Settlement in the Tarai Region of Uttar Pradesh' has discussed the types and pattern of rural settlements in a systematic way. He has highlighted the various factors which control the location of rural settlements in the Tarai Region of Uttar Pradesh.

Regional Distribution of Rural Settlements

Evolution of Settlements:- In the pre-historic time, the Khasis an Austro-Asiatic group of people, came to these hills from south-east Asia (Cambodia-Laos) in the Rillum, they came from the east and probably settled down in groups at different places, forming villages. The Khasis are predominantly shifting cultivators. Permanent wet cultivation, however, is developing slowly. Outside the main settled areas, a few houses are scattered and they occasionally shift from place to place.

As the rural settlement like elsewhere in Khasi and Jaintia Hills is mainly an agricultural workshop any change in agricultural landscape brings modification in the rural habitat. During pre-historic period people were mainly

¹Sharma, R.C. (1972), Settlement Geography of Indian Desert, New Delhi.

²Singh, L.R. (1958), Op.cit., p.8.

hunters and food-gatherers, and used to live in rock-cut caves and bushes. Their residential colony started with the practice of cultivation. The information about this change is meagre and speculative, but some idea about it can be gained from evidences available through ancient sites and archaeological remains, distribution of religious centres, such as temples, churches etc., distribution of tribal communities, contemporary historical accounts and literature and nomenclature of settlements. For the convenience of analysis this changing historical background has been subdivided into the following heads :

- (i) Pre-historic settlements,
- (ii) Settlements of the British Period,
- (iii) Post-Independence Settlement.

(i) Pre-historic Settlements :-

There is no evidence of pre-historic settlement of the region except for the recent claim by some scholars that the Rongram valley of the Garo Hills was inhabited in the Palaeolithic times, based on their findings in the Daojalihading excavation site of the said valley.

The history of the Khasis and the Jaintias may be traced from the early part of the 16th century only, because prior to this, there is no record or tradition that they ever owed allegiance to a single prince. When they first emerged from obscurity, they were split into numerous communities each under

its own head. The most well known in the 16th and 18th centuries are only the Jaintia Rajas (Kings) and to some extent, the Syiem (Raja or Chief) of Khyrim in the Khasi Hills.¹ It is supposed that the earliest Jaintia Raja reigned from about A.D. 1500 and the Jaintia Hills area was formed into a single kingdom with capital at Jaintiapur and had within its jurisdiction a tract of plain country lying between the town of Sylhet and the Cachar border and also the territory stretching from the foot of the Hills overlooking the Barak valley to the Kalang river in Nowgong district. Having lived in the plains for long, the Jaintia Rajas were brought to some extent under the influence of the Hindus. They had diplomatic ties with the Ahom and Kachari Kings, but on 15th March, 1835, the last of the Jaintia Rajas, Rajendra Singh, was dispossessed of His kingdom by the British. The Khasis previously had been known only as troublesome marauders upon the plains of Sylhet. A line of forts was kept up under the hills to check their incursions. The Khasi Hills came under the British in 1883 with the submission of the last of the important Syiems, U Tirot Singh. There were 30 Syiems or kings ruling over their respective territories and 12 dolois or small rulers when the British came to the area.

Among the old administrative centres, Jaintiapur, Nongkhlaw, Mairang, Nartiang, Raliang, and Khrungma situated in the Khasi and Jaintia Hills are worth mentioning. There were as many as 30

¹Singh, R.L. (1971), India : A Regional Geography (Ed.) Varanasi, p.677.

Khasi confederates, the most important of the confederated states being (i) the State of Ossimlea ruled by the Nongklaw Raja, (ii) Principality of Khyrim consisting of seventy villages, (iii) Bor-manik's country with 28 villages and forming a part of the province of Khyrim, (iv) The kingdom Charra with 25 villages, (v) the State of Nurtung with capital at Nartiang, (vi) the Principality of Nuspung with 20 villages, (vii) the Maharam principality consisting 24 villages. (viii) the Muriow Kingdom with 25 villages and (ix) the State of Ramrye.¹ These principalities existed from the 16th century till the arrival of the British in early 19th century. It may be noted that while the Khasi Hills region was split into a large number of small States, the Jaintia Hills formed only one kingdom, known as the Jaintia Kingdom.

(ii) Settlements of the British Period :-

Under the British, the cultural landscape of the region underwent considerable changes through development of settlements and communication lines; particularly after the formation of the Khasi and Jaintia Hills district in 1835 and the Garo Hills district in 1866. The tiny village of Cherrapunji was selected in 1827 as the capital of the Province, which owing to heavy rainfall (1,300 cm.), was shifted to a place known as Yeddo (IEODOH) (later named as Shillong),² in the Khasi Hills in 1864.

¹Singh, R.L. (1971), Op.cit., p.678.

²Ibid.,

Shillong has since then developed into a really good administrative headquarters-cum-sanatorium. A few years later in 1867 an extensive survey in the Garo Hills was made for the selection of a site for the headquarters of Garo Hills, and subsequently the present town of Tura came into existence as the first urban centre in Western Meghalaya. Jowai (1872, Pop.4,502) in the Jaintia Hills also became an important town by that time.

Steps towards development of roads were undertaken by the British for administrative convenience. In 1877 a road, 107 km. long, joining Shillong with Gauhati via Barapani, Umsning, Nongpoh and Burnihat with sharp hair-pin bends was opened for wheeled traffic. Earlier a road running from Gauhati across the hills via Nongklaw, Mairang, Mawphlang, Cherrapunji, Mawsmal, Mawblang and Theriaghat to Bholaganj in Sylhet for a distance of 208 km was constructed, which was taken care of partly by the inhabitants of the native States of K and J Hills and partly by the British Government. However, this road lost its importance after the construction of the Shillong-Gauhati Road.

With the arrival of the Britishers this region experienced numerous changes in its settlements. The British constructed several roads to connect inaccessible places for administration. Several rural habitations came to develop around them which in course of time became permanent. Such permanent habitation also restricted the shifting character of cultivation to a little extent. Further changes

in the distribution of rural settlements came due to increase in communication facilities.

The coal minning areas of this region attracted people and led to the establishment of several minning settlements. The Britishers always paid much attention towards the tribes especially with a view to win them to christianity. Several institutions to teach English were opened and free coaching was given but their influence remained only localised. Because of the Ramakrishna Missionaries tried to capture some of the interior areas and they tried to spread their thinking by giving education to the tribes. Example of Ramakrishna Mission Schools can be found even today in some places viz., Milliem, Cherrapunjee etc..

(iii) Post-Independence Period:-

After independence there has been rapid development in the growth of educational institutions of various grades, medical services and roads. The coal minning areas in southern Khasi hills witnessed a number of new settlements. As a matter of fact the number of road-side linear pattern settlements have evolved. Several trading centres developed at suitable locations. A number of old settlements lost their agricultural landscape and attracted administrative, commercial activities.

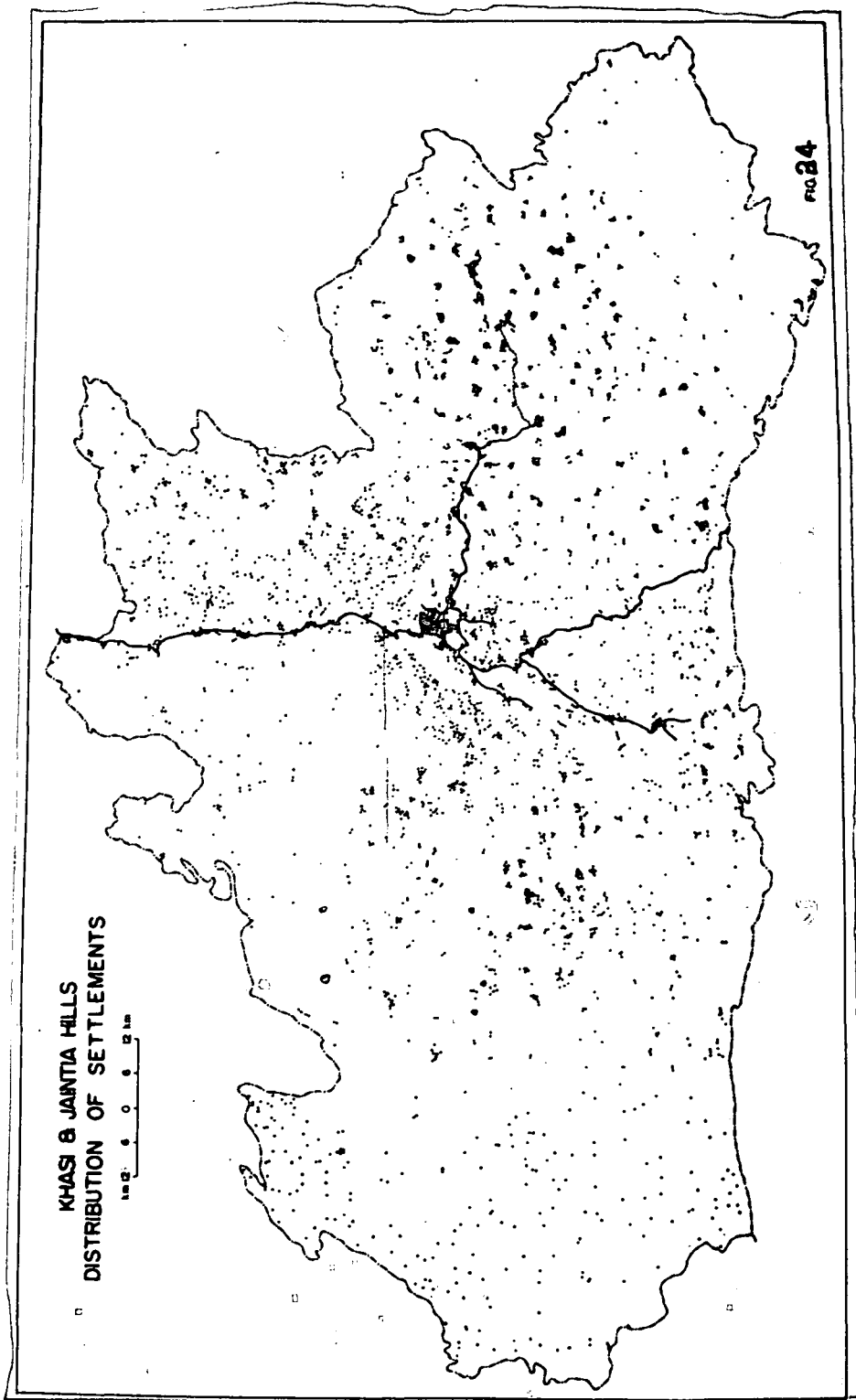
Distribution of Rural Settlements:

The population of the plateau resides usually in a single collection of houses, situated on a higher level than surrounding fields with a view to secure natural drainage.

In the highly dissected plateau of Khasi and Jaintia Hills, geological, topographical and micro-climatic conditions have exerted their influence on the distribution and sitting of settlements besides cultural and historical factors. The complexity of structure, terrain and drainage has caused relatively uneven distribution of settlements. The rugged areas of the plateau possess more uneven or irregular distribution of settlements, while the relatively flat area (the central part of Khasi hills and northern part of Jaintia hills.) show more or less even distribution of settlements. In the more dissected and uneven areas settlement grew only on small plains adjacent to river basins, while the scarps, steep slopes, divides and ridges remained forest covered. In the plateau as a whole, however, settlements grew up on uplands away from the river valleys and utilise the lowlands or river valleys for cultivation. In the rugged areas it is seen, isolated hamlet or isolated homestead associated with isolated patchy agricultural land. On the other hand in the relatively flat plains and table lands, semi-compact fragmented and dispersed settlements are seen. The northern hill region of the plateau is intersected by numerous streams and studded with rocky hillslopes with isolated peaks, ranging to almost of equal heights, is marked by relatively dispersed settlements. Though a number of roadside linear settlements have been evolved through time along the National Highway.

The hilly and highly dissected area (the western part) of the plateau is dotted with widely spaced small villages and isolated hamlets. The eastern part of the plateau has relatively gentle slope than the southern scarp. A large number of large size settlements with permanent agricultural land along the river valleys as well as along the National and state highways are a marked characteristics of this part of the plateau. The southern scarps are very steep and dissected with a number of narrow gorges and 'V' shaped valleys, with a descent of over 305 metres (1000 ft.). The researcher observed, inter-locking spurs around north-eastern part of Cherrapunjee as a characteristic feature of its landscape. This part of the region is thickly forested in some parts and dotted with tiny hamlets. Cherrapunjee and Dawki are the two most important large settlements located in this part.

The population of the plateau resides usually in a single collection of houses, situated on a higher level than surrounding fields with a view to secure natural drainage. Normally, in a large size village, extensive cultivated areas or the crowding of old established sites, sometimes throw-off small clusters of popⁿ in hamlet form situated usually at short distances from main settlements. This type of map settlements have been noticed



during field work by the researcher. For example, due to the population pressure and availability of cultivable land at short distances, a group of two to three houses tends to settle there. The Sithliew village located near the Laitlyngkot village is an example of this type, in south of Shillong town.

A minute and critical analysis of the sites of settlements on the plateau reflects their favourable or restrictive characters. A variety of geomorphological factors weights heavily in the choice of sites of settlements. For example, dry and healthy surface of ground, accessibility to adequate, perrenial and unfailling supply of water for domestic use as well as other purposes, proximity to natural routes in the past or lines of modern transport, ground of moderate slope, safety from defence points of view, particularly in the pre-British period of insecurity and political instability, etc.. Amidst the predominantly agrarian community of this region, as much cultivable land as possible is released for cultivation by selection of elevated sites for settlements on less fertile or sterile - patches of land.

The settlement distribution map (Fig. 24) of Khasi and Jaintia Hills reveals a complete regional variation of distribution of rural settlements. The western part

of Khasi Hills district is thinly settled, indicating a dispersed or random distribution. The settlements found here are mainly in hamlet and isolated house form. This part of Khasi Hills is thickly forested and the terrain is very much dissected, with a number of large and small streams flowing north and southwards. Settlements are located near the streams and on the hill slopes.

The central plateau is thickly settled with compact and semi-compact settlement pattern. The important settlements found in this region are Mairang, Nongthliew, Lawbyrtun, Marngar, Mawthapdoh, Jakrem, Nongspung, Mawphlang, Myllem, Laithyngkot, Smit, Barapani, Shrynstaw and Thynroit, etc..

The northern part of Khasi Hills is showing two distinct areas of settlement distribution; one, east of the Shillong-Gauhati road and the other, west of the Shillong-Gauhati road. If one sees the western part of the Shillong-Gauhati road, here settlements are found in compact as well as semi-compact pattern. In some places, settlements are evenly distributed. The most important settlements are Nongkhraw, Umla, Mawhati, Umtnga, Mawsopah, Mawkyring, Lumsynteng, Umroi, Bhoilymbong etc.. On the other hand, towards the western part of Shillong-Gauhati road, settlements are found scattered and isolated

farmstead predominates. This part locally known as 'Jirang' area and Jirang is the only large settlement found there. Other important settlements found here are Nongkhlaw, Umlang etc.. The Burnihat, Nongpoh, Barapani area locally known as the Bhoi country.

Physiographically, this part is represented by a number of isolated small hills of almost equal height. The area is dominated by radial and trellis pattern of streams. Vegetation is gradually getting thinner and thinner due to large scale deforestation practices (Plate-17). River valleys are not so deep. At places the slopes of the mountains are exposed with rocks. As a whole this represents with undulating topography and a number of ridges. Due to the gentle slopes and presence of the long-stretched peneplained surface a few large size settlements are located along the Shillong-Gauhati National highway where the people practised sedentary cultivation.

The southern part of Khasi Hills (around Mawsynram, Cherrapunjee area and Umngi, Umiew river basin) represents a dissected topography with narrow valleys and gorges. In this part, the settlements are evenly distributed in hamlet form. In some places, one finds compact settlements. Most of the settlements are found along the river valleys

and steep slopes. For example, Nongshyluit, Nongstein, Umblai, Thiedding, Mawphu village are located along the steep slope of the Umiew river valley.

The settlement distribution map (Fig. 24) of Khasi and Jaintia Hills reveals that, in Jaintia Hills settlements are found more or less in compact form in comparison to the western and north-western parts of Khasi Hills. This is because most of the settlement sites chosen in Jaintia Hills are near the springs. The settlers, in this part more or less do not practice shifting cultivation as the Khasis do. Valley cultivation is a most important practice in this part of Khasi & Jaintia Hills. Therefore, settlements are mostly found near the agricultural land in a compact and semi compact form. Some of the important large settlements are Mawdymnial, Khlientyrski, Sokinling, Muphiang, Mawpyut, Lumshyrmit, Longdum, Jongkalu, Mapra, Mungkrem, Kokalaw, Kyndong, Tuber, Myhsa, Myhtang, Nartiang, Kyrwen, Myndihati etc.

The south-eastern part of Jaintia Hills is sparsely settled. This part of Jaintia Hills is densely forested and is very steep (Fig. 18). The Saipung Reserved forest area supports very few settlements. This part of Jaintia Hills, due to thick forest cover, infertile land and steep slope, it is almost impossible to practice agriculture.

Therefore, whatever small settlements exist they depend upon forest product. Further south, the Narpuh Reserved Forest area is also without any settlement, except one or two isolated huts.

Distribution of Settlement
According to Population Size

The study of the distribution of rural settlements according to population size seems very significant for this region. As in hilly regions the growth of settlements are restricted by the physical and geomorphic factors. In this analysis an attempt has been made by the researcher to explain the possible geographical and geomorphological factors which favours as well as restrict the growth of settlements of various population size. The researcher has taken the number of settlements according to the population size for two time period - i.e. 1961 and 1971, as data for 1951 and 1981 are not available. But data regarding total number of inhabited villages are available for 1951 to 1971 only (1981 census has not yet published for Meghalaya that is why the researcher could not get 1981 data). The total number of inhabited villages of Khasi and Jaintia Hills have been given in the following table-VIII(i).

TABLE-VII(i)

Number of Inhabited Villages (Khasi and Jaintia Hills)

Year	Number of inha- bited villages	Increase
1971	2,245	+253
1961	1,992	+402
1951	1,590	-

*Census of India (1971), Meghalaya, Housing Reports and Tables, Series-13, Part-IV.

(Figures in parenthesis indicate % increase)

The above Table-VII(i) reveals that the total number of inhabited villages of Khasi and Jaintia Hills have increased from 1951 to 1961 (402) and again from 1961 to 1971 (253). The year 1971 show a declining growth in the total inhabited villages. The following table-(ii) show the distribution of inhabited villages according to population size for 1961 and 1971.

Table-(ii) reveals that the increase in the number of villages in the second category (200-499) is the highest (127). But the increase in the fourth category (1000-1999) is 14 only. In terms of percentage growth the fourth category shows 56 per cent increase in 1971 over 1961 and the first category (less than 200) shows

TABLE-VII(ii)

Numbers of villages classified by size of population (Khasi and
Jaintia Hills) 1961-71

Year	Total No. of inhabited villages	Less than 200	200-499	500-999	1000-1999	2000-4999	5000 above
1961	1,992	1,450 (72.79)	409 (20.53)	108 (5.42)	25 (1.25)	-	-
1971	2,245	1,503 (66.94)	536 (23.87)	161 (7.17)	39 (1.73)	6 (0.26)	-
<hr/>							
Increase	253 (12.70)	53 (3.65)	127 (31.05)	53 (49.07)	14 (56.0)	6 (100.0)	-

*Census of India (1971), Meghalaya, Housing Report and Tables, Series 13, Part-IV. Figures in Parenthesis indicates percentage to total.

least growth rate (3.65 per cent). In 1961 there was no village in the 2000-4999 population size but in 1971 there are six villages in this category. As a matter of fact, the number of inhabited villages in the first category (less than 200 population) are largest in both the years.

There are a number of geographical as well as geomorphological factors which favours the growth of small villages and restrict the growth of large villages. From the analysis of the location of settlements it is clear that most of the settlements found in Khasi and Jaintia Hills are located near the springs and river valleys. The main purpose being the easy availability of water for domestic as well as other uses. People of this region practice jhum cultivation, and this type of cultivation can not support large villages. Therefore, wherever they found suitable land for shifting cultivation they had to settle there, forming a small-sized village. The other factors being the dissected topography and steep slopes restrict the growth of large settlements. In Jaintia Hills, though some large villages are found, they are only near the river valleys, permanent agricultural land and along road sides. Therefore, it is apparent that large size villages are less in number than small size villages.

TABLE-VII(iii)

Number of villages according to Population size 1971

666

Thanas	Area in	Total No. of villages	Average Area under one village	Population				
				Less than 100	100 249	250 499	500 999	1000 & above
Shillong	5,837.2	878	6.64	304	317	178	58	21
Nongpoh	1,985.0	303	6.55	123	112	55	11	2
Cherra	2,224.7	497	4.47	245	161	61	25	5
Dawki	1,099.3	238	4.61	117	68	34	14	5
Jowai	3,287.7	328	10.02	111	96	64	45	12
Khasi & Jaintia Hills	14,434.9	2244	6.43	900	754	392	153	45

253

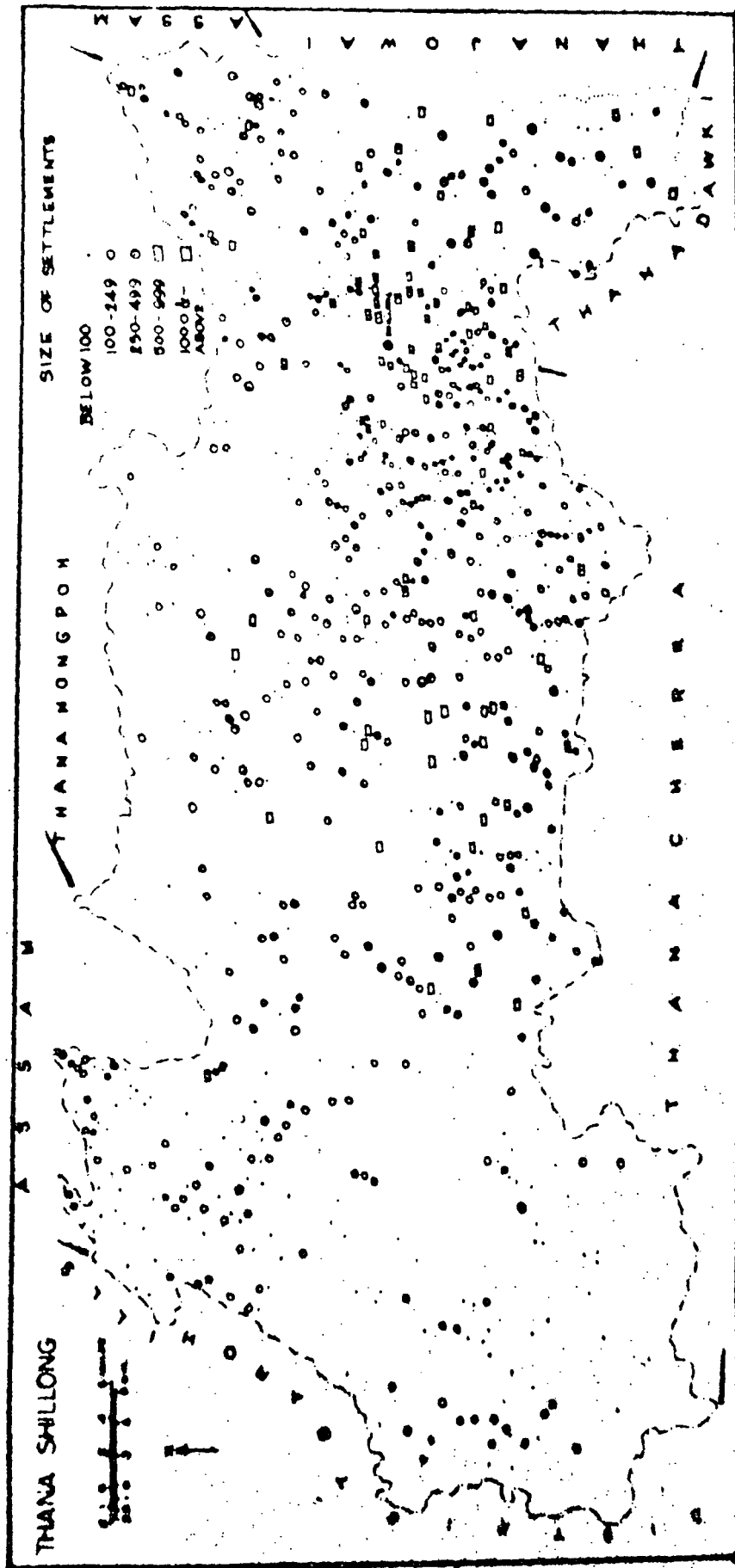


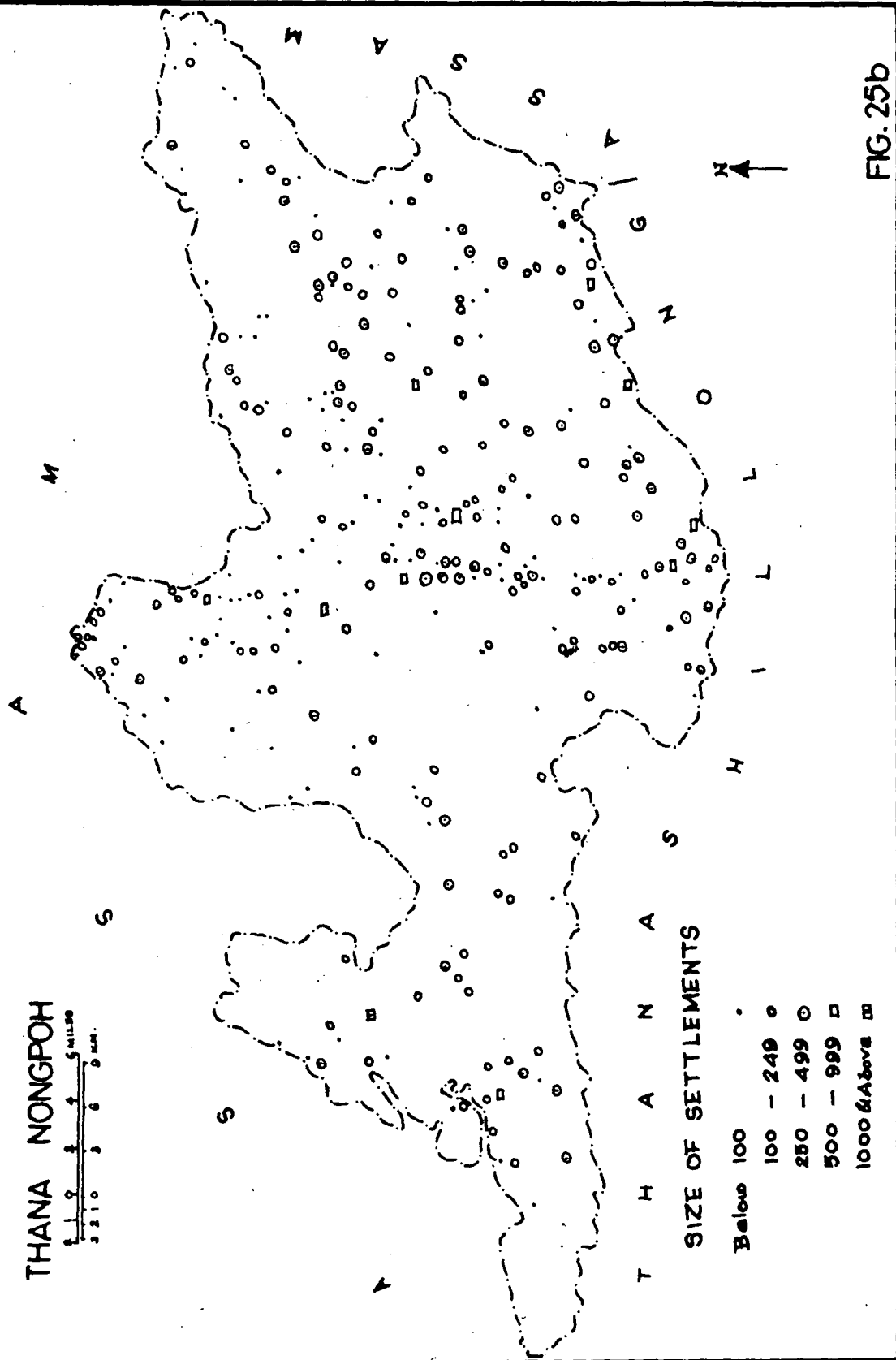
FIG 25a

Distribution at Thana Level:

The distribution of villages according to population size in Thana level, gives more interesting picture (Fig. 25 a to e). According to 1971 census, there are five Thanas in Khasi and Jaintia Hills of Meghalaya: viz., (i) Shillong Thana, (ii) Nongpoh Thana, (iii) Cherra Thana, (iv) Dawki Thana and (v) Jowai Thana. The following table-VII(iii) represents the distribution of inhabited villages according to population size of all the five thanas.

Shillong Thana - Shillong thana with an area of 5837.2 sq. kms. is the largest thana in Khasi and Jaintia Hills of Meghalaya. According to 1971 census the total population of Shillong thana was 326,571 persons. From the contour map of Khasi and Jaintia Hills (Fig. 29a), it is clear that Shillong thana has maximum elevation of more than 1500 metres. This area comes under the central Upland Zone. In most of the areas, elevation is ranging between 900 to 1200 metres. Due to dissected topography in the western part of the thana, settlements are comparatively less. A large number of settlements are having population less than one hundred and are distributed in a sprinkled manner. In the southern part of the Upland Zone closed to Cherra thana, the maximum elevation is less than 900 metres, and due to relatively flat area settlements

THANA NONGPOH



SIZE OF SETTLEMENTS

- Below 100 .
- 100 - 249 o
- 250 - 499 O
- 500 - 999 □
- 1000 & Above ■

FIG. 25b

are more or less evenly distributed. Some of these settlements are, Mairang, Myllem, Lawbyrtun, Nongspung, Smit, Nongkrem etc.. In the eastern part of the thana the elevation is between 900 to 1500 metres. In this part settlements are found clustered with a few large settlements, for example; Umlakhen, Tyntring, Nongrah, Mawlynrei, Sohryngkham, etc.. Table-VII(iii) reveals that 70 per cent of the total villages are having population less than 250 persons, 20 per cent of the total villages are having population less than 500 persons, 6.6 per cent having less than 1000 persons and 2.4 per cent of the total inhabited villages are having population above 1000 persons. In Shillong thana, one village covers an average area of 6.64 sq. kms.

Nongpoh Thana - Nongpoh is the northern most thana of Khasi Hills, with an area of 1985.6 sq. kms. According to 1971 census, it has a total population of 52,735 persons. In the northwest part of this thana, bordering Assam, where elevation is reaching below 350 metres; concentration of settlements are more than any other parts (Fig. 25b). Burnihat and Nongpoh two important settlements of this thana are located on the Burnihat-Nongpoh peneplain. In the eastern part of the thana adjoining to Assam, settlements are more or less evenly distributed.

Along the tributaries of the river Umsnang some compact settlements are also found. In the southern part of the thana as the elevation is gradually increasing and slopes are relatively steep, the concentration of settlements are also less. Linear type of settlements are found on both sides of the road leading from Gauhati to Shillong. Umsning and Nongpoh are two important settlements of this thana. Table-VII(iii) reveals that 77.5 per cent of the total villages are having less than 250 persons, 18.15 per cent of the total villages are having more than 5000 persons. A single village covers an average area of 6.58 sq. kms. in this thana.

Cherra Thana - With an area of 2,224.7 sq. kms.

Cherra thana is the second largest, next to Shillong thana. According to 1971 census, the total population is 83,987 persons. In the northern part of the thana as elevation is less than 400 metres, with gentle slope, concentration of settlements are more (Fig. 25c). In this part settlements are compact and uniformly distributed. Settlements are also located along the tributaries of the rivers Um Rilang, Umngi and Kynshiang (Jadu-kata), Umiew, and Umsohmyngkew. The important settlements in this part are viz., Mawpat, Nongnam, Jakrem, Laitmawsing, Mawkyrwat, Sohmyiang etc.. In the western part of the thana, the

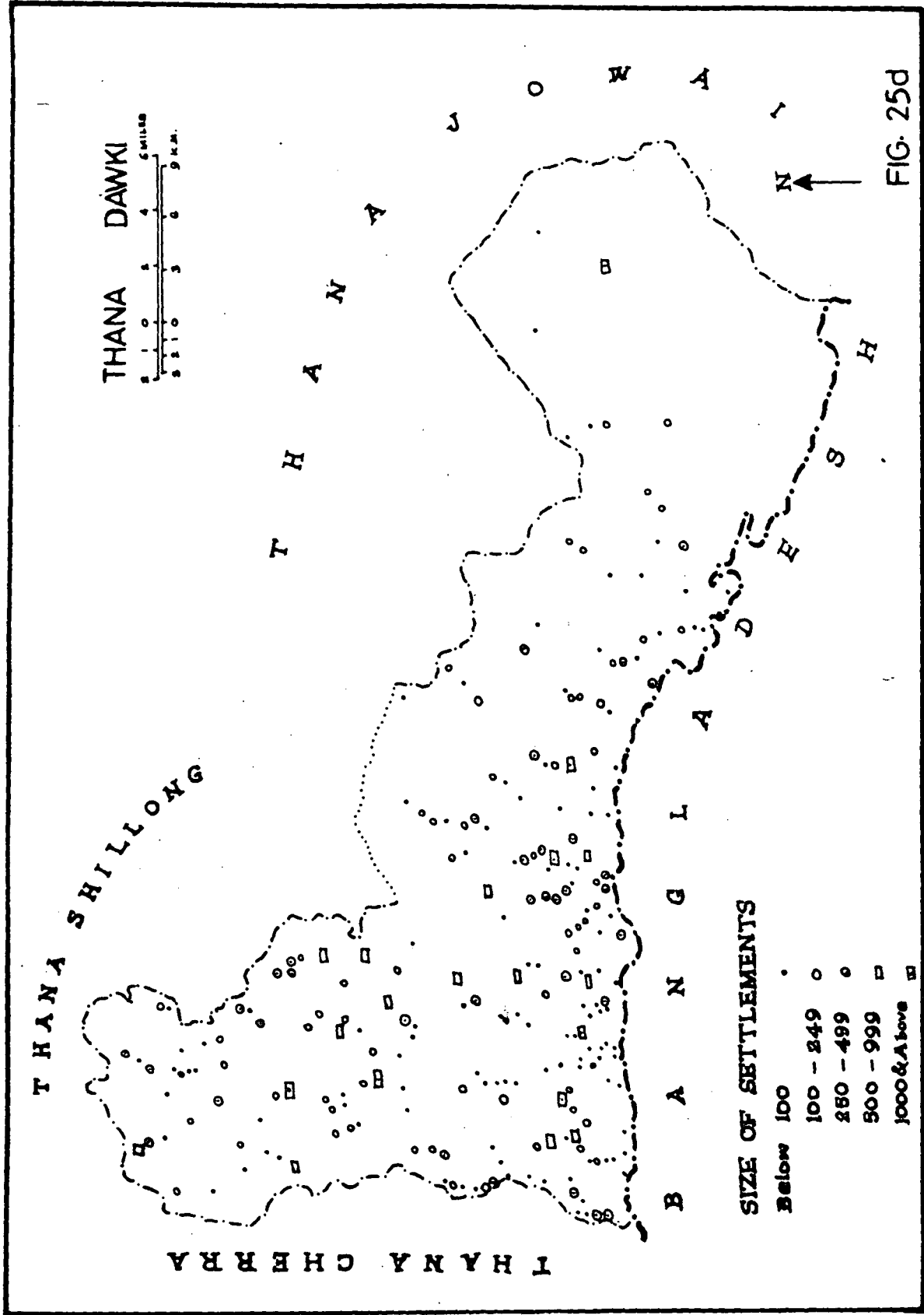


FIG. 25d

slope is very steep, at places it is above 23 degrees (Fig. 18). In this part the number of settlements are significantly less and these are sparsely distributed. The eastern part of the thana shows some important compact as well as linear settlements along Shillong-Cherra road. Some of the important settlements are viz., Laitryngew, Sohrarim, Pomsahmen, Saitsohen, Laittyra, Sohbar, Laitkynsew, Mawsmal, and Therria etc.. Table-VII(iii) reveal that 81.69 per cent of the total villages have less than 250 persons, 12.27 per cent have less than 500 persons, 5.03 per cent of the total villages have population less than 1000 persons and 1.006 per cent of the total villages represent more than 1,000 persons.

Dawki Thana - Dawki thana is the smallest thana in Khasi and Jaintia Hills with an area of 1,099.3 sq. kms. This thana comes under Shillong and Jowai sub-divisions. According to 1971 census, the total population of Dawki thana is 27,918 persons. The area under Shillong sub-division, of Dawki thana shows high concentration of settlements than the area under Jowai sub-division. The eastern part of the thana shows sparse settlement distribution (Fig. 25d). In the northern part though settlement are scattered, they are evenly distributed. A number of large settlements having population above 500 persons are also

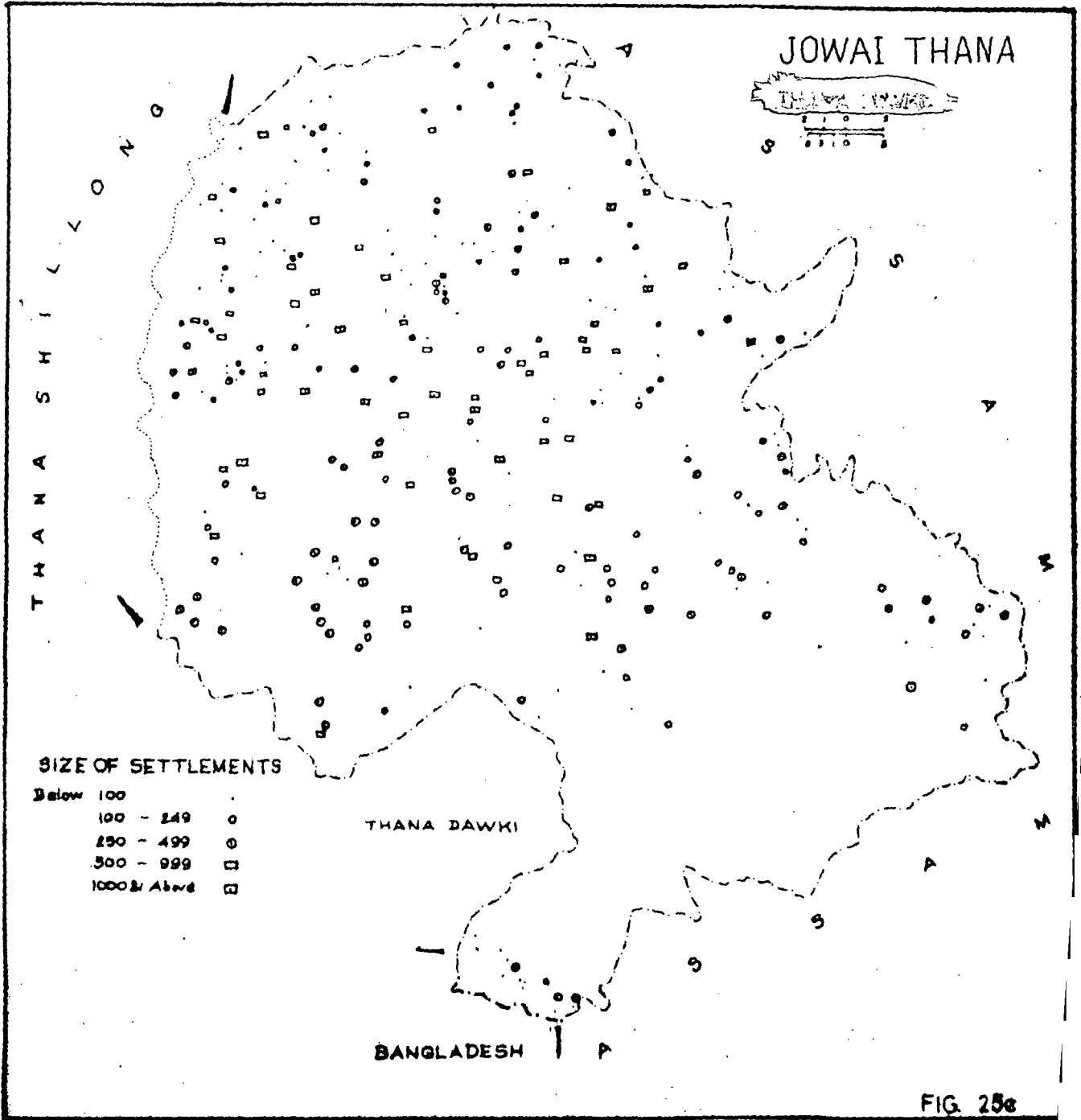


FIG. 25c

found in this thana. In the western and southern part, settlements are distributed in compact form. Dawki is the most important settlement in this area. Other important settlements are Pynewsla, Laitsohphei, Pangtung, Nohwet, Washer khmut, Pamshutia, Wahkdait, Laminshnong, Nongtalang and Muktapur etc.. The Table-VII(iii) reveals that 77.73 per cent of the total settlements are having population less than 250, 14.28 per cent have less than 500 persons, 5.88 per cent have less than 1000 persons and 2.10 per cent of the total villages have population more than 1000 persons. It is interesting to note that as the size of population is increasing the number of villages are decreasing. This indicates that small size settlements are much more than any other size of settlements. Very few settlements located in Dawki thana have population more than 1000 persons viz., Pynursla, Lyngkerdem, Lumshnong and Dawki etc..

Jowai Thana - This thana occupies the major portion of Jaintia Hills, bordering Assam on the north and east. Dawki thana has an area of 3,287.7 sq. kms. having a population of 99191 persons, according to 1971 census. In most of the eastern part the elevation is less than 1300 metres. In many places slopes are steep. In the northern part very few settlements are found, due to exposed rocky

surfaces and less fertile soil. Most of the settlements around Jowai town are of compact type (Fig. 25e). A large number of settlements are located near or close to the springs. Some of the settlements in the central region are located near agricultural land, along the broad-river valleys of Myhriang, Myntang and Krakoa rivers. These are only fifteen settlements located on the extreme south of the thana bordering Bangladesh. This part of the thana is characterised by very steep slope and dense forest (Fig. 18). The important settlement on this part is Umkiang. Table-VII(iii) reveals that 63.10 per cent of the total settlements represent less than 250 persons, 19.51 per cent of the total settlements have less than 500 persons, 13.71 per cent of the total settlements have less than 1,000 persons and 3.65 per cent have more than 1,000 persons. The important villages having population more than 1,000 are Nongtalang, Wahjajer, Nongbah, and Sohmyntiang.

The above analysis of rural settlements distribution according to popⁿ size at thana level show an interesting picture. In all the thanas, the largest number of settlements represent less than 250 persons. The percentage of villages ranging from 63.10 per cent (Jowai thana) to 81.69 per cent (Cherra thana) are of this

category. Very few settlements are having population more than 1000 persons. The percentage of village above 1000 persons ranges from 0.66 per cent (Nongpoh thana) to 3.65 per cent (Jowai thana). The density of rural settlements is highest in Cherra thana (1 village/4.47 sq.kms.) and it is lowest in Jowai thana (1 village / 10.02 sq. kms.).

Location of Rural Settlements

+The first settlers in a new and virtually undeveloped environment have to exist in a self-sufficient manner. This was just as true to the early and isolated settlers of Khasi and Jaintia Hills. Historical accounts suggest that there were waves of migrations into North-East India through the mountain passes and, these migrants were rather invaders who belong to the "Indo-Chinese linguistic family" of which two most important families are the Mon-Khmer and Tibeto-Burman. The Mon-Khmer, which constitutes, the Khasis and the Jaintias, was driven by subsequent Tibeto-Burman horders into the Khasi Hills which is the only part of north-east India in which that sub-family exist.¹

The first settlers with their necessarily limited knowledge, made more or less rational judgements concerning

¹Singh, R.L., (1971), India : A Regional Geography (ed.), p.676.

choice of sites for their habitation. Important to them was availability of arable and grazing land. In addition, a close supply of water. Water was essential as was the proximity of building material and fuel. The first settlers in a place must often have made false starts and sometimes settled down permanently on a less good site even with a better site nearby. In a similar way, mistakes may have been made which can be seen clearly in the light of later developments. Thus, we find in some areas a division of the original settlements into two, with the suffixes 'old' and 'New' ('rim' and 'Thymmai' in local language). For example 'Nongrim' meaning 'old settlement' and 'Nongthymmai' meaning 'new settlement'.

The above factors are really the basic elements of an agricultural settler. However, if the area were settled during a troubled period, defence could become the determining in deciding the village location. A hill-top or a meander core could become the optimum site. Nevertheless, the best defensive site would be chosen in conjunction with the other factors. Normally, it seems that water availability is the most important factor, but it may be overweighed by the combined effect of the others.

The location of dwellings is, of course, decisive

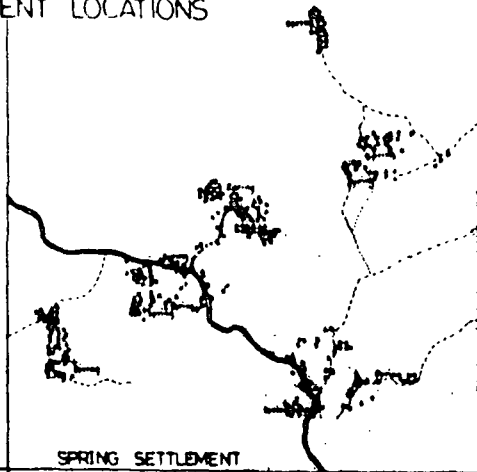
in the distribution of population. There are two zones of population discussed by Fluckiger; one - the zone of permanent houses and the other - the zone of temporary houses. It is the permanent houses upon which the census is based. But the main concern is on both the permanent as well as temporary settlements for this study. The basic 'hypothesis' is to find out why there are temporary settlements and why there are permanent settlements. What are the factors influencing them etc., Forest line play a part in fixing the upper limit of elevation of isolated permanent houses, but because in the limit of houses there is the element of human choice. In the region, generally houses are located approximately, 100 metres below the forest line. But man often makes a poor adjustment of house location to climatic conditions, because of economic or social factors. Man may, as some times along pass routes, locate his house in defiance of climatic conditions. The peculiarity of this region is, if there is little level land in a valley, the houses will be on the slopes in order to spare all level land for agricultural practices. Typical examples of location of houses are found in Khasi and Jaintia Hills. Settlements located along the water courses are mainly permanent.

The location of settlements are the expression of

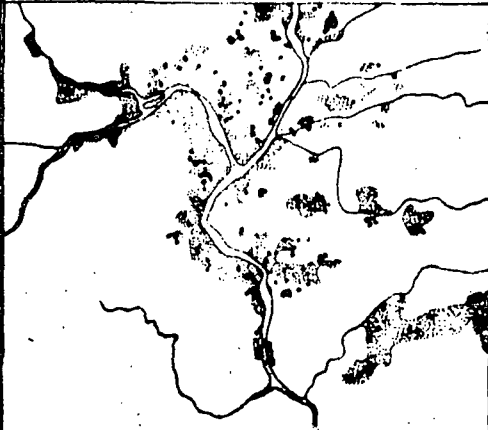
SETTLEMENT LOCATIONS



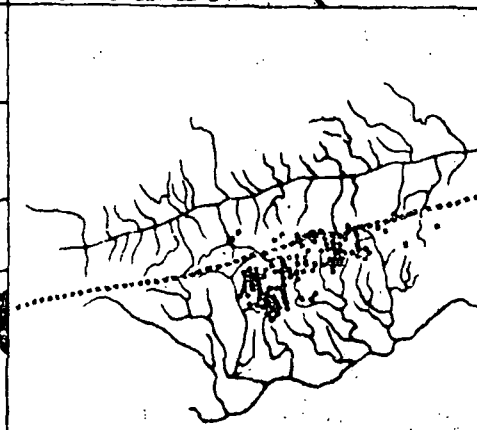
VALLEY SETTLEMENT



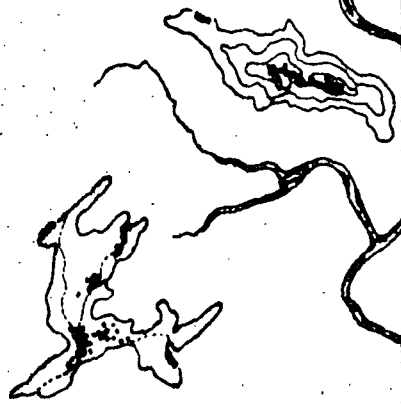
SPRING SETTLEMENT



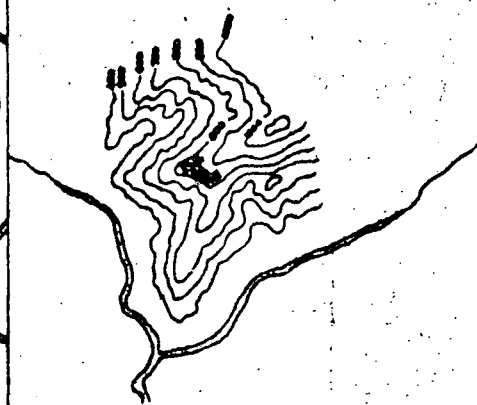
SETTLEMENT NEAR AGRICULTURE LAND



WATERSHED SETTLEMENT

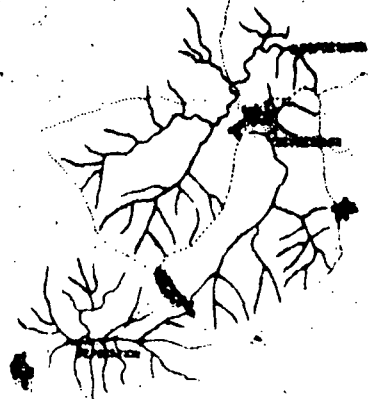


HILL-TOP SETTLEMENT



HILL-SLOPE SETTLEMENT

SOURCE:-
TOPOSHEET NO. 709, 708, 039, 038



SETTLEMENT NEAR DEPRESSION

km 0 km

FIG 20

the geographical factors favourable at a particular spot in the landscape. In an agricultural country like India, the factors determining man's choice of a site for location of a village is the site which is near to his agricultural land. The site should also be favourable from the point of view of their physical factors such as the level ground, the year round availability of water, high ground in relation to its surroundings in terms of safety from flood and defense point of view, fodder and fuel from the forests and grasslands. The accessibility from the point of view of means of transport and communication - lines is also an important factor in the location of settlements. The following are some of the important sites where settlements are mainly located, viz., (Fig. 26):

- (i) The settlements along the river valleys,
- (ii) The settlements located near springs,
- (iii) The settlements along the interfluves or watershed zones,
- (iv) The Hill-slope settlements,
- (v) Settlements in Depressions.

(i) Settlements along the river Valleys:-

As regards location and siting the settlements exhibit two tendencies (i) tendency to prefer and (ii) tendency to avoid. Settlements are conspicuous by their absence along the banks of the major and main streams.

On the other hand settlements frequently dot the courses of minor tributary streams (Fig. 26). Interestingly during field observation the researcher came across such settlements which are located along major rivers in Jaintia Hills (Fig. 26). Generally, in this region along the river valleys, the region is plain with a thick deposit of transported soil in an extensive area. These are the most attractive region for agricultural practices. Though, a few number of settlements found in this area they are small in size and serve as the farm house. Large-size settlements are not found in major river valleys. Because, along the entrenched stretches of most of the rivers and streams, the possibility of frequent overflow of the water during floods is a common occurrence. In major valleys the texture of drainage is coarse which means a sparse distribution of water-bodies. The larger a stream, the deeper is the channel. This means greater handicaps to movements. The slopes towards the major channels is steeper and does not favour an effective use of land. Steeper slopes facilitates a quicker run-off and hinders the formation of deep soil layers. The major valleys, owing to steeper slopes and deeper channels, are not easy to be terraced for paddy cultivation.

The preference for minor valleys is due to several

reasons. Various orders of tributaries and sub-tributaries result in the division and sub-division of the major slopes in the same order. Consequently local relief is subdued and local slope is much gentler than the main slope. These gentler slopes are less subject to erosion and offer better conditions for soil formation. Gully erosion and ravines seldom extend to these areas. These aspects of the minor valleys enhance their habitability. In the case of minor streams the water channels are closely spaced. This ensures a more efficient and easy water-supply. However, from the topo-sheets of Khasi and Jaintia Hills, it is seen that most of the riverain settlements are located on the gentle valley slopes.

During field observations the researcher came across some of the important and typical example of this settlement site in the southern part of Khasi Hills around Cherrapunjee. Along the Umiew river valley the riverain settlements are viz., Nongshyluit, Nongstein, Umblai, Thieddieng, and Mawphu etc.. Along the valleys of Rashi Nadi the following settlements are found, viz., Jalaphet, Mukhein Rashu, Myntriang, Samasi, Lakasein etc..

(ii) Settlements near Springs :-

In addition to the riverain settlements, other water-seeking settlements are found on or close to natural

or artificial source of water, such as, springs, wells, tanks or lakes etc.. From the topo-sheets of Khasi and Jaintia Hills, it is clear that the only water-point settlement, apart from the river valley settlements, are the settlements located near or close to the springs (Fig. 26). The topo-sheet No. 83 C/11 of Jaintia Hills reveals that almost all the settlements are located near the spring. A few example of spring settlements are, Khonshnong, Mynthlu, Kremyrshiang, Myntriang, Snongrim, Tongseng, Tangnub, Malasngi, Lumthalang, Daistong, Saipung, Lura, Molhai, Saibal, etc.. Again, the toposheet No. 83/ C/7 reveals that the settlements found in this area are scattered due to their location near spring. Some important settlements of this type are Snongrim, Mausliang, Malang, Mulamahnoh, Impala, Um Satal etc.. The toposheet No. 78 o/15 of part of Khasi Hills shows some settlements of this type viz., Meiong, Mawlyndian, Diengsaw, Mawstang, and Mawflang etc.. The north-western part of Khasi Hills also show some of the spring site settlements, viz., Manai, and Nongktieh etc.. It is interesting to find that spring site settlements are found more in Jaintia Hills, than in Khasi Hills.

(iii) Settlements along the interfluves or Watershed Zones:-

On closer scrutiny it appears that even in the

minor valleys the settlements are seldom located on the river banks. They are frequently sited on the interfluves. These interfluves are invariably triangular in shape. They slope in three directions - the two shorter slopes are towards the two adjacent streams, while the longer one is towards the confluence. Taking such an interfluve into consideration, the villages, as a rule, are seen located in the central portion of the divide. Such a location has several advantages. The distance from the settlements to the two side-streams, are easily accessible. At the same time side-streams are not so close as to cause damage during torrential rains when they are in spate for an hour or so.¹ Crest region, often left uncultivated, constitutes the marginal land and, therefore, siting of settlements over here does not mean any loss of land to agriculture. The crest lines are better graded and gently sloping. They are least dissected and, therefore, they serve invariably as the natural lines of communication. In forested areas, foot tracks and mule-paths follow the crest lines, because these are easy to be traced.

The settlements along the watershed zone are quite large in number and the distribution form varies from

¹Prasad, A. (1973), "Chotnagpur : Geography of Rural Settlements+", p.227.

place to place (Fig. 26). If one examines the 1:50,000 topographic sheets of Khasi and Jaintia Hills, the area covered by toposheet No. 83 C/3 shows clearly a number of large and small rural settlements. Some of them are visited by the researcher during the field study viz., Umlarem, Jarain, Khangsi, Sushen, Mawlang, Amulong, Padu, Nohrun, Umsaw and Umsning etc.. These are some of the large and small settlements located on the water-shed zones formed by numerous tributaries of the Myntdu Nadi and Um Ngot river. Again, the area covered by the toposheet No. 78 O/3 of Khasi Hills shows the distribution and location of watershed settlements. To name a few, Phlangdilolu, Nonglumjew and Mawliaw are located on the watersheds formed by numerous tributaries of the Kynshi river. In the southern part of Khasi Hills some important watershed settlements are, Laitsohum, Mawsynram, Mawhiang, Pongkung, Nongdom etc.. Except a few large size settlements rest of these are connected by foot tracks only.

(iv) Settlements on hill-slope:-

Worn-out stumps of hillocks, Mounds, slight eminences of a few metres and mild sloping flanks of hills or hillocks on any geological formation offer dry and healthy sites for settlements. The location of settlements on low hills or hillocks elevated terrain is the marked characteristic feature of the plateau. A number of large

and small size settlements are located along the hill-slopes of this region (Fig. 26). The northern, north-western and south-eastern part of Khasi and Jaintia Hills, show a number of small villages, which are located on small hillocks. The southern and south-western part of Khasi and Jaintia Hills where steep slopes predominates, the hillslope settlements are the marked characteristics of this region. From the average slope map (Fig. 18) of the Khasi and Jaintia Hills, it is clear that this part of the region represents dissected topography with very steep slopes - hence, compels the settlers to construct their houses on hill-slopes. Steeper slopes facilitates a quicker run-off and hinders the formation of deep soil layers. The major valleys, owing to steeper slopes and deeper channels, are not easy to be terraced for paddy cultivation. Therefore, these hillslopes are selected for settlement sites and valley plains are spared for agricultural practices (Plate 18).

(v) Settlements located in depression :-

Very few settlements are found located in areas of depression in Khasi and Jaintia Hills (Fig. 26). A few examples may be given such as; Umkyrpong, Akshe, Pala, Samasi and Laphet, etc.. However, in some places, these depressions are left mainly for agricultural practices

and settlements are located slightly above these depression areas.

From the above analysis of location of settlements and their siting, it is understood, that (i) most of the small size settlements are found located either near the natural springs or along small streams which serves their water need. (ii) several large size villages are located along the river valley, where few patches of agricultural land are available, along the watersheds or ridge tops or interfluves and along the important road sides (iii) Hill slope settlements are also many in number, (iv) Very few settlements are located near the depression sites. (v) A large number of isolated hamlets in sprinkled form in the western part of Khasi Hills are located along small streams in forested areas.

Types of Rural Settlements

The factors which have led to the variations between different types of settlement, are many and varied. It is important to realise that the type so produced is a result of a number of forces, working either in conjunction or in opposition, over a long period of time. Some of these forces are still at work. But the types in this region are largely a result of forces acting continuously,

but with varying intensity. Later, changes in the types of settlement were mainly associated with the growth of minning and quarrying villages, newly constructed roads and availability of new settlement sites around agricultural land.

In Khasi and Jaintia Hills the following five types of settlements are generally seen, viz., (Fig.27):

- (i) The dispersed - cluster,
- (ii) The dispersed - cluster with isolated households,
- (iii) The isolated households along the village path,
- (iv) The isolated households, and
- (v) The linear settlements.

(i) The Dispersed-Cluster:-

Several villages of this region have dispersed cluster type. The factors responsible for the development of dispersed-cluster, seen to be several patches of fertile lands, dependence of agriculture on rain waters, undulating terrain and practice of shifting cultivation. A few example of such villages are, Mawlaitang, Lawmei (the Diengiei area), Smith, Laitshi (the Myllem-Laitkor area) (Plate-19) and Mawpdang (the Mawpat area) of Khasi Hills. The Central part of Jaintia Hills around Jowai town many villages are of this type. A few example may be given here; Lura, Lumthlang, Tongseng, and others.

(ii) Dispersed-cluster with isolated households:-

The dispersed-cluster or semi-compact with isolated households represents an intermediate stage between the agglomerated and hamleted settlements.¹ This settlement is characterised by the presence of one easily recognisable nucleated site and one or two small hamlets closely linked with the main site by foot path (Fig. 27). These attached settlements must have grown due to the increasing pressure on the main site which compelled the inhabitants to seek living outside the village. But these people could not go far from the main settlement due to social links and economic interdependence. Another cause that seems more important in this region is the Khasi law of inheritance and shifting (jhum) cultivation. Some of the villages of this type are Laitkor, Myllem (the Myllem-Laitkor area), Um Lakhen, Mawtawar (the Mawpat area), and Jabar (the Diengiei area). A few examples from Jaintia Hills are as follows : Nongkhroh, Bankamar, Saibol, Daistong and others.

(iii) The isolated households along the village Paths :-

Almost all the villages in Khasi and Jaintia Hills

¹Singh, R.L. (1961), Meaning, Objectives and Scope of Settlement Geography, The National Geographical Journal of India, Vol. VII, Part I, p.100.

are connected with Kutcha village paths. The village paths either are made by the cutting up of the slopes or are natural village drains. In the former case, the land is high on one side and low on the other. While in the latter case the village paths are lower than the houses. In the first case, houses are very often situated on the lower side, and in the second case, on both sides. The most important controlling factor of such settlement type is the village path which is sometimes very narrow and undulating. Some examples of this type of settlement are Mawlyndep, Mawklot, Nongbsap, Lumdiengan, Pynthorkseh, Lolmunting, Nongtraw, Nongbhata, and Shormu from Khasi Hills and Ladgo, Nongdhar, Nongkharai, Mynso etc. are some of the isolated households found along the village paths.

The southern and south western part of Khasi Hills are dotted with a large number of isolated villages along the village paths (Fig. 27). Some of these villages have chosen small stream site due to the availability of drinking water. A few example of this type of settlement are Pandoloi, Madan sohum, Umsawlia and Nongkdait etc..

(iv) The isolated households:

The isolated households are seen in the undulating terrain where water points are frequent, fertility of the

land is low, and shifting cultivation is done. This type of settlements are found mostly in western and north-western part of Khasi Hills and North and south-eastern part of Jaintia Hills.

The main factor which controls the tiny size of the settlement is the localised agricultural practices. With rugged terrain, unfertile soil and steep slopes and the practice of (jhum) shifting cultivation which are unable to support large size villages. Some examples of this type of settlements are Mawkari, Hirsong, Jynthru, Umdap, Mawthlong, Surungbat, Umwang, Umdenkalai, Nonglyngdoh, Lewsyr, Lumkulia, Umlei, Umryngku etc. from Khasi Hills and Ladao, Mynso, Maskat are some of the examples of isolated settlements located near springs - streams or hill slopes of Khasi and Jaintia Hills.

(v) The Linear Settlements :

Linear settlements are located in areas of elongated fertile down lands which are used for cultivation. Ample availability of drinking water and sunny sides of the slopes seem to be important factors. There are broadly two types of linear settlements found in Khasi and Jaintia Hills, viz., (a) Linear settlements along the watershed zone and (b) Linear settlements along the main roads (Fig. 27).

(a) Linear Settlement along the Watershed:-

A number of linear settlements along watershed are located all over Jaintia Hills and in some parts of Khasi Hills also. The factors influencing watershed linear settlements are mainly the availability of drinking water and agricultural land. Moreover people practise jhum cultivation along the hill slopes and whatever plain land available nearby are put to permanent agricultural purposes they have to build houses on top of the slopes. In this region, the watershed areas are elongated ridges, this is one of the reason for the growth of linear settlements. A few examples of this type of settlements are Jongkalur, Rytlang, Pala, Larket, Pdeingryngkah, Daistong, Khaidong, Meistem, Mosakhia and Mynsang etc..

(b) Linear Settlements along the main roads:-

The growth of linear settlements along main roads has some economic importance. These villages serve as the centre for economic activities to the villages located nearby. Agricultural products and other commodities meant for export and import out and inside the villages, generally done through these villages some examples of this type of villages are Piengwait, Sohmynting, Demthring, Mustem, Jalong, Bapung, Khliehriat etc. of Jaintia Hills and Jorabat, Burnihat, Nongpoh, Myllem, Smith, Laitlyngkot

etc. of Khasi Hills. (Plate No. 20-22).

Factors contributing to different
Types of Rural Settlement

The above analysis of regional types of rural settlements reveals that the evolution of a particular type of rural settlement is not only the result of single geographic feature such as relief but the assemblage of several environmental features as well as cultural and economic features.

(a) Physical Factors :- The dispersed cluster and dispersed cluster with isolated households types of settlements are found more in numbers in areas of fertile lands along the river valleys. Other important physical factor which supports the linear settlement type is the elongated ridge tops. The isolated type of settlements are also governed by certain physical factors and the important factors operating in Khasi and Jaintia Hills are regional slopes and streams and upto some extent the natural springs. The nature of terrain is also another important physical factor which controls the types of rural settlements. In Khasi Hills, the western part is characterised by undulating terrain and steep to moderate slope and that is why in this part the isolated type of settlements are dominating.

(b) Socio-Economic Factors:- Among the socio-economic factors responsible for different types of rural settlements, the Khasi law of inheritance and the regional pattern of cultivation i.e. Jhumming are the most important factors. The dispersed cluster with isolated households types of settlements are the result of these two factors. The isolated households are the result of excess population growth in the main village which could not support large population because of the practice of jhum cultivation. Due to this a section of people from the main village, went out to form small villages around a few patches of jhum land. The linear settlement located along the main roads are also due to the effect of economic factor. These villages are mainly large in size and acts as the commercial centres for the small and isolated villages located around.

However it is clear from the above analysis of the location and types of rural settlements in Khasi and Jaintia Hills that the contribution of physical factors are more pronounced than the socio-economic factors. Though the role of socio-economic factors in certain types of rural settlements, viz., agricultural, mining and commercial villages are more than physical and geomorphic factors.

Rural House Types

In the early development of systems of human shelter man first responded biologically to the animal need for a protected and private sleeping shelter. At later periods as cultural development achieved significant forward steps, human beings variably extended the concept of simple shelter from the physical elements of cold, dampness, wind and sun into an increasingly complex set of culture traits clustered around the growing concept of the "family home".¹

Most of the houses are constructed in accordance with the environmental conditions and availability of raw material in the surroundings. Although with fast development of science and technology the man has also adopted new techniques in house construction. There is great variation in house types from one region to another region. There is a great variation which ranges from the old Khasi type to the modern Assam type. Each dwelling structure with a compound and in some cases, cattle shed is occupied by each household irrespective of the number of members and income. The old Khasi type of houses are oval shaped (Plate 23). These houses are usually raised on the plinths

¹Spencer & Thomas, Op.cit., p.129.

where ?

some half to one metre above the ground. The house is usually divided into three rooms - a porch, a centre room, and a sleeping room.

In the old Khasi type the porch is used as the store room in which the inmates keep their agricultural tools and implements and fire wood. The centre room serves as the kitchen as well as the sitting room. Two sides of the building are usually separated from the centre to serve as sleeping compartments while part of the remaining side is used as the washing place where water containers are kept and the remaining wall in this side is covered into a shelf for arranging the utensils. The hearth of the room in these houses, as the researcher has seen during the field study, is in the middle of the room. It is an open one, with no arrangement for the smoke to leave the room. Above the hearth, is a swinging frame where articles are put to be dried up such as firewood, crops, dry fish and cane or bamboo articles.

In addition to the above, the centre room is also furnished with short wooden stools (Lyngknot) and higher cane or bamboo stools (Mula). The sleeping compartments are always provided with wooden bedsteads and boxes where clothes are kept. In the modern types the arrangement of

LAYOUT INSIDE COMMON HOUSE TYPE

BACK

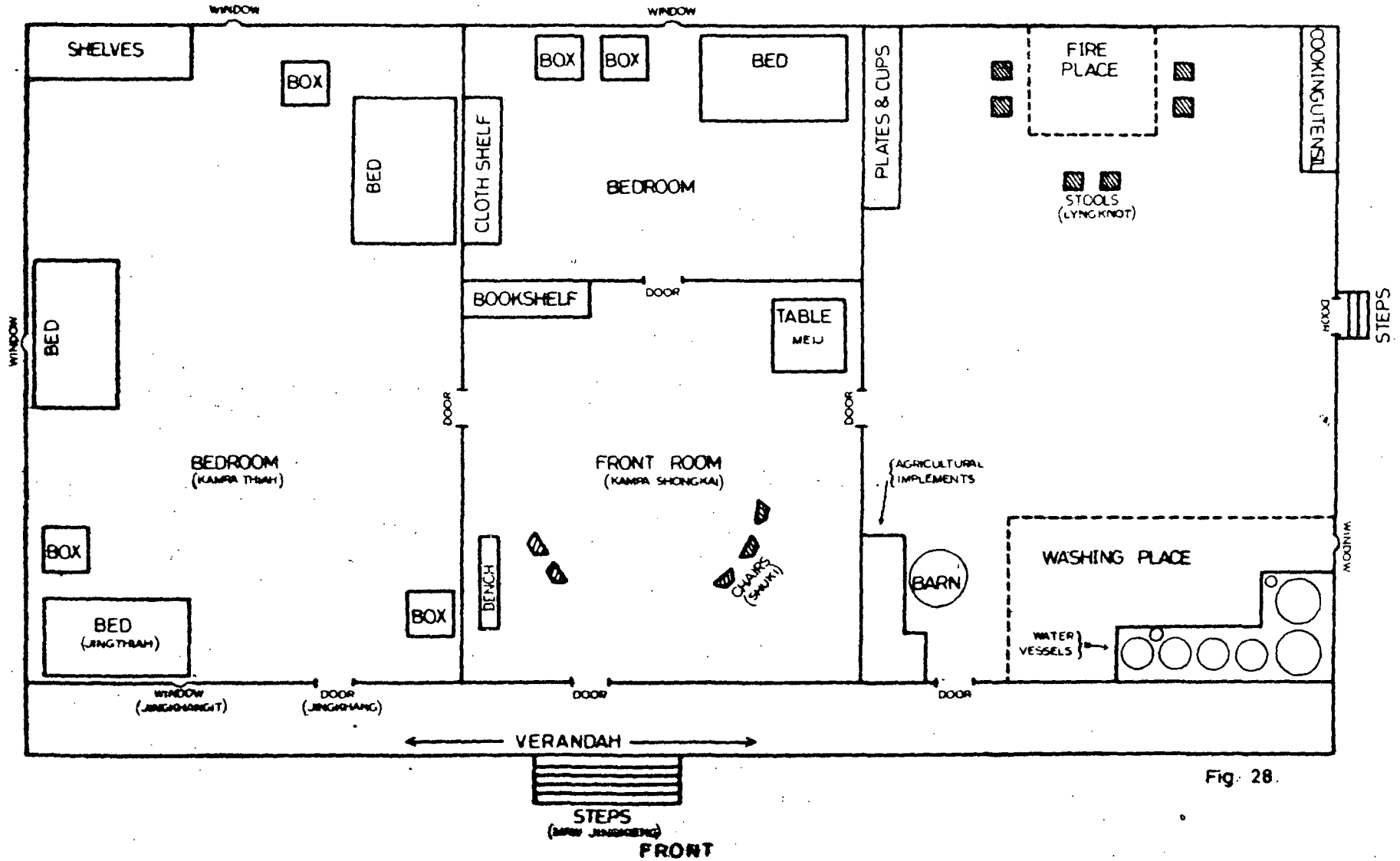


Fig. 28.

287

287

kitchen is more or less like that of the centre room of the old Khasi type. In some of these type of houses a separate room is attached where water containers are kept and washing is performed. The other rooms are furnished with wooden bedsteads, boxes, both ~~steel~~ and wooden and wooden almirahs. However, whenever the people could afford, the benches, chairs, tables etc. are arranged in a separate room (Fig. 28). In this connection it may be pointed out that the Khasis prefer to entertain their friends in the kitchen even in cases where a separate sitting room is provided. In this case, the sitting room is meant only for strangers.

Building Material:

There are very few houses of pure traditional Khasi type. These houses are restricted to the interior parts only. Most of them are improved type and some are modern. The improved types are still constructed with materials that are used for the construction of the traditional Khasi type, but they are hygienic in two ways : they are ventilated and have raised floor. The general practice is that the floor of the house is raised about a metre high to avoid dampness of the ground. First of all, stone wall foundations or upright stones are erected on the ground. On these foundations, wooden structures

are made. In constructing the walls, either split bamboos or ekra (thin bamboo sticks) plastered with mud (Plate-24) or wooden planks are used. The floors are almost always made of wooden planks or split bamboos which are supported by timber beams. Most of the houses have roofs of kerosene oil tins and few have corrugated iron-sheets or thatched roofs. Number of houses using different materials for walls and roofs are given in the Appendix-I.

Building materials that are used in the construction of houses in rural areas may be local and non-local (imported). Local materials are wood, bamboo, thatch, grass (locally known as 'U-Tynriew' (Plate 25) and stones. The non-local materials are cement, iron-bars, tin and corrugated iron-sheets. The use of these materials in house construction depends solely on the financial capacity of a house-holder.

On the basis of locally available building materials for house construction, in different parts of the Khasi and Jaintia Hills represent different pattern of house style. In Khasi village, generally, the walls are either of planks, stone or the lower half with stones while the upper part with wood or reeds. The roof is thatched. The leaves of grass are pasted on the sides of

the walls. In Bhoi houses on the north of Shillong plateau are mostly made of bamboo, the roof is thatched and the house is like a pile dwelling with a platform and balcony. However, design differs from place to place. If one goes farther north of Nongpoh the wall of the houses are seen mostly plastered with mud (Plate 26). Towards south of Nongpoh and north of Barapani the wall is without mud plastering with some exception. Again, it has been noticed by the researcher during the field investigation, that towards east of Barapani the walls of the houses are plastered with mud.

In War areas, some houses are like mechang, raised with a balcony. The War house is generally built on a platform with the main house resting on the hill-side and the portion on the platform projecting therefrom, the object being to obtain more space. The area of the houses is often limited, owing to the steepness of the hill-side. In the War region, there is a village known as 'Mawsew', the most typical houses are found here. This area is often affected by strong winds and there is danger of the roof being blown away. Therefore, people of this region tie their roofs to big boulders, on the four corners of the house. For this purpose they use a kind of resting plant.¹

¹Panda, P., Patterns of rural house construction in Khasi and Jaintia Hills, p.11.

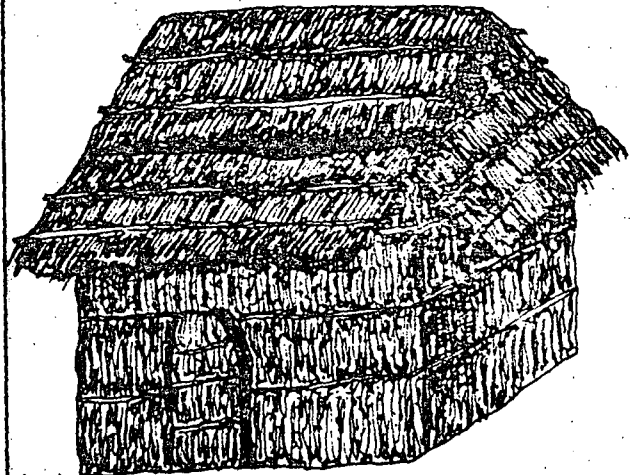
The religious house which is found in almost every big village (particularly Non-Christian) is of a typical character. In the construction of this house the inhabitants of the village do not use 'iron nails' and some types of wood. Before cutting the wood that is used, they perform certain rituals. The religious houses are built by the entire village manpower collectively. It may be noted that every third year, one half of this roof of the religious houses is replaced, probably to keep the roof in good repair.¹

Old houses represent the above noted style and are made of the material described above. However, now-a-days, only a few houses of typical nature are found in the villages surveyed by the researcher. Most of the houses are very much improved, except those in very interior part of Khasi and Jaintia Hills. For example, thatch, as the only roofing material and wooden planks, as the walling materials are, in most houses, now replaced by flattened Kerosene oil tins, plain sheets and corrugated ironsheets (Plate-27). In some of the villages, while wooden planks are still used as material for the walls, they are now covered from outside, either with thatch or

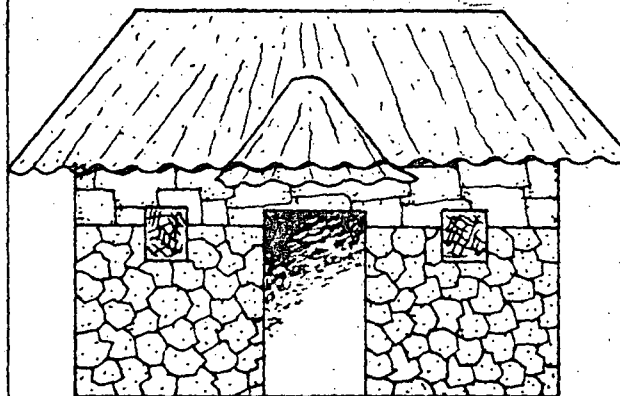
¹Panda, P., Op.cit., p.11.

any other imported materials. Housing in nearly half of each villages surveyed in Khasi and Jaintia Hills are taller than the traditional ones, having wide walls and better ventilation facilities.

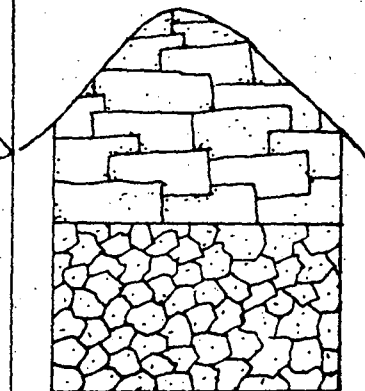
K H A S I H O U S E



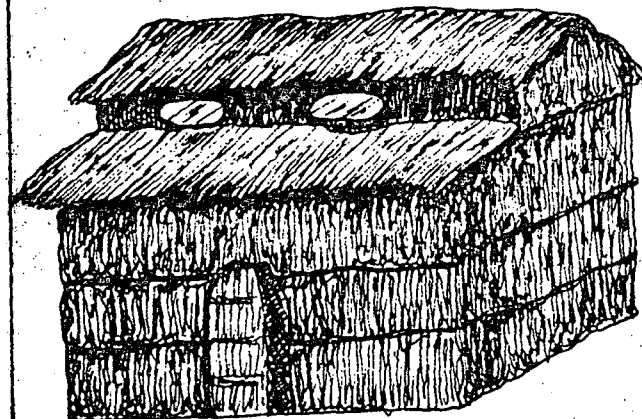
(1) Roof and Wall Thatch



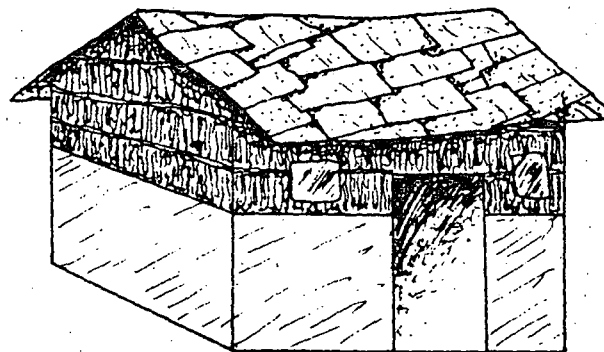
(2) Wall-halfstone and half
K.oil tins, roof-corrugated sheets



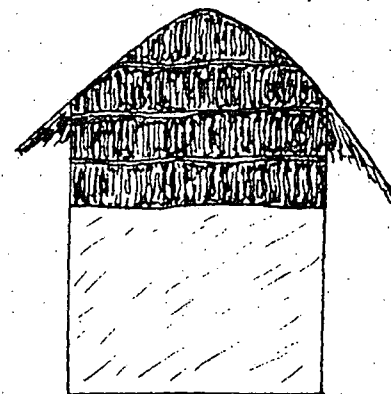
(Side)



(3) All Thatch House
(Two tier roof)

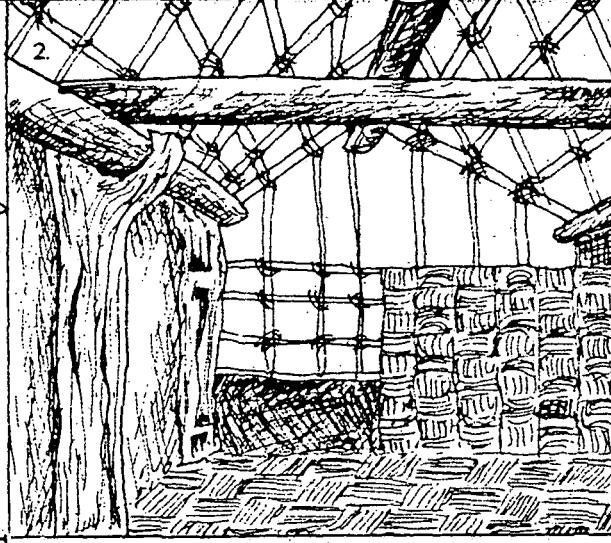
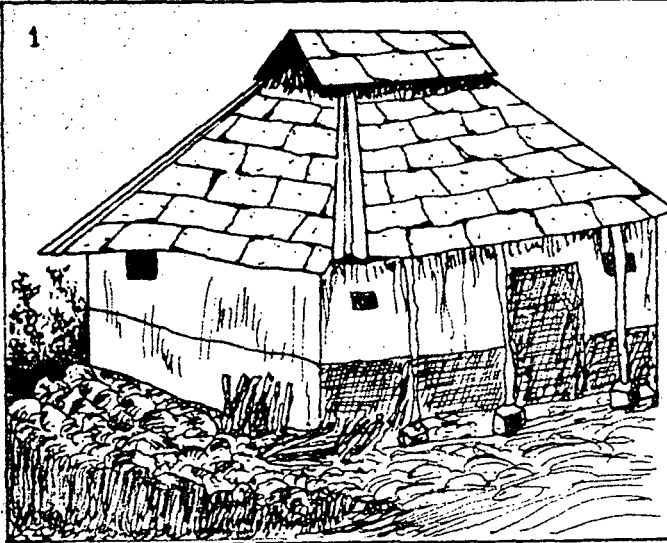


(4) Wall - Half flattened tin
and half thatch
Roof - K.oil tins



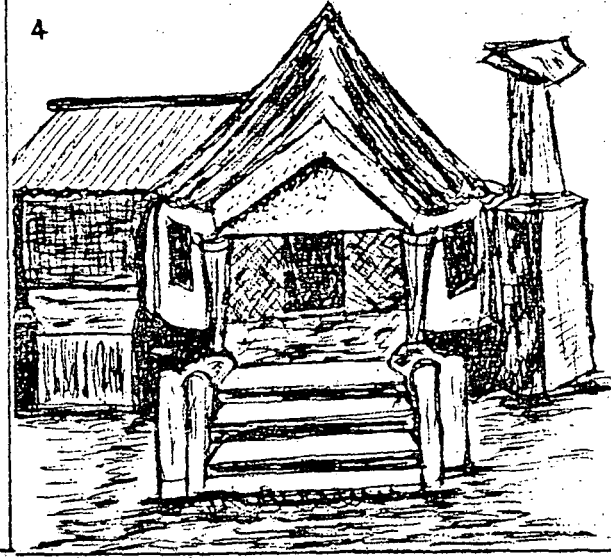
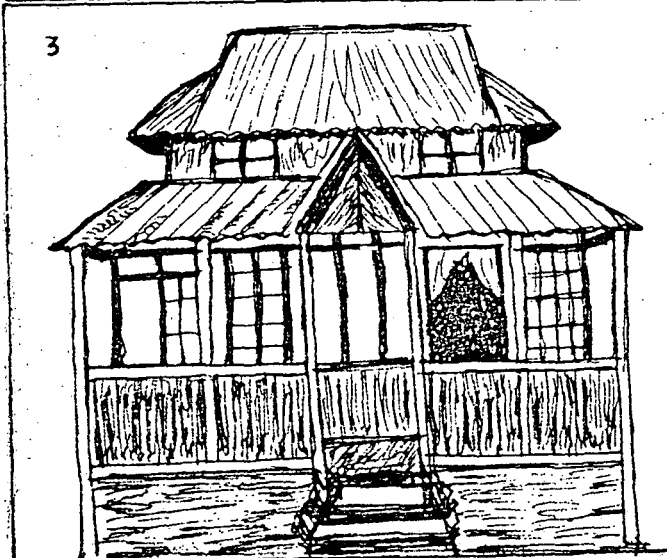
(Side)

FIG. 29a



1. Jaintia House
Roof - K.oil tins
Wall - Thin bamboo
stick

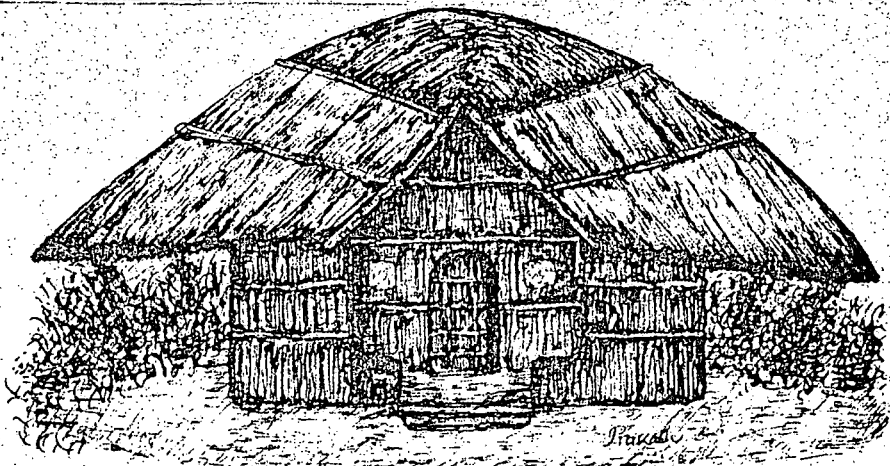
2. A Khasi House under
construction



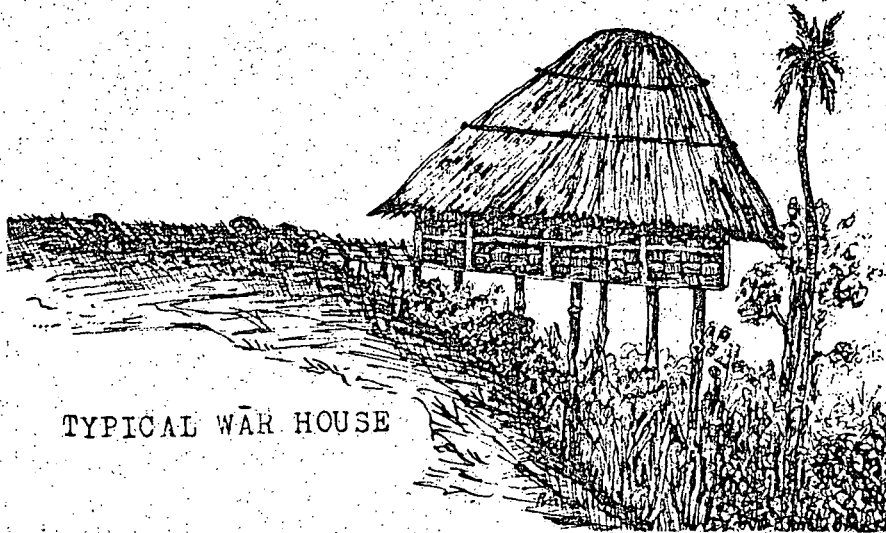
3. An Assam Type
Khasi House

4. Oval Shape Khasi
House

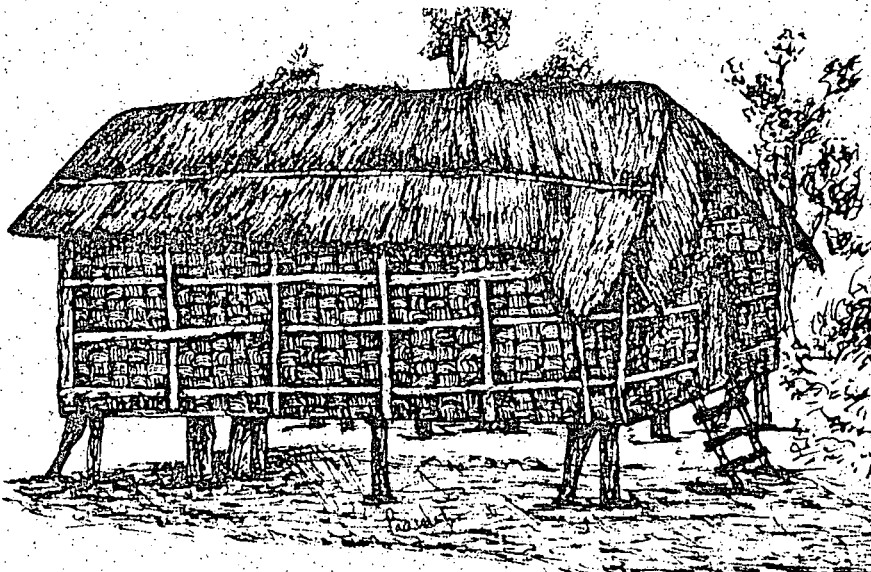
FIG. 29b



TYPICAL KHASI HOUSE



TYPICAL WAR HOUSE



TYPICAL BHOI HOUSE

CHAPTER - VIII

INFLUENCE OF LANDFORMS ON LOCATION AND
DISTRIBUTION OF RURAL SETTLEMENTS

"Nature prepares the site and man organises it to enable him to satisfy his desires and his needs."

- Vidal de la Blache

Settlements have gradually grown up and evolved over a long period of time and by studying the site, pattern and arrangement of house one can see something of the influence of landforms on them. Although the types and pattern of rural settlements are related to both the physical and socio-cultural processes, and the agro-pastoral economy and tempo of life, yet the predominantly governing factors of settlements ecology are the relief, gradient of the slope, drainage pattern, fertile soil for cultivation and upto some extent micro-climate of the region.

A minute and critical analysis of the sites of settlements on the plateau reflects their favourable or restrictive characters. A number of geomorphological factors weighs heavily in the choice of settlements, for example, dry and healthy surface, accessibility, perennial and unailing supply of water for domestic use as well as other purposes, moderate slope area etc.. The pattern of

rural settlement is governed by the geomorphic features and the flood protection system.¹ Thus the natural levees along the creeks, rivers and the embankments are preferred perimeters leading to a linear settlements.

Bernhard von Cotta (1808-1879) was certainly one of the first geologist to recognize that environment has a profound influence on man. Cotta's observations are a preview of growing modern interest in geologic effects on human beings, animals and plants. He notes that geologic and geomorphic factors are involved in the location and form of settlements, the character of architecture and the other types of aesthetic expression of any region. The characteristics that formerly prevailed because of local or nearby resources are today disappearing because of the long-distance importation of rocks and other construction materials.

Considerable qualitative work on the distributional pattern of rural settlements have been done in various climatic zones of India. Agrawal² (1971) made a study of landforms and settlements in Jabalpur and its environs. Kharkwal³ (1969) contributes a study of landforms and

¹Singh, R.L. (1972), Rural Settlement in Monsoon Asia (Ed.) p.34.

²Agrawal, Meera (1971), Morphometric evolution of landforms and settlements in Jabalpur and its environs, Ph.D. Thesis (unpublished), B.H.U., Varanasi.

³Kharkwal, S.C.(1969), Landform and Settlement in Nainital and its environs, Ph.D. Thesis B.H.U., (unpublished).

settlement in Nainital and its environs and interpreted its settlement geography in terms of its terrain evaluation. Singh,^{1,3}(1976) studied Micro-landforms and their relation upon settlement size and pattern in Palaman upland. Singh,² (1968) presents a pioneer study in landforms and settlement distribution in the southern uplands of eastern Uttar Pradesh. Singh,³(1970) in his study a topography and towns in the Chota Nagpur Highlands, outlines nine morphological segments in Chota Nagpur Highlands, to portray relation between towns and topography. Verma⁴ (1968) analysed geomorphology and human settlements of Ranchi Plateau. Yadava⁵, (1979) studied landforms and settlements of Hazaribagh plateau.

Quantitative work on the evolution and distribution of the rural settlements in relation to geomorphology which is an essential prerequisite for rural settlement and landuse planning has received scanty attention in Indian context. The Khasi and Jaintia Hills of Meghalaya

¹Singh, O.P.(1976), Palaman Upland : A Study in Landform and Settlement, Ph.D. Thesis, B.H.U.(Unpublished).

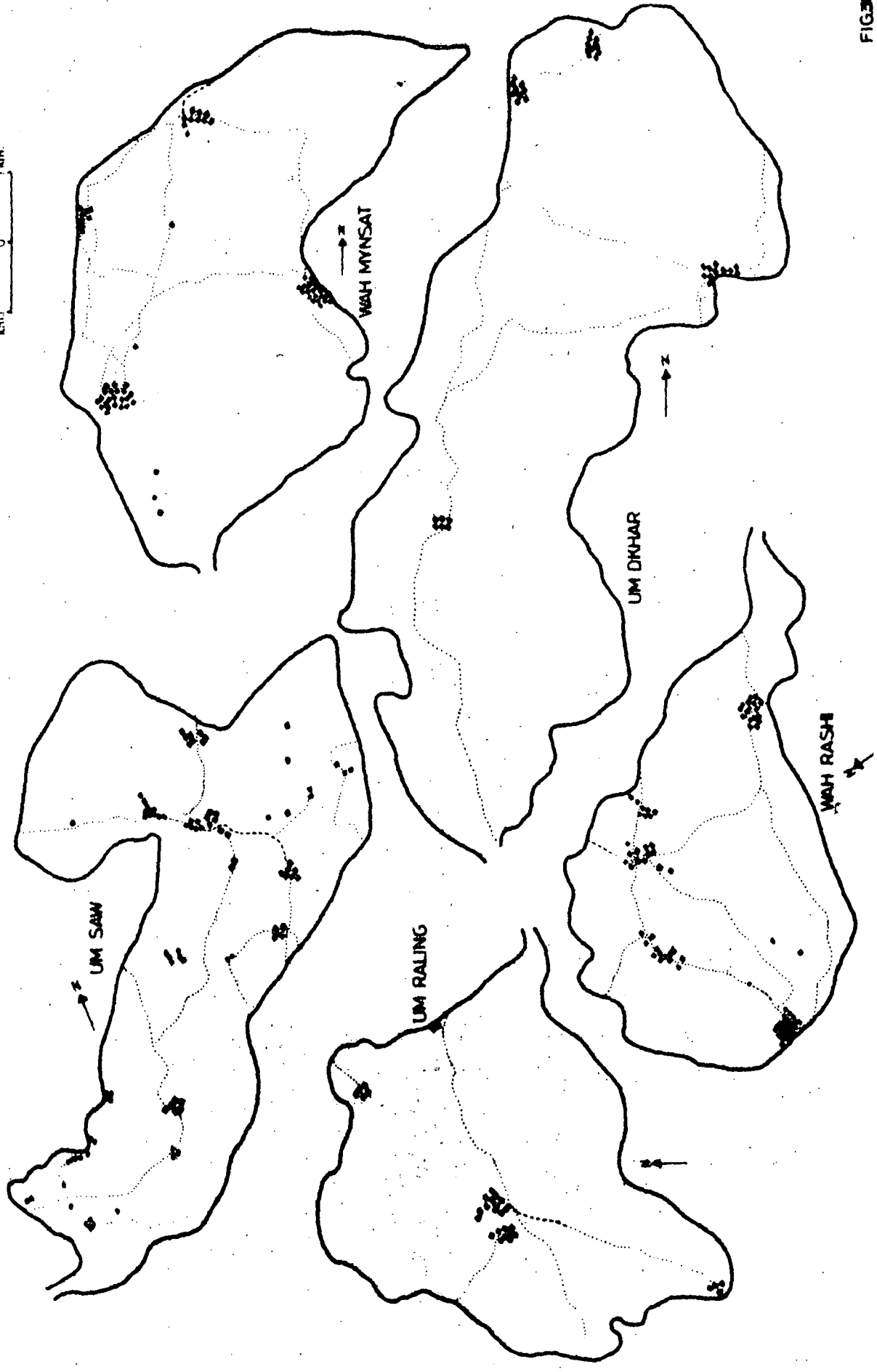
²Singh, K.N.(1968), Southern Uplands of Eastern Uttar Pradesh : A Study in landforms and settlements - distribution, Ph. D. Thesis (Unpublished), B.H.U.

³Singh, R.P. (1970), Topography and Towns in the Chotonagpur Highlands, The Magadh Univ. Journ. Bodh Gaya, 3(1), 93-103.

⁴Verma, P. (1968), Ranchi Plateau, Its Geomorphology and Human Settlements, Ph.D. Thesis (Unpublished) Allahabad Univ.

⁵Yadava, S.R.S. (1979), Hazaribagh Plateau : A Study in Landforms and Settlements, Ph.D. Thesis, B.H.U. Varanasi.

**KHASI HILLS
SETTLEMENT DISTRIBUTION**



FIGURE

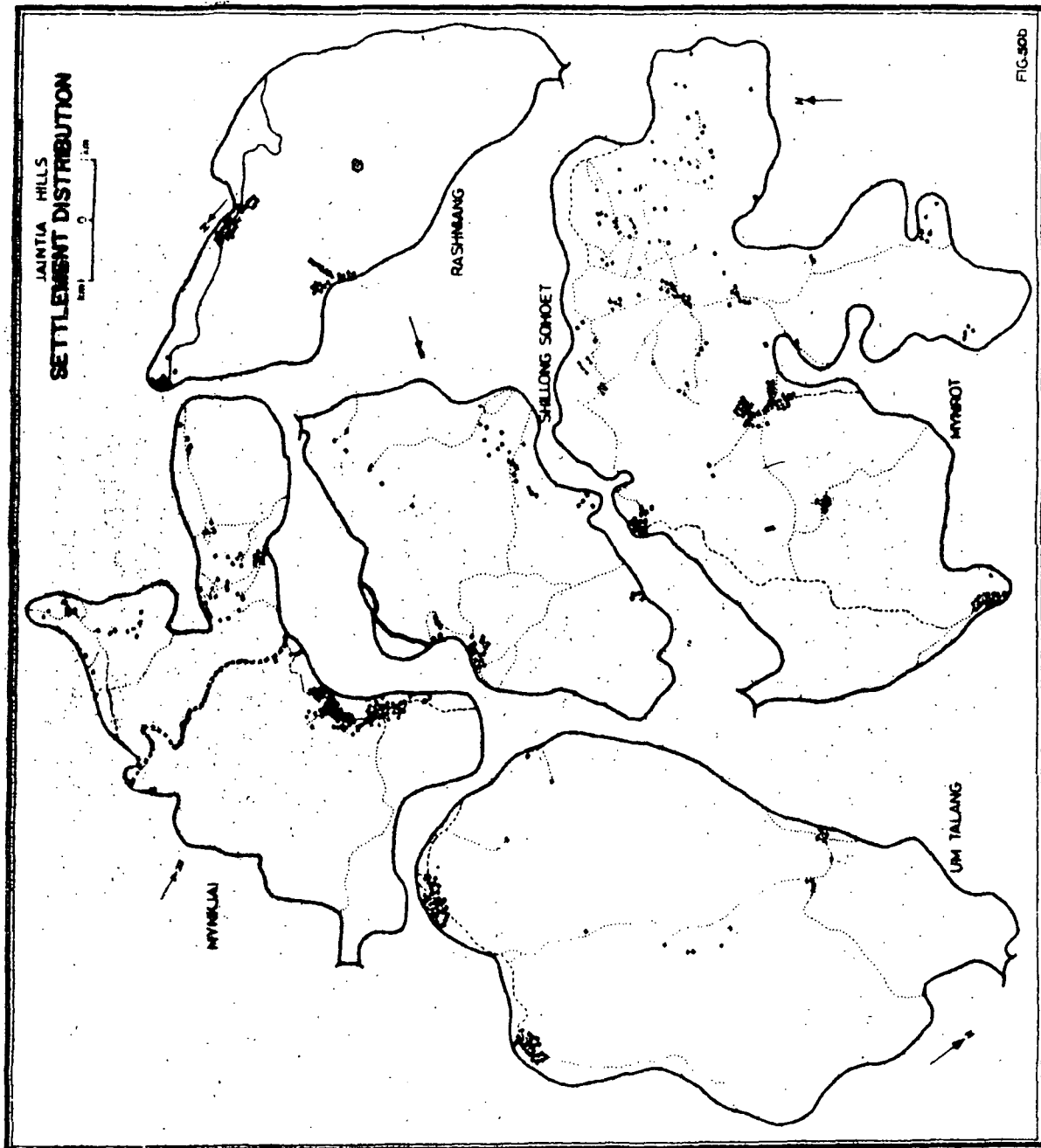


FIG. 50b

reveals certain interesting characteristics of location and distribution of settlements. This study is therefore, a humble attempt to quantify and to bring out certain links between the geomorphic characteristics of the region and distribution and location of settlements. The study is conducted with the help of 1:63,360 and 1:50,000 topographic maps of survey of India and is restricted to 10 selected small drainage basins in Khasi and Jaintia Hills for detailed study.

The influence of underlying rocks structure is more indirect than direct. The forms of the landscape are the result of inner structural and geomorphic processes, such as elevation, depression and flooding. The solid earth yields building stones and soil, metals, coal & salts, a stable or unstable foundation, greater or lesser difficulties confronting transportation routes, many or few springs, good or bad drinking water etc.. It forces streams into very even or irregular flow, promotes or hinders navigation, increases or decreases the usefulness of water for power and produces various patterns of streams.

Distribution of Settlements

The rural settlement - distribution map (Fig.30a,b) of the ten selected drainage basins of Khasi and Jaintia

Hills reveals that most of the basins show random distribution. Some of the basins show very few settlements which are located at a greater distances from each other (one village covers approximately 6 sq. km. area).

To test the distribution of settlements the Chi-square distribution test has been considered by the researcher. It has been found that the statistic chi-square (χ^2) as defined below have a particular distribution which is known as Chi-square distribution, only if the E_i values are the correctly estimated frequencies.¹

$$\text{Chi-square } (\chi^2) = \sum_{i=1}^n \frac{(O_i - E_i)^2}{E_i}$$

where, O_i = the observed value

E_i = the estimated value.

Any value of χ^2 based on the correctly estimated values will have to be less than the corresponding upper limit given in the tabulated value (i.e. it has to be insignificant). If any value of χ^2 comes out to be greater than the value given in the table (i.e. it is insignificant), the assumptions under which the frequencies have been estimated may be wrong.

¹Kendall, M.G., (1945), The Advanced Theory of Statistics, pp.309-11.

For the distribution and location of settlements the researcher has further tried to bring out the influence of geomorphic features by superimposing settlement map on Relief, slope, drainage and agricultural land map separately.

Hypothesis :- Before the analysis the researcher has formed certain hypothesis as follows :-

- (a) To study whether the distribution of settlements are clustered or random: A null hypothesis has been formed that, the number of rural settlements in each sq. km. tends to be equally distributed;
- (b) The large-size settlements are located along the water-shed zone and important communication lines.
- (c) Average slope of an area controls the shape and architecture of house.
- (d) The availability of water and fertile soil generates 'pull factor' on the location of rural settlements.

ANALYSIS

In order to test the distribution of settlements the values of chi-square (χ^2) have been calculated for all the basins and the same have been represented in Table-VIII(i).

The Table-VIII(i) reveals that the calculated value of all the basins are found to be much higher than the tabulated value and hence, these are significant. Thus

**KHASI HILLS
RELIEF AND SETTLEMENTS**



FIG. 31A

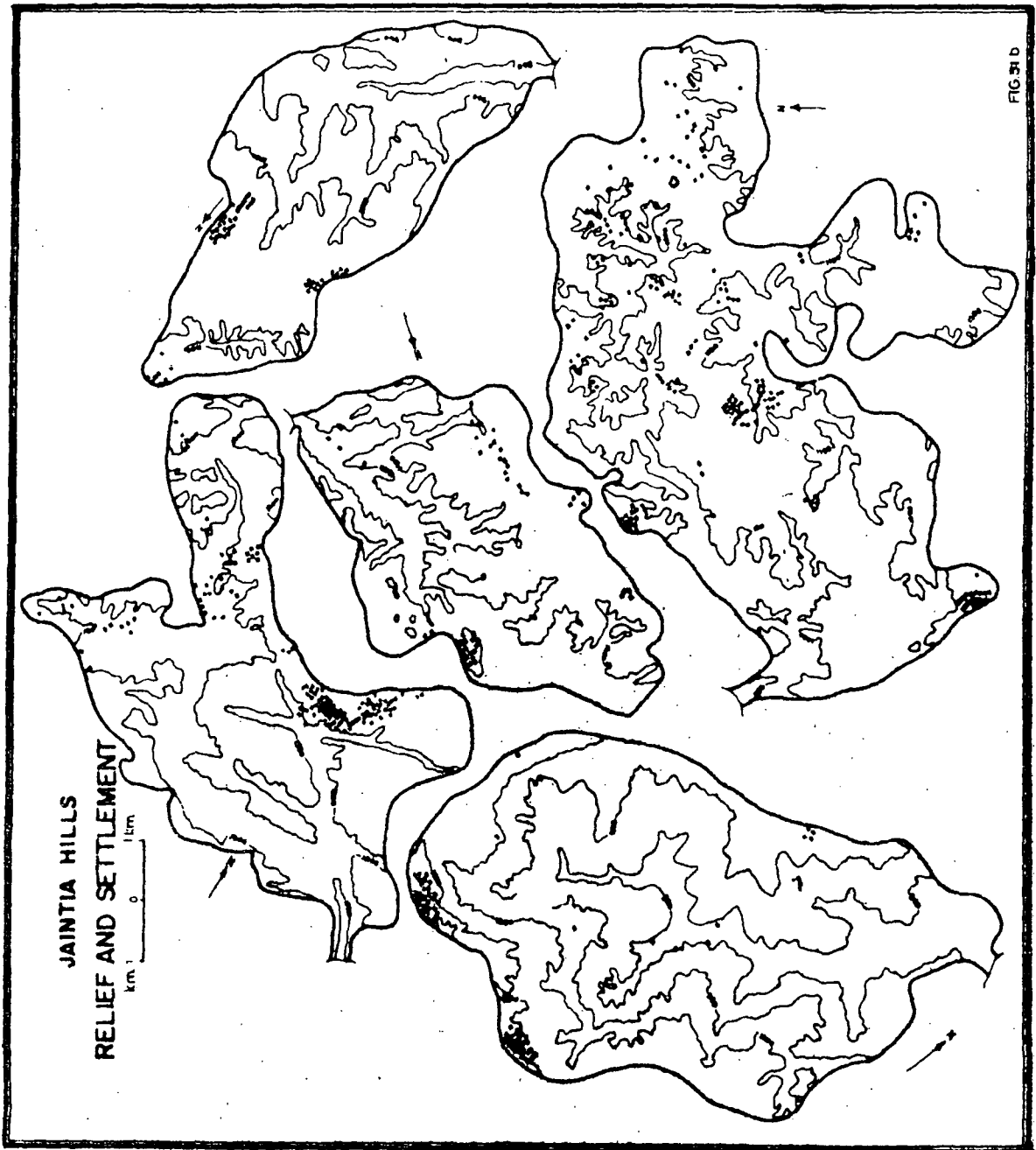


FIG. 31 D

TABLE-VIII(i)

Chi-square distribution Test of Ten Small
Drainage Basins

Sl. No.	Basins	Expected No. of villages	x ² values	Degrees of Freedom
<u>Khasi Hills</u>				
1.	Umdkhar	1.19	247.57	29
2.	Umsaw	3.95	76.10	22
3.	Wah Mynsat	2.89	310.69	21
4.	Wah Rashi	4.40	194.23	16
5.	Um Raling	2.48	78.65	12
<u>Jaintia Hills</u>				
6.	Mynrot	3.84	478.23	49
7.	Um Talang	1.86	415.08	36
8.	Shillong sohoet	2.75	119.89	19
9.	Rashniang	4.96	116.78	19
10.	Mynkjai	8.87	238.05	15

the hypothesis (a) the settlements are equally distributed in each grid (1 sq. km.) is rejected. The settlements are not distributed uniformly. In other words the settlements in all the basins are randomly distributed.

Relief and Settlements

Among the ecological factors, influencing the settlement, relief (Fig. 31a,b) occupies a prominent place. Vidal de la Blache noted that nucleation of settlement was most apparent in areas where the area of arable land was continuous to permit uniform agrarian practice. Dispersed settlement was more often associated with broken relief in mountainous areas. "The scattered manner of grouping suits localities as a result of the dissection of

relief, soil and hydrography, the arable land is itself divided up."¹ Thus, the nucleated villages of this region give place to the hamlets.

The geomorphology of a site and its soil conditions are two physiographic details to be investigated. Is there enough room for the settlement, and is it accessible? Does the landscape block ventilation? Is there erosion? Is the soil suitable for agricultural use and building material? The influence exerted on settlements by the landform is partly direct and partly indirect. The relief of the land exercises a direct influence particularly through slope, elevation and ruggedness. The direct influence is that of elevation and landforms on settlements. The lowering of temperature with elevation, the increase of precipitation, whether in form of rain or snow, with increasing elevation, the importance of slope towards or away from the sun, are some examples of direct influence. In fact it may be said that in the mountainous areas, where relief and geological structure present obstacle to human settlement and where the disadvantages of configuration are reinforced by disadvantages of climate, soil etc. human activities have resulted in discontinuous cultivation and settlement.

¹Vidal de la Blache; (1959), Human Geography, p.316.

In the present study the chi-square (χ^2) distribution test reveals that the settlements of the basins are randomly distributed. A study of the landform characteristics of the basins show negative as well as positive sites which favours as well as hinders the location of settlements (See Chapter VII). Some of the basins support large number of settlements, while others support a few. It is interesting to note that most of the large size settlements are located along the watershed zone, (conforming the hypothesis) while small size settlements and isolated hamlets are located scattered all over the basins. Some of the basins are covered with thick forests and others show exposed rocky slopes and infertile soil. Thus the main areas of attraction in these basins for settlement purpose are stream beds. In Khasi and Jaintia Hills, the nature of settlements are also very much associated with the material culture of the local tribes. In this region more than 40 per cent of population practice jhum cultivation. So, the location and distribution of settlements also much depends on the availability of cultivable land. As the jhum cultivation can not support large number of population it is therefore, seen that large-size villages are surrounded by small size settlements having their own jhum lands.



FIG. 590

Slope and Settlement

Average slope of an area is the most important controlling factor for settlements. Concave and gentle slopes, tillite fans, and river flat-terraces have comparatively deeper soil deposits, and they provide most suitable sites for human settlements, and agricultural fields. Steep slopes are generally avoided for house construction. In Khasi and Jaintia Hills most of the large-size settlements are located on gentle to moderate slope zones and small settlements, isolated hamlets are located on moderately steep to steep slopes.¹ In the western part of Khasi Hills, the terrain is very much dissected and the north-western part is characterised by isolated hillocks supports dispersed and isolated houses.

The superimpose map of average slope on settlements of ten small basins of Khasi and Jaintia Hills reveals an interesting relationship between slope and location of settlements. It is apparent from the (Fig. 32a, b) that the gentle and moderate slopes favoured much for the growth of settlements. The hilly terrain and steep slopes are the main factors which controls the shape and size of settlement. In areas of steep slope villages are not found in clustered form. Generally, houses are situated

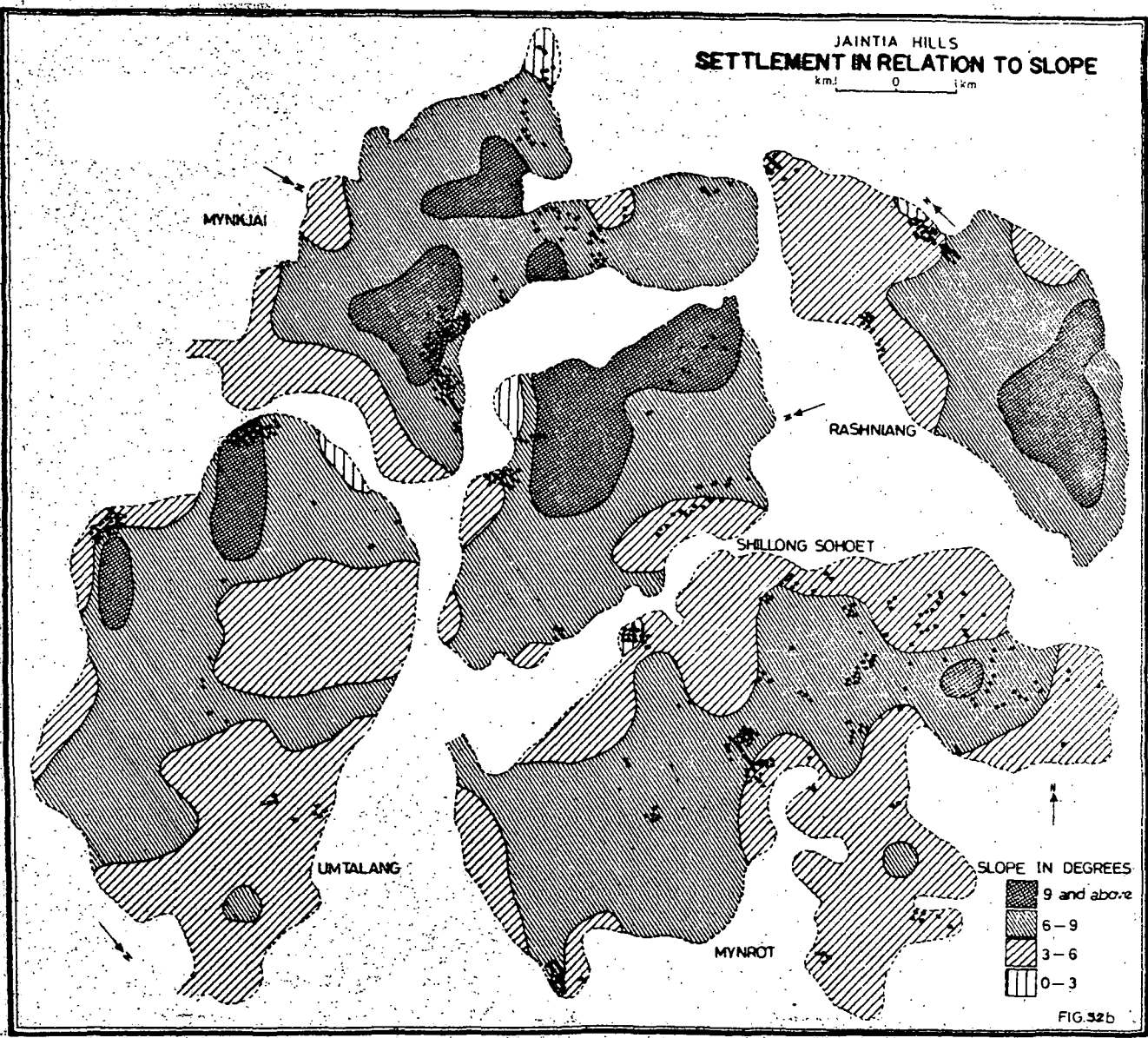
¹ Panda, P. (1982), An Analysis of Slope in Khasi and Jaintia Hills (Meghalaya), Hill Geographer, Vol.1, No.1, pp.42-46.

at a considerable distance; the upper portion of village being frequently situated at an elevation of 60 to 75 metres above the lower part. In the southern and north-western part of Khasi Hills, houses are generally built on a platform, the main house resting on the hill-side and the portion on the platform projecting therefrom, the object being to obtain more space (Plate 28). The area of the houses is often limited, owing to the steepness of the hill-side. In villages some 95 per cent of the houses consist of single stories with verandahs, built on pillars to raise them 0.5 to 1.5 mt. or sometimes more above the ground. During field study the researcher observed some interesting points in the construction of these pile dwellings. It has been observed that the pile dwellings are mainly constructed on hill slopes and as the gradient of the slope increases the length of the piles also increases (Plate 29). The framework of these type of houses are of timber posts, the walls are of woven bamboo. Roofs are generally thatched and economically well-to-do people of course use corrugated iron sheets.

The hypothesis (C) that slope of an area controls the shape and architectural plan of the house is thus conformed in this study. The superimposed map (Fig. 32a,b) of Khasi Hills reveal that the average slope of these basins range between less than 6 to above 18 degrees. The four basins viz., Umsaw, Umdkhar, Wah Rashi, Um Raling show the slopes less than 6 to above 12 degrees. The

JAIINTIA HILLS
SETTLEMENT IN RELATION TO SLOPE

km: 0 km



only basin Wah Mynsat which is located near the western boundary of Khasi Hills shows slope more than 18 degrees. The southern part of this basin represents very steep slope with cliff and exposed rocky surface over which the Wah Mynsat stream flows.

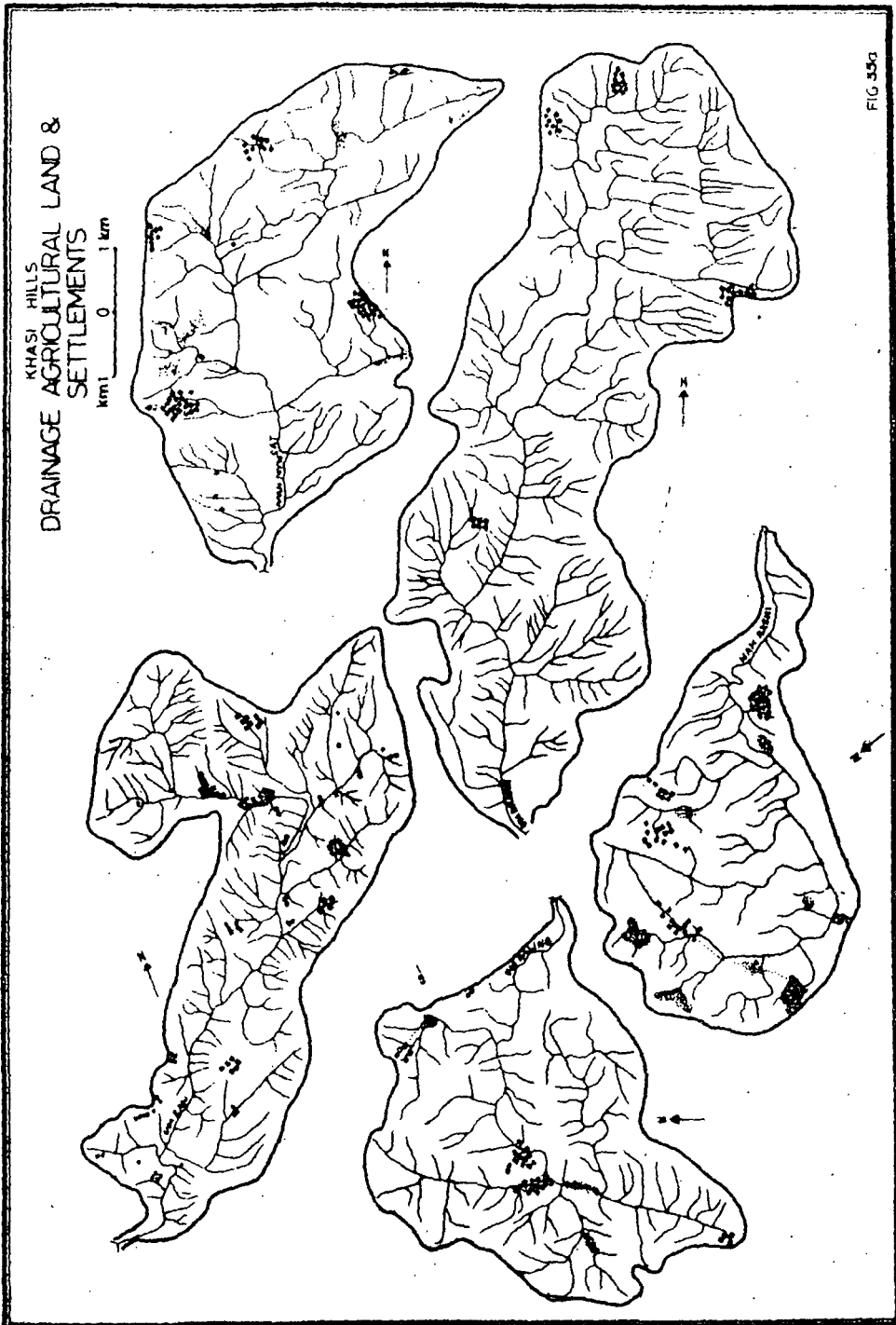
It is interesting to note that the 0 to 6 degree category of slope found only along the watershed zones of all the basins. These are the areas characterised by flat ridge tops, which supports maximum number of settlements. The superimposed map (Fig. 32a) shows that in Um Raling basin out of five settlements, three are located on this category of slope. In Wah Mynsat basin, out of four large settlements - two are located on this zone. Umdkhar and Wah Rashi basin also shows maximum number of settlement concentration on this category of slope. The second category (i.e. moderate slope) supports the next highest number of settlements. Um Raling, Umdkhar; Wah Rashi and Wah Mynsat basins show almost all the settlements located in gentle and moderate slope zone. One large settlement in Wah Mynsat basin and five settlements in Umsaw basin are found located in moderately steep slopes (12-18 degrees). Only the isolated houses are located on steep slopes.

The five basins of Jaintia Hills (Fig. 32b) reveal that the average slopes of these basins range between

less than 3 to 9 degrees. All the four categories i.e. gentle, moderate, moderately steep and steep slopes are represented in these basins. Very few areas are under the gentle slope category. Maximum number of settlements are located on moderate slope zone. The Um Talang, Mynrot, Shillong sohoet and Rashniang basins have some compact settlement and dispersed-isolated hamlets on this zone. Two large linear settlements which are located along the watershed zone of Mynkjai and Mynrot basin are on the moderately steep slope. The area under steep slope (i.e. above 9 degrees) support very few settlements. One large settlement in the south of Um Talang basin and some isolated hamlets in Shillong sohoet and Mynkjai basin are located on steep slopes.

The above discussion brings out some of the interesting findings that:

- (i) The gentle and moderate slope support a large number of settlements, whereas the steep slopes does not favour that much for the growth of large size settlements;
- (ii) The hilly terrain and slopes are the main factors which controls the shape and pattern of house construction.
- (iii) Due to steepness of slope, village are not found in cluster form. Generally, houses are situated at a considerable distance.
- (iv) Location of settlements on flat-ridge tops and steep hill slopes indicates the

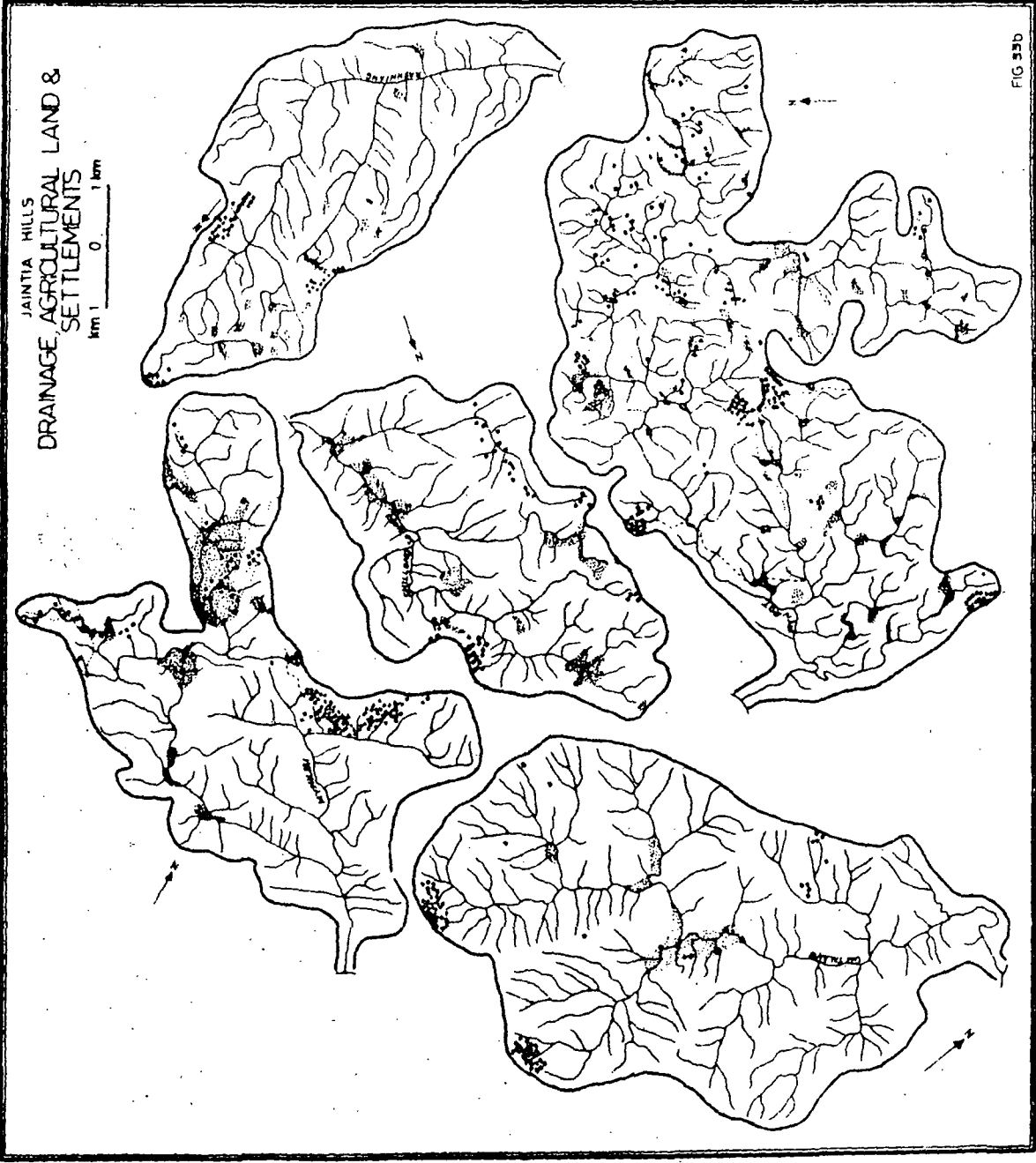


defensive character of the settlements. Some times, because of limited agricultural land along the river valleys forced the people to select such areas for settlement.

Drainage, Agricultural Land & Settlement

Normally it seems that in hilly tract like Khasi and Jaintia Hills, water availability is also an important factor which attract and favours the growth of settlements. But it may be overweighted by the combined effect of the availability of arable land and the proximity of building material and fuel. The agricultural land and drainage relationship with rural settlement in all the selected basins of Khasi and Jaintia Hills show that in some of the basins the only influencing factor is water, whereas in other basins both water and agricultural land are the main controlling factors for the growth of rural settlements.

The superimposed map of drainage, agricultural land and rural settlements (Fig. 33a) of five basins in Khasi Hills reveal that the Umsaw and Umckhar which are located in the north of Shillong town near Nongpoh village and south-west of Nongstoin have limited agricultural land. The settlements of these two basins are located in dispersed-cluster form along the watershed and along the river valleys. The important settlements of these two basins are Marngar, Umpyrking, Nongsohbar, Nartap etc. of



Umsaw basin and Nongmawait, Nonglumjew, Mawmarin etc. of Umdkhar basin. Rest three basins, the Um Raling, Wah Mynsat, Wah Rashi show patches of agricultural land and settlements are located at or near these lands. It is interesting to note that most of the settlements are located along the watershed zone, which are either flat ridgetops or along the slopes leaving the river plain available for cultivation. Houses situated on the upper slopes give the residents the opportunity to look after their cultivation sites which lie down slopes.

The five drainage basins of Jaintia Hills (Fig. 33b) reveal that, most of the river valleys which provide agricultural land are seen dotted with isolated hamlets. These hamlets are serving as farm houses. The large settlements are located along the valley slope or on the flat-ridge tops sparing the valley plain for cultivation purpose.

From the above discussion the interesting findings are as follows :

- (i) Availability of drinking water along with arable land acts as the "pull factor", this hypothesis is conformed in this study.
- (ii) The possible cause of settlements being located along the steep valley slopes and water shed zone are due to non-availability of arable land which forced the inhabitants to spare the limited valley plain for cultivation purpose and build their houses over such sites.

- (iii) There is no house or human habitation in the building of which man has not had to take into account the proximity of water. During field observation the researcher came across such isolated hamlets and small villages in these drainage basins which are situated primarily near springs or streamlets.
- (iv) The actual distribution and location of settlements is clearly associated with factors such as gradient of slope, water resources, availability of arable land and relief.

Transport and Communication

In the present-day world, the transport and communication network is one of the most important factor for the development of an area. The present study is not directly concerned with transport and communication as such, however, the relationship between the topography and the development of transport and communication lines which is also an important factor that controls the size of settlement may be emphasized. Settlements in this region tends to be isolated in character. The main cause could be the practice of shifting cultivation (jhum) which force the inhabitants to live isolatedly only because this type of cultivation can not support a large size village and the available land for jhumming is also limited. Secondly, the geomorphology of this region, which is characterised by rugged topography and undulating terrain, steep slopes and heavy erosion restrict the growth of large size villages.

Due to the rugged topography and dissected terrain, presence of a large number of rivers, escarpments and steep slopes the development of road communication is still obstructed. The existing road system have been constructed through some natural gaps and by cutting the gentle to moderately steep mountain slopes. In such topography, the construction of roads, embankments, bridges and culverts tremendously increase the cost of construction. Besides the hilly tracts are thickly forested and have poor sandy and red laterite soil.

In Khasi and Jaintia Hills of Meghalaya, road transport is the only and important means of communication system. There is no railways transport in this region. The main roadways i.e., the National High Way No... which passes through this region from Gauhati (Assam) through Shillong to Jowai. Other major district roads are (i) Shillong-Cherrapunjee road, (ii) Shillong-Dawki road, (iii) Shillong-Raibah road and (iv) Shillong-Nongstoin road. This shows that Shillong is the centre which connects all the major towns of this region. These roads have a great significance in economic development of this region. There are other minor roads viz. Kutcha roads, gravelled roads, several foot tracts which connects a number of large and small size settlements in this region.

(i) Shillong-Gauhati road - This is the National Highway connecting Gauhati (Assam), Shillong and Jowai towns. This road has been constructed in a zig-zag way with a number of hair-pin bends, which passes through the Khanapara (Assam), Burnihat, Jorabat, Nongpoh peneplane surface, rising gradually upwards in a labyrinth way. It is a heavily traffic ridden road both for passengers and goods. The important villages located along this road are Burnihat, Jorabat, Nongpoh, Umran, Naya Bunglow, and Barapani. All these settlements are example of linear settlement.

(ii) Shillong-Cherrapunjee Road - This is another important roadways in Khasi Hills, which connects a number of coal mining areas and the 'Cherra-Mawmluh cement Factory' located in Cherrapunjee. This road has been constructed by cutting mountain slopes and over the flat ridges. During rainy season, it is very often affected by minor debris fall, thus, hampering the movement of traffic. The important settlements located along this road are viz., Umlyngka, Myllem, Mawflang, Mawbat, Dympep, Sohrarim, Laitryngew (coal mining area) and Cherrapunjee. The interior village people often visit these large villages to sell vegetables and other items.

(iii) Shillong-Dawki Road - Separated from the Shillong-Cherrapunjee road after 15 kms. from Shillong

this road runs south-eastward to Dawki, which passes through the hilly tracts. At places, after the Laitlyngkot village towards Pynursla this road becomes very difficult for traffic movement. The important villages located along this road are Laitlyngkot, Kyrdemkulai, Mawkhen, Mawliem, Lyngkyrdem, Pynursla, Mawsbem, and Dawki are few of them. All these villages are example of linear settlements located along the road.

(iv) Shillong-Raibah road - This road passes through several gaps, over the flat ridges in a zig-zag way touching the Mawsynram platform. The important settlements located along this road are Lyngiong, Pamsangut, Laitmawsiang, Umlidam, Weiloi, Masngi, Mawsynram, Mawryngkoh, Trongpleng and Raibah.

(v) Shillong-Nongstoin Road - This road joins Shillong with Nongstoin, which passes through thickly forested and hilly areas. It is the only road which directly connects the western part with Shillong city. Thus, making it a most important transportation line in relation to economic importance. All the large and small size settlements in this region depend directly on this road for their necessary requirements. Some of the important large villages located along this road are Sohiong, Mawmaram, Langtan, Nongkynshi, Kynshi and Nongstoin.

(vi) Shillong-Jowai Road - This is the only road (National Highway) which directly connects the Jowai town of Jaintia Hills with Shillong city. Thus, making it the most important roadways which practically serves all purpose in this region. A number of large linear settlements are located along this High Way which in a way acts as the market centre for the interior settlements.

In order to get more clear picture of the influence of topography on transport system the researcher has studied the ten selected drainage basins in detail. Therefore on this light, it will be easier to examine the influence of transport and communication lines on the location of rural settlements in these basins.

The distribution of rural settlement map (Fig. 30(a) & (b)) of ten drainage basins of Khasi and Jaintia Hills reveal that the settlements are randomly distributed. Due to the hilly terrain and presence of transverse gullies, extended gullies and a number of parallel ridges that hinders the development of cluster settlement forms. The average area calculated for each settlement is found to be more than 6 sq. km./village. Owing to the difficult terrain and the location of settlements at greater distances the inter-settlement movements both for social and economic

purpose creates difficulties. Most of these settlements are difficult to reach. They are minimally connected with each other by village paths. Only one basin of Jaintia Hills located along the Jowai-Badarpur road and one basin (Umsaw) of Khasi Hills is located along the Shillong-Jowai road. At a much later stage of economic development of the area did a few metalled roads cross one or two basins.

Climate and Rural Settlement

"Climate fixes the boundaries of human settlements."¹ Apart from relief, gradient of slope, availability of drinking water and agricultural land, the climatic factors e.g. temperature, precipitation, amount of sunshine and humidity are the chief elements which determine the zone of permanent and itinerary settlements. Humidity, cloudiness, sunshine and visibility may become criteria for certain decisions in the selection of settlement sites and in the design and structure of the houses. Assuming, it has been decided to construct a house in a given rural area, local micro-climatic conditions weigh heavily in the selection of the best site.² Ideally, a complete site study should include the Micro-climate along with such matters as relief, average slope, drainage etc..

¹ Semple, E.C.(1911), Influences of Geographic Environment, p.607.

² Critchfield, H.J.(1979), General Climatology, p.330.

Wind - In hilly or mountainous areas, wind is the most important climatic element in the selection of site. It produces direct effect on the positioning of the building and modifies temperature and moisture conditions. The areas of high velocity of winds are generally avoided if practicable for the construction of house, or the houses are designed in a way so that there is adequate ventilations. Local relief is also significant as well as the most permanent of the common controls of wind direction at a specific site. In Khasi and Jaintia Hills, it has been observed by the researcher that the people generally avoid the windward slopes, and summits for house construction, and build their houses in small depressions and a little below the top of the hills. In order to gain protection from the frost in winter and strong winds, generally activated by temperature inversion along the slope of the hills. But interestingly, in the War* region, there is a village known as 'MawsheW" and the most typical of the houses are found here. This part of the region is often affected adversely by strong winds and there remains a danger of the roof being blow away. The inhabitants, therefore, tie their roof to big boulders on the four corners of the house. For this purpose, they use a kind of resting plant.¹

*The southern part of Khasi Hills locally known as War region.

¹Panda, P.(1980), Pattern of rural house construction in K & J Hills, p.11.

Temperature - Temperature conditions, other than those directly influenced by the exchange of air between the site and its surroundings, are controlled by insolation and elevation.¹ Sites in deep valleys have a shortened period of possible sunshine, which may be a distinct disadvantage in winter. In Khasi and Jaintia Hills, the settlements are located on the sunniest slopes. In some parts of this region especially in southern Khasi Hills, however a few settlements are located in deep valleys (Plate 30). A settlement location in the bottom of a valley does not provide good ventilation.² Reflected sun radiation when combined with the absence of the ventilation may increase the temperature in the valley. However, those villages which are located in deep valleys have some favourable conditions such as availability of drinking water, agricultural land and security point of view.

During winter, cold winds descend from the hill tops towards the valleys. Air descending along the slopes increases its temperature via adiabatic heating process. A settlement located at the foot of a slope will thus have higher temperature than one at the top of the slope under the same given micro-climatic conditions. Therefore, it is seen that in all the 10 small drainage basins

¹Critchfield, H.J. (1979), Op.cit., p.332.

²Golany, G. (1979), Arid Zone settlement site selection : A Case of Egypt, p.9.

maximum number of large size settlements are located along the upper slope zone and watershed zone. These locations of settlement have double advantage, firstly, these settlements will not get high temperature and secondly, houses looking away from the ridge tops are protected against cold winds. It is interesting to note that the tribal people on the basis of their experience, construct doors and windows on the leeward side. Such architecture of houses protects the people from cold winds and the vigouries of weather.

Precipitation - Difference in the amount of precipitation will not be greatly significant in the normal range of site possibilities, unless there are wide variations in elevation and orographic conditions in which case leeward slopes will usually be drier. Sites exposed to the wind will be most affected by driving rains. A location at the bottom of a valley may make a settlement subject to run-off flooding. In Khasi and Jaintia Hills, the settlements of the ten drainage basins, very few are located along the river valleys and that too in the areas free from inundation.

The southern face of Khasi Hills around Mawsynram-Cherrapunjee area, rainfall is maximum in comparison to any other part of the plateau. The maximum rainfall recorded in Cherrapunjee-Mawsynram area is 12,00 mm. It is

the wettest part of the world. Due to heavy rain in this part, the construction of houses are also different from the rest of the Khasi Hills. The walls of the houses are generally of stone, or the lower half of the walls are made up of stone and rest of wooden planks or 'ekra' (a type of locally available wall material). This system locally known as 'half-walling'. In the vast tract the predominance of the thatch roof is striking, simply because thatching grass is easily available. Economically well-to-do people use corrugated ironsheets for the construction of roofs. The thatch roofs are given a pitch as steep as it can to ensure a quick run off of rain water. Thatch usually consists of a typical long grass locally known as 'U Tynriew'.

During field observation some interesting characteristics about the roof and wall of rural houses are noticed. The foregoing discussion brings out clearly, that in all the small drainage basins selected for this study, a direct relationship exist between location of settlements and availability of water and agricultural land. Some of the interesting findings are as follows :

- (i) At the higher altitudes there tends to be higher relative humidity and consequently a lower temperature. There is also the possibility of making use of the adiabatic winds for natural cooling. Ascending adiabatic winds will lower temperatures one degree for every hundred metres.

- (i) Therefore, the upper slopes are the better choice for a settlement location. In these drainage basins also it has been noticed that maximum large size settlements are located on the upper slope and watershed zones.
- (ii) The only suitable land for sedentary agriculture is the narrow strip of valley land along some major rivers. This zone can not be expanded due to a number of physical factors. And in one hand Jhumming is not suitable for a large sized village. To continue to support the growing population new agricultural techniques will also be necessary.
- (iii) Land suitable for agriculture must not be used for non-agricultural purposes e.g. settlements, built-up areas and transportation net works etc.. Therefore, it is seen that the settlements in these basins are located on hill slopes and ridge tops, sparing the available plain land for agricultural purposes.
- (iv) It is interesting to note that, in some basins, a few isolated and temporary houses are found. This is due to the effect of shifting (jhum) cultivation in this region. After a year or two, of growing crops in one place, the cultivators used to leave the land when crop yields started to fall because of the over-cultivation. The abandoned land was allowed to recuperate as fallow land for a number of years. Along with this, the cultivators used to abandon the farm-houses which are located near these lands for a temporary period.
- (v) Apart from the topography average slope, availability of drinking water and cultivable land the effect of climatic elements are strongly directional. The orientation and design of a house is governed by elements like windforce, precipitation, temperature, humidity which have a close bearing on house construction.

Advantage of the altitude in the site selection process :-

- (a) Higher sites have a comfortable temperature and are cooler. They can introduce a comfortable environment for work and residency.
- (b) Higher sites enjoy relatively clean air and have little or no dustiness. Potentially, they are healthy places for residence compared to the low land.
- (c) Relative humidity is higher at the upper elevations and contributes to the climatic comforts.

In two areas higher sites may create problems.

First, with regard to accessibility, water source, and infrastructure, a large investment may be required. Second, consecutive inadequate space for the site may not be available at higher elevations. In addition, strong winds at higher elevations may make the upper part of the slope rather than the summits more suitable.

CHAPTER - IX

SUMMARY AND CONCLUSION

The Khasi and Jaintia Hills are part of the Shillong Plateau. Being part of the Shillong Plateau, it is the north eastern extension of the Peninsular Shield. The rocks of the region have more in common with those of the Peninsular region, rather than those of the surrounding Himalayan ranges of the north-eastern part of India. The study area being in proximity to the Himalayan ranges, appears to be very much associated with Himalayan mountain movements. The geographic history of the region is therefore, of very complex nature.

Lithology and Structural Characteristics

The structural characteristics of rock formations of the Khasi and Jaintia Hills reveal that the region has witnessed a number of earth movements.

- (i) Basement deformation is evident in the gneissic group of rocks.
- (ii) The pouring out of plateau basalts (The Sylhet Traps) through fractures and faults in the basement, uplifted and subsided the adjacent blocks.
- (iii) In some areas evidence of cross folding are also present.

The foliation trend of the rocks seems to be mostly North-East - South-West in the western part and East-West in the southern part of the Khasi and Jaintia Hills. The Shillong Plateau which is often viewed as a dismembered portion of the Peninsular Shield, seems to be in some ways similar to the Salt Ranges of the West. However, there are remarkable contrasts between the two tracts, while the Salt Range includes a comparatively complete sequence of rocks from early Palaeozoic to early Tertiary period, the Shillong Plateau is largely made up of pre-Cambrian rocks, Mesozoic and Tertiary sediments.

Topography

The physical landscape of Khasi and Jaintia Hills records the succession of climatic variations through different geological periods. It retains both fossils and active erosion surfaces. The successions are of the following order :

- (i) The ancient rock cover, along with the intrusive rocks have been subjected to intensive weathering.
- (ii) The granite and gneiss of the region have been weathered to lateritic soil.
- (iii) The chemical weathering predominates, mainly in the southern part of the region. The dissolution process is in active form in parts of Mawsynram and Cherrapunjee area. The oxidation process can be marked from the exposed rock surfaces, over which a coat of reddish-yellow colour may be noticed.

- (iv) The Shillong group of rocks are generally, composed of quartzite-schists, which show an interaction of mechanical and chemical weathering.

The Khasi and Jaintia Hills of Meghalaya display erosion surfaces at different elevations from the sea level. Due to the presence of various rock types in the region, they are quite different in their resistance to fluvial erosion and weathering. Thus, the identification of erosion surfaces are rather, more complex. The researcher has identified five erosion surfaces with the help of superimposed, projected profiles, longitudinal profiles, altimetric frequency graphs and with the help of field evidences. These are as follows :

- (a) The Exhumed Gondwana surface;
(1800 mt. - 1500 mt.)
- (b) Cretaceous surface,
(1500 mt. - 1200 mt.);
- (c) Eocene surface (Jaintia group),
(1200 mt. - 900 mt.);
- (d) Pleistocene surface;
(900 mt. - 600 mt.);
- (e) Recent surface, (600 mt. - 300 mt.).

Due to erosion, sedimentation, folding, faulting, intrusions, movements of land and sea, the present landscape of Khasi and Jaintia Hills are characterised by the following landform features:

- (i) The uplifted Shillong Plateau ending in scarps, unfurls a composite picture of the Khasi and Jaintia Hills;

- (ii) The presence of scarps in the southern face of Khasi Hills comes under the sway of the summer monsoons, recording highest rainfall (of the world) in Mawsynram - Cherrapunjee area.
- (iii) The breaks-in-slopes between different levels of the undulating terrain and presence of many waterfalls and rapids, define erosion surfaces of different periods.
- (iv) In some parts the undulating peneplains along with river valleys dominate the landscape.

The hill-slope profiles around Shillong indicate the intimate association of soils and gradient of the slopes.

- (i) The association of particular soils with distinct slopes demarcates - different zones for landuse.
- (ii) The agricultural practices around Shillong display striking varieties. It has been developed under the influence of rapidly changing socio-economic forces operating in the context of the limitations and potentialities of the physical environment.
- (iii) The scarp face is missing in all the hill slopes, the whole surface being covered with thick debris slope.

It may be stated here that in initial stage of the hill slope development the scarp might have been present, but gradually, because of heavy rainfall associated with erosion caused by 'Jhumming', this face has been turned to a convex shape at the top and a concave at the pediment slope zone. The average slope of Khasi and Jaintia Hills varies between 0 to 20 degrees and above. These variations

in slope are directly influenced by the topography, lithology and structural characteristics of the rocks. It is interesting to note that in the region the slopes have greater influence on patterns of landuse. There are five slope categories as prepared by the author viz. (i) gentle (0-5 degrees); (ii) moderate (5-10 degrees); (iii) Moderately steep (10-15 degrees); (iv) Steep (15-20 degrees) and (v) Very steep - (above 20 degrees) and may further be analysed and useful information may be gathered on the basis of slope sub-units for micro-regional studies.

Drainage

The region is drained by large and small streams with their numerous tributaries,

- (i) The drainage system of the region is, to a great extent, controlled by the central plateau; which acts as the major water-divide zone. From the Central Plateau, the rivers flow down towards the Brahmaputra valley in the north and to the plains of Bangladesh in the south.
- (ii) The northern rivers have formed plain embayments at their entrance to the plain, thereby, making the northern boundary of the region fairly irregular.
- (iii) The southern rivers are entering the plains of Bangladesh in deep gorges; with a number of waterfalls, varying in heights between 14 mts. to above 400 mts: e.g. the Mawsmal falls (348 mts.), on the southern fringe of Cherrapunjee.

The patterns of drainage in the Khasi and Jaintia Hills reflect the influence of initial slopes, inequalities in rock-hardness and structural controls. The researcher has identified six types of drainage patterns in the region. Among these, the trellis, rectangular, radial and parallel patterns of drainage are found extensively.

The quantitative analysis of ten sample basins of the region reveal that;

- (i) There is no direct relationship between area of the basin and number of stream segments.
- (ii) The area of the basin is highly correlated with the length of the stream.
- (iii) The hypothesis, that 'bifurcation ratios within a basin decreases with the increasing order' has been confirmed. The five basins viz; UmRaling, Mynrot, Umdkhar, Umsaw and Mynkjai show decreasing bifurcation ratios with increase in orders.
- (iv) Empirical data from the sample basins indicate that due to the recent uplift, the topography is not well developed, hence the valley network is not complete.
- (v) The organization of fluvial hierarchies, as manifested in the 'laws' of stream numbers and mean stream lengths, in some basins, are not functionally related.
- (vi) The standard sinuosity index indicates that only UmRaling and Rashniang flow in a straight course while, rest eight stream flow in sinuous courses.
- (vii) The UmRaling, Rashniang, and WahRashi basins with high topographic sinuosity indices indicate that these basins are still in their early stage of basin development.

- (viii) The Umdkhar, Umtalang and Shillong shoet; which are located in the periphery of the central plateau region; indicate that these basins are in their early mature stage of development with high 'hydraulic' sinuosity index.
- (ix) It has been observed by the researcher, that a rise in drainage density occurs with increasing relief. The relief, supported by steep slopes, favourable lithology and abundant rainfall also affect the drainage density of the region.
- (x) The drainage density and constant of Channel maintenance show an inverse relationship, with a high negative coefficient of correlation (-0.99).
- (xi) The area of the basin and constant of Channel maintenance show high positive correlation (+0.73).
- (xii) Drainage density is negatively correlated with area of the basins (-0.70).
- (xiii) Bifurcation ratios are highly correlated with the length of second and third order streams.
- (xiv) Topographic sinuosity index is negatively correlated with 'hydraulic' sinuosity index.
- (xv) Number of first order is highly correlated with second order (+0.82); number of second order is highly correlated with number of third order is highly correlated with number of fourth order streams.

The study and interpretation of landforms indicate their influence on the present location, size and distribution of rural settlements in the region. The study brings out a marked variation of settlement and their distribution in space.

- (i) It has been observed that in the Jaintia Hills, a large number of settlements are permanent in nature. These are mostly, located near the cultivation sites.
- (ii) In the Khasi Hills, the smaller settlements seem to be temporary in nature. These villages shift from one place to another in search of agricultural land.
- (iii) Most of the large settlements are located around the city of Shillong in Khasi Hills and around Jowai town in Jaintia Hills. Along Gauhati-Shillong, Shillong-Jowai, and other major roads a number of large linear settlements are located.

The increase in the number of villages according to the population-size indicates highest growth in 200-499 population group. But, in terms of percentage, a cent per cent growth has been recorded in 2000-4,999 size villages. It is interesting to note, that a large number of villages come under less than 500 population sized settlements. The highest number of smaller settlements may be due to the following factors :

- (a) The villagers practise the age-old shifting cultivation (Jhum);
- (b) Shifting cultivation (Jhum) can not support large sized villages.
- (c) Because of the Jhum cycle, the villagers have to leave agricultural lands as fallow. In the process, they go to distant places in search of cultivable lands and they construct farm houses on those plots, newly acquired. In this process the farm houses gradually grow into a small village.

In the Khasi and Jaintia Hills most of the settlements

are located near the springs and along the streams. This indicates the influence of springs and drainage on settlements, which provide for the drinking water requirements of the settlers. Although, a considerable number of settlements are located along the watershed zones forming a linear pattern, and sparing the valleys for cultivation purpose. It is interesting to note that the location of settlements in the Khasi and Jaintia Hills are the expression of the geomorphological factors, favourable at particular spots in the landscape. The study brings out six important sites which favour the location of settlements. Interestingly, in the region, the availability of drinking water and agricultural land attracts the location of settlements; although, a large number of villages are located along the hill slopes and ridges.

It has been noticed that a number of factors, which have affected the difference in the patterns of settlements in the region are largely a result of forces acting continuously, but with varying intensity. Later, changes in the settlement patterns are mainly associated with the growth of 'mining villages', newly constructed transportation lines and availability of new settlement sites near agricultural land. However, the present study brings out mainly five patterns of settlements in Khasi and Jaintia Hills. Among these, the linear, dispersed cluster and isolated households are striking.

The landforms, particularly, the micro-relief features are associated with micro-climates and the building materials are reflected in the house types and in the house structures of the region. The researcher observed that most of the houses are constructed in accordance with the socio-economic and environmental conditions of the region. A marked variation in the house types has been observed in Khasi as well as in Jaintia villages, which ranges from the old types to the modern Assam types. The old type of houses are oval shaped. These old types are usually raised on the plinths, some half to one metre and some times more than one metre above the ground. It has been noticed, that the use of building materials also differs from place to place. This in turn affects the house design. Generally, the locally available building materials consist of wooden planks, bamboo, split bamboo nets, thatching grass, stones etc.. However, now-a-days, only a few houses, of traditional nature, are found in the villages of Khasi and Jaintia Hills. Most of the houses, now, are very much improved, except those in very interior parts. During field studies, the researcher observed, that thatches are the only roofing material and wooden planks are the main walling material in most houses and now are being replaced by flattened tins of oil-barrels, plain tin sheets and corrugated ironsheets.

The study of influence of landforms and climate on location and distribution of rural settlements confirms the following hypothesis :

- (a) It confirms the hypothesis that larger settlements are located along the watershed zones.
- (b) It confirms the hypothesis that slope of the area controls the shape and architecture of houses. It has been noticed that the pillars on which the main house rests upon, increases in length with increase in gradient of the slope.
- (c) It confirms the hypothesis that the availability of water and fertile soil generates 'pull factors' on the location of rural settlements. In the area a large number of 'wet-point' settlements (near the spring and along the streams) are noticed.

And the study rejects the following hypothesis :

- (a) It rejects the hypothesis that number of settlements are uniformly distributed over the region. The researcher found with the help of the chi-square test, that the settlements are randomly distributed.

Dispersed settlements are more often associated with broken relief in mountainous areas. The relief of Khasi and Jaintia Hills exercises a direct influence on settlements, particularly, in terms of the slope, the elevation and the ruggedness of the terrain. The influence of the slope on settlements is of particular importance. In the region, most of the large-sized settlements are located on gentle to moderate slope zones and smaller settlements are located

on moderate to steep slopes. Hence, on steep slope zones, settlements are not found in clustered form.

The only suitable land for sedentary agriculture are the narrow strips of valley-land along some of the major rivers. This zone can not be expanded due to a number of physical and geomorphological factors, and 'Jhumming' is not suitable for the large-sized villages. Therefore, to support the growing needs of the population, new agricultural techniques are necessary, commensurate with the regional needs. Land suitable for agriculture must not be used for non-agricultural purposes, e.g. settlements, built-up areas and transportation networks etc.. It has been observed, that the settlements in the region are located on hill slopes and ridge-tops, sparing the available plain areas for agricultural practices. Isolated hamlets are built on the slopes, surrounded by jhum lands. This helps the farmers to keep watch over the agricultural land.

Apart from the topography, average slope, availability of drinking water and cultivable land, the effect of the micro-climatic elements on settlements are strongly directional. The orientation and design of houses in the region are governed by windforce, rain-fall, temperature and humidity etc..

It has been observed in the preceding discussions and the summary of this study that the human occupancy of the land, location, distribution of settlements and house types are to a great extent, related to the factors of physical, geomorphological and to some extent the cultural controls of the area. The Khasi and Jaintia Hills is a land of great inequalities. Great differences in elevation and relief brings about contrasts in climate, natural vegetation, surface drainage, underground water-supply and soil profiles. These in turn influence the variation in landuse pattern and various aspects of settlements. Extensive areas between 1500 mt. and 1200 mt. present a variety of morphological features which are clearly expressed over the landscape.

The study of rural settlements related to geomorphological features is interesting in itself, and is likely to become more interesting and rewarding if viewed in the perspective of dynamic changes in the region. The study brings out broadly two types of influence of topography on the location, size, structure and distribution of rural settlements in the region. These are as follows :

- (a) Static and
- (b) Dynamic

Static Factor - Generally, the settlements which are located in the inaccessible and relatively isolated areas have less chance to come under the influence of changing physical environment. These settlements includes the typical old types. Their size remained small due to the practice of 'jhum' cultivation. The use of primitive agricultural technique in the practice of 'jhum' cultivation gives low yielding capacity. Therefore it is not suitable for a larger village.

In the hilly forested area of marked physical inequalities, habitable sites as well as the economic resources, particularly the cultivable lands are meagre and infrequent. In all such areas the distribution of settlements conforming to the distribution of natural resources, has become uneven and infrequent. Some of the factors which have positively contributed towards the dispersal or uneven distribution of settlements are physical inequalities and relief, inaccessibility and isolation, dissection of the surface, and fragmentation of the habitable sites, fine texture of drainage and ubiquity of water-channels; numerous hills and streams acting as natural dividers of land, diffusion of resources, low capability of land etc.. In these area settlements are tend to be located in the proximity of 'jhum' land. Generally, jhumming is done on the moderate to steep

slopes. That is why settlements are not found in clustered form in these slope zones.

Of all the factors of physical environment, soil and water-points appears to be most eloquently expressed in the general fabric of rural settlements in this part. Location of settlements, density, size and house types all depend directly upon the agricultural productivity of land. In a region, like the Khasi and Jaintia Hills where the method of agriculture are primitive (jhumming) and the amount of rainfall is much variable, agricultural productivity is largely a function of soil. On the other hand, fertility, thickness and texture of soil vary with the amount of slope and different zones of the hill slopes (see Chapter V). The extension and intensity of landuse are broadly determined by slope.

The old type of houses which are not exposed to modern development is mainly due to their relative isolation and inaccessible factor. The direct influence of topography and natural resources is very much reflected in the use of building material and house design. The old type of houses are oval shaped. These are usually raised on the plinths some half to one metre and sometimes more than one metre above the ground. It has been noticed that the pillars upon which the main house rests-upon increases in length as the gradient of the

slope increases. Generally, the locally available building materials consists of wooden-planks, bamboo, split bamboo-nets, thatching grass, stones, reeds etc..

The use of local building material, the rugged terrain and the influence of micro-climatic elements, the architectural design of these houses are found to be of peculiar nature. One of the greatest struggles of man in this part of the North-Eastern Region has been to protect himself against the heavy downpours of rains (which records the World's highest rainfall). Rainfall, therefore, is the most important climatic factors that has been constantly influencing the character of settlements. To ensure a quick run-off of rain water the inhabitants make their roofs accordingly. The four corners of the roof (and in some other part of the region only that portion of the roof which faces the windward side) are tied with a kind of resting plant to check the roof against high valocity of wind. Generally, the settlement sites choosen are located on the leeward side. The doors and windows are constructed to get maximum ventilations.

Dynamic Factor - Fundamental changes that have been and are being introduced in the geographical environment of the region are bound to affect the cultural landscape i.e. habitation of man which is the concern of this

study. The changes are so fast, so massive and at times and places, so unpredictable that it is difficult to take a very long-range view of them. From the stand point of the present, it may not however, very difficult to project the pattern of settlements that is likely to evolve during the turn of this century. To do so it is necessary to highlight on some of the most dynamic and powerful factors of the landforms and the environments. Most of these factors have been thoroughly examined in the preceding chapters.

The factors of physical landscape which have played very important role in determining the courses and pattern of settlements in the region are not likely to undergo fundamental changes. The hills, ridges, monadnocks, scarps, waterfalls, nick-points, degree of slopes, amplitude of relief, alignment of streams, river regimes and aspects of climate etc. are likely to remain unchanged during the foreseeable future. But it does not mean that physical environment will remain totally unchanged, unaltered and static. The factors of physical environment have been changing and are to change further.

The region has suffered in the past from physical isolation and was cut-off from the main stream. Primitive subsistence economy, shifting cultivation (jhum), self-

sufficiency was practised on family level. Occupance of land in the beginning has been selective and discriminatory. Subsequent occupance became fragmented and patchy and produced small hamlets and individual homesteads. The existing pattern of landuse practice in this region is causing tremendous soil erosion. The erosion is caused by largescale deforestation and land clearing for the purpose of acquiring more land to put on shifting (jhum) cultivation. As the pressure of population is increasing and without any change in the prevailing technology the cycle of shifting has been progressively going down. Therefore, a small group of people break away from the parent settlement and started living in nearby forested areas. By clearing the forest they started 'jhum' cultivation. The small cycle of shifting (jhum) cultivation is proving disastrous and due to heavy soil erosion many areas have turned into barren hills which have become unfit for any economic use or even settlement purpose. Therefore at places deserted or 'ghost' settlements are noticed due to the above stated factors.

It is interesting to note here that the settlements which are located around Shillong city and Jowai town are large in size having population 4000 to 5000 and above. These are the villages which are recording a dynamic change in terms of economic development, size, house types

and architectural design. The building materials reflect the influence of modern technology. Some of these settlements are located on the flat-ridge tops, water-shed zones which enjoys better communication facilities with the nearby urban areas. These settlements being in proximity to the urban areas practise commercial farming. The villagers generally supply vegetables, potato etc. to the urban areas. Urban influences, changed values, new jobs in villages, liking for openness, rural electrification all are leading towards a changing design of the settlements and house types.

The existing line of communication are of recent origin and their impacts on the rural settlements can easily be recapitulated. More areas are now accessible by metalled roads. The continued growth of roads has produced remarkable effects on the rural settlements and economy. The number and size of settlements along these communication lines have increased. Small clusters have expanded while some of the big ones have grown to small town. Discovery of new coal mining areas have also their own influence in the changing pattern of rural settlements. The 'break-away' settlements which are originating from the large settlements are now heading towards urban areas and newly constructed road-sides. These types of settlements are likely to change their orientation for subsistence farming to commercial farming.

APPENDIX-I

Distribution of Census Houses by Predominant Material of Wall and Roof (1971)

State/ District	Total number of Census Houses	Predominant Materials of Wall								
		Grass, Leaves, reeds or bamboos	Mud	Unburnt bricks	Wood	Burnt bricks	G.I. sheets, others	Stone	Cement concrete	All other materials & materials not stated
1	2	3	4	5	6	7	8	9	10	11
Meghalaya	T 224,538	146,347	17,369	206	39,914	595	9,737	2,546	7,048	776
	R 190,768	127,458	15,589	160	32,496	428	7,420	2,533	3,912	772
	U 33,770	18,889	1,780	46	7,418	167	2,317	13	3,136	4
United Khasi & Jaintia Hills	T 137,025	67,601	12,031	150	39,619	328	9,297	2,546	4,692	761
	R 106,702	50,848	10,258	123	32,272	164	7,226	2,533	2,521	757
	U 30,323	16,753	1,773	27	7,347	164	2,071	13	2,171	4

T = Total
R = Rural
U = Urban

Table contd...

350

250

Appendix-I contd..

Predominant material of Roof								
State/ District	Grass, leaves, reeds, thatch	Tiles Slate, Shingle	Corrugated iron zinc or other metal sheets	Asbestos cement sheets	Brick and lime	Stone	Concrete R.B.C/ R.C.C.	All other materials and materials not stated
	12	13	14	15	16	17	18	19
Meghalaya	T 146,829	267	75,446	967	13	21	970	25
	R 143,912	186	46,088	336	13	21	192	20
	U 2, 917	81	29,358	631	-	-	778	5
United Khasi & Jaintia Hills	T 65,999	207	68,965	873	5	21	941	14
	R 64,637	126	41,470	252	5	21	182	9
	U 1,362	81	27,495	621	-	-	759	5

T = Total
R = Rural
U = Urban

BIBLIOGRAPHY

- Ahlmann, H.W., (1928) : The Geographical Study of Settlements, Geog. Rev. Vol. 18(1), pp.93-128.
- Ahmed, E., (1948) : Settlements in the United Provinces of Agra and Oudh, Unpublished Ph.D. Thesis, Univ. of London.
- _____, (1952) : Rural Settlements type in U.P., A.A.A.G., Vol. XLII, (3), pp.223-46.
- _____, (1962) : Indian village Patterns, Geog. Outlook, May, vol. III, (1), pp.5-15.
- _____, (1965) : Indian Drainage, Geog. Outlook, 4, pp. 9-21.
- _____, (1968) : Distribution and causes of gully erosion in India, Int. Geog. Union, Selected Papers, Part I, pp.1-3.
- _____, (1969) : Origin and geomorphology of Thar Desert, Annals, Arid Zone, 8(2), pp. 171-80.
- _____, (1973) : Soil Erosion in India, Asia Publ. House.
- _____, (1977) : Geology, Structure, and Geomorphology of trans Himalayan Nepal, Geog. Outlook.
- Ahmad, K.S. and Kureishy, K.V. (1961) : Growth of Settlements in West Pakistan, Pak. Geog. Rev. Vol. 16(2), pp.1-13.
- Anas, M., (1954) : The Pattern of Rural Settlements in the Sub-Himalayan Regions(East), The Geographer, Vol. 6(2), pp.23-36.

- Asthana, V.K.(1987) : Morphometric evolution of landforms in Almora and its environs, Nat. Geog. Jr. India, 13(1), pp.37-54.
- Bandhopadhyaya, P.(1957) : Settlements Patterns of East Kolhan, Geog. Rev. India, Vol. 19(1), pp.20-26.
- Bandhopadhyaya, M.K.(1972) : Geomorphological Characteristics of the Southern part of the Khasi Hills, Geog. Rev. India, Vol.34(2), pp.184-89.
- Bareh, H. () : History and Culture of the Khasi People, Shillong.
- Barkataki, S. (1969) : India - the land and the People - Assam. New Delhi, National Book Trust, 163 pp.
- Barua, B.K. (1952) : Early Geography of Assam, Nowgong.
- Barua, N.C. (1968) : Geomorphology of Barapani area in Meghalaya Plateau, Proc. Pre-Cong. Symp. IGU, Gauhati, Nov. pp.25-32.
- Birch, B.P. and Hudson, J.C.(1970) : On the Theory of Rural Settlements, A.A.A.G., Vol. 60, pp.610-14 (Comments & Reply).
- Biswas, S. and Ghosh, A.K. () : Impact of Shifting Cultivation in Meghalaya, pp.77-79.
- Bose, A.B. and Jodha, N.+S (1968) : Some observations on factors influencing settlements of household, Man in India, 47(3)&(4).
- Bowman, I. (1926) : The Scientific Study of Settlements, Geog. Rev., Vol. 16, pp.647-53.

- Brown, E.H. (1970) : Man shapes the earth. Geog. Jour. 136., pp.74-84.
- Brown, L.A. (1967) : Rural Settlements in Israel : A Model and Selected applications, (Xerox report), Dept. of Geography, Univ. of Iowa.
- Bryan, K. (1940) : The Retreat of Slopes, A.A.A.G., Vol. 30, pp.254-68.
- Census of India,(1971) : Meghalaya, Housing Report and Tables, Series 13, Part IV.
- Chattarjee, S.(1970) : Meghalaya : A Separate Geographical entity, Mod. Rev. 126(6), Jan. pp.447-50.
- Choudhury, J.N.(1977) : Evolution of Shillong, North-Eastern Spectrum, 1(5), pp.9-14.
- Champman, C.A.(1952) : A New Method of topographical analysis. Am. Jour. Sci. Vol. 250, pp.428-52.
- Chisholm, M.D.(1962) : Rural Settlement and Landuse, London.
- Chorley, R.J. (1957) : Illustrating the Laws of Morphometry, Geol. Mag. Vol. 94, pp.140-50.
- _____,(1966) : The Application of Statistical Methods to Geomorphology in (Durry ed.) Essays in Geomorphology, pp.275-387.
- _____,(1969) : Fluvial Processes, p.38.
- _____,(1957) : Climate and Morphometry, Jr. Geol. 65, pp.628-68.

- Clarke, J.I.(1966) : Morphometry from Maps, in (Dury, ed.) Essays in Geomorphology, pp. 235-74, London, Heinemann.
- Commerce Research Bureau(1972): Profiles of +Agricultural development in States : Meghalaya; "Rains never fail here but man do", Commerce (Ann.), pp.130-31.
- Cotton, C.A. (1942) : Climatic Accidents in Landscape making, Christchurch, No.2, p.354.
- _____,(1952) : Geomorphology (6th Ed.) New York, John Willy and Sons, 505 pp.
- _____,(1952) : The Erosional grading of convex and concave slopes, Geog. Journ. Vol. 118, pp.197-204.
- Couzan, M.P.(1969) : Spatial data from Nineteenth century manuscript Census : A Critique for Rural settlements and Landuse analysis, Prof. Geop. Vol.21, pp.337-43.
- Cutting, W.E.H.(1960) : Analytical theory of erosion, Jour. Geol. Vol. 68, pp.336-344.
- Datta Ray, B.(1977-78) : Occupational mobility among Khasis of Shillong, Pnar of Jowai and Cords of Tura, three urban centres of Meghalaya, Shillong ICSSR Project, NEICSSR.
- Davis, W.M. (1899) : The Geographical Cycle, Geog. Jour 14, pp.481-504.
- _____,(1913) : Meandering valleys and underfit rivers, A.A.A.G. Vol.3, pp.4-5.
- Dikshit,K.R.(1970) : Polycyclic landscape and the surface of erosion in the Deccan Trap Country with special reference to Upland Maharashtra, Nat. Geog. Jr. India, 14(3 & 4), pp.236-52.

- Duggal, S.L. (1961) : Moñadabad district : Settlements in relation to landuse, The Indian Geog. Vol. 6(1), pp.54-69.
- Durry, G.H. (1951) : Quantitative measurement of available relief and texture of dissection, Geol. Mag. Vol. 88, pp.339-43.
- _____ (1952) : Map Interpretation, Pitman. London
- _____ (1952) : Methods of Cartographical analysis in geomorphological research, Ind. Geog. Soc. Silver-Jubilee Sovenir, pp.136-41.
- _____ (1954) : Contribution to a general theory of meandering valleys, Amer. Jour. Sci., Vol. 252, pp.193-224.
- _____ (1967) : Essays in Geomorphology, Heinemann, London.
- Dutta, S.K. (1968) : Palaeogeography of the Assam Plateau, Proc. Pre-Cong. Symp, IGU, Gauhati, pp. 43-49.
- _____ (1976), : Agriculture in Meghalaya still in poor shape, Times of India, 9 Feb. 4:7.
- Evans, J.S. (1972) : General Geomorphometry derivations of altitude and descriptive statistics; Spatial Analysis in Geomorphology (ed.).
- Evans, P. (1964) : The Tectonic Framework of Assam, Jour. Geol. Soc. India, Vol. 5, pp.80-96.
- Everrard, C.E. (1963) : Contrast in the form and evolution of hillside slopes in central cyprus, Inst. Brit. Geog., Vol. 32, pp.31-47.

- Fair, T.J.D. (1947) : Slope form and development in the interior of Natal South-Africa, Geol. Soc. S. Africa, Trans., Vol.50, pp.105-119.
- Fenneman, N.M. (1928) : Physiographic divisions of the United States, Anns. Ass. Amr. Geog., Vol. 18, pp.264-353.
- _____ (1931) : Physiography of Western United States, Mc Graw-Hill Book Co., New York.
- Geyl, W.F. (1961) : Morphometric Analysis and World wide occurrence of stepped erosion surfaces, Jour. Geol. Vol. 69, pp. 388-416.
- Gilbert, G.K. (1909) : The convexity of hill tops, Jour. Geol., vol. 17, pp.344-50.
- Ghose, B. et. al.(1967) : Quantitative geomorphology of the drainage basins in the central Luni Basin in western Rajasthan, Zeitschrift fur Geomorphologic, Vol. 11, pp.146-60.
- Ghose, B. and Pandey, S.(1966) : Geomorphology of Central Luni Basin, Western Rajasthan, Annals, Arid Zone, 15(1).
- Glock, W.S.(1932) : Available relief as a factor in the Profile of a landform, Jour. Geol. Vol. 40, pp.74-83.
- Gorshkov, G. and Yakushova, A. (1967) : Physical Geology, p.66.
- Goswami, D.N.D.(1968) : Environmental significant during the Palacocene Lower Eocene Period in the Western Part of the Meghalaya (Garo Hills), Proc. Pre-Cong.Symp. IGU, Gauhati, pp.35-39.

- Gregory, K.J. and Walling, D.E. (1973) : Drainage Basin form and Processes: A Geomorphological Approach, Edward Arnold (Pub. Ltd.) pp.3-4 & p.46.
- Grossman, D. (1971) : Do we have a Theory of Settlement Geography, Prof. Geog. Vol. 23(3), pp.197-203.
- Gupte, R.B. and Rajaguru, S.W. (1971) : Bate Pleistocene Geomorphological history of rivers of Western Maharashtra, Int. Symp. Deccan Traps and other Flood Erruptions, Proc. Part. I. Bull. Volcanology, 35(3), pp.686-95.
- Gurdon, P.R.T. (1975) : The Khasi, Delhi, ~~Cosmo~~. 227 pp.
- Hack, J.T. (1960) : Interpretation of erosional topography in humid temperate regions, Amer. Jour. Sci. Vol. 258, pp.80-97.
- Hanwell, J.D. and Newson, M.D. (1969) : Techniques in Physical Geography, New York.
- Heron, A.M. (1953) : Geology of Central Rajputana, Mem. Geol. Surv. India, Vol. 79.
- Hijulstrom, F. (1935) : Studies of the Morphological activity of rivers as illustrated by the river Fyris, Univ. Upsala, Geol. Inst. Bull. 25, pp.221-527.
- Horton, R.E. (1945) : Erosional development of Streams and their drainage basins, hydrophysical approach to quantitative morphology, Bull. Geol. Soc. Amer., Vol. 56, pp.275-370.
- Hudson, J.C. (1967) : An Algebraic Relation between the Losch and Christaller Central Place Networks, Prof. Geog., Vol. 19, pp.133-35.
- _____ (1969) : A Location Theory of Rural Settlements, A.A.A.G., Vol. 59, pp.365-81.

- India, Registrar General, Census 1961, Assam; Village Survey Monograph : Mawnai (United Khasi and Jaintia Hills dist.), Ed. N. Phillip, Delhi, Manager of Publ. 60, p.65.
-
 _____, : Village Survey Monograph (Jowai P.S. United Khasi and Jaintia Hills dist.), Ed. E.K. Pakyntein, Delhi, Manager of Publ. 65.
- Jafri, S.S.A.(1977) : Levels of socio-cultural development of settlements : A case study of United Khasi and Jaintia Hills dist. North-East. Geog. 10(1-2), pp.51-55.
- Jordon, T.C.(1966) : On the nature of settlement Geography, Prof. Geog. Vol. 18, pp.26-27.
- Kaushic, S.D. () : Human settlements in the Western Central Himalaya, pp.329-332.
- King, L.C. (1962) : Morphology of the earth, Oliver and Boyd., London.
- King, C.A.M.(1966) : Techniques in Geomorphology, Edward Arnold, (Publ. Ltd.)London.
- Krishnan, M.S.(1953) : The Structure and tectonic history of India, Mem. Geol. Surv. India, vol. 81, p.75.
-
 _____ (1960) : Geology of India and Burma, 4th Ed., Higginbothams (Pvt. Ltd.) Madras.
- Kumar, A. (1971) : Geomorphic Interpretation of Drainage and relief of Eastern Ranchi Plateau, Upper Bharat Bhugol Patrika, 7(1), pp.18-33.
-
 _____ (1979) : Geomorphology of Simdega and its Adjoining area, Bihar. The Nat. Geog. Socit. India, Research Publ. No.22, pp.126.

- Leopold, L.B. and et.al.(1969): Fluvial Processes in Geomorphology, p.100. Freeman.
- Lobek, A.K. (1939) : Geomorphology, Mc Graw-Hill Book Co., New York.
- Losyakova, K.M. (1969) : On the mapping of the settling process, Soviet, Geog. Rev. and Trans. vol. 10, pp.618-23.
- Macgregor, D.R.(1957) : Some observations on the geographical significance of slopes, Geog., Vol. 42, pp.167-73.
- Mc Cullah Patrick (1978) : Modern Concepts in Geomorphology.
- Melton, M.A. (1958) : Correlation structure of morphometric properties of drainage system and their controlling agent, Jour. Geol. 66, pp.440-460.
- Miller, A.A.(1953) : The Skin of the Earth, Mathuen, London.
- _____, (1961) : Climate and Geomorphic Cycle, Geog. Vol. 46, pp.185-97.
- Miller, O.M. and Summerson, C.H.(1960) : Slope zone maps. Geog. Rev., Vol.50, pp.194-202.
- Milton, L. (1965) : Quantitative expression of drainage net patterns, Aust. Jour. Sci. 27(8). pp.238-40.
- Monkhouse, F.J.(1954) : The Principles of Physical Geography, Univ. of London Press, Ltd. London.
- Morisawa, M.(1959) : Relation of quantitative geomorphology to streamflow in representative Watershed of the Appalachian Plateau Province, Columbia Univ. Deptt. Geol. Tech. Report, 20, p.94.

- Mukhopadhyaya, S.C.(1969): Some Aspects of Geomorphology of part of Subarnarekha Basin around Mahali, Murup, Bihar, Geog. Rev. India, 31(2), pp.33-40.
- Murthy, M.V.N.(1968) : Geomorphological evolution of the Assam region. Proc. Pre-Cong. Symp. IGU, Gauhati, pp.10-15.
- Ongly, E.D.(1974) : Fluvial Morphometry of the Cobar Pediplain, A.A.A.G., Vol. 64, No.2
- Pallister, J.W.(1956) : Slope form and erosion surfaces in Uganda, Geol. Map., Vol. 03, pp.465-77.
- Panda, P. (1980) : Patterns of rural house construction in Khasi and Jaintia Hills : Meghalaya. Himalaya, Mand. & Nature, Oct. pp.9-11.
- _____ (1981) : Climate and Rural Architecture of Khasi Hills; Himalaya, Man and Nature, pp.13-14.
- _____, (1981) : Influence of landforms on Location and distribution of rural settlements in Khasi and Jaintia Hills, Meghalaya. Nat. Geog.
- _____ (1982) : A Study on average slope of Khasi and Jaintia Hills, Meghalaya. Hill Geog. Vol. 1(1), pp.42-46.
- Pascoe, E.H.(1959) : A Manual of the Geology of India and Burma, Vol. II (3rd - Ed. revised) Govt. of India Press, Calcutta.
- Patnaik, S.N.(1979) : Geomorphology and Agriculture in Meghalaya Plateau, Unpublished M.Phil. Dissertation, Geog. Deptt. N.E.H.U., Shillong.
- Prasad, A.(1973) : Chotnagpur; Geography of Rural Settlements, Ranchi Univ., Ranchi, 467 pp.

- Rai, R.K. (1980) : Geomorphology of Sonar-Bearma Basin. Concept Publ. New Delhi.
- _____, (1980) : Morphometric analysis of Umran Basin of Meghalaya.
- _____, (1980) : Hill Slopes, Landuse and Soil erosion around Shillong (Meghalaya), Geog. Rev. India, Vol.41, No.4.
- _____, (1982) : Environmental Framework and Landuse and Panda, P. on hill slopes around Shillong, Proc. Symp. Allahabad Univ.
- _____, (1970-71) : "The Study of hill side slopes in the Sonar-Bearma Basin", Geog. Outlook, vol. VII, pp.170-75.
- _____, (1981) : The Study of hill slope and its impact on Landuse around Sagar. Trans. Ind. Geog. Vol. pp.65-71.
- Ray, S. (1978) : Studies in Geomorphology of India.
- Rieh, J.L.(1983) : Recognition and significance of Multiple erosion surfaces, Bull. Geol. Soc. Amer, Vol. 49, pp.999-1024.
- Russel, R.J.(1949) : Geographical Geomorphology, A.A.A.G, Vol. 39, pp.1-11.
- Scheidegger, A.E.(1961) : Theoretical Geomorphology Englewood Cliffs, N.J.Prentice Hall, p.333.
- _____, (1964) : Lithologic Variations in Slope development theory, U.S. Geol.Surv. Circ. 485.
- _____, (1965) : The Algebra of Stream order numbers, U.S. Geol. Surv. Prof. Paper 525B, pp.187-89.

- Scheidegger, A.E. (1966) : Stochastic branching processes and the law of stream order numbers, Water Resources Research, 2(2), pp.199-203.
- Schumm, S.A.(1965) : The evolution of drainage systems and slopes in badlands at perth Amboy, New Jersey, Geol. Soc. Amer. Bull. 67, pp.597-646.
- _____ : Fluvial Geomorphology in River Mechanics, River Morphology(Ed.).
- Sharma, R.C.(1960) : Western Rajasthan - A Study of house types : Nat. Geog. Vol. III, pp.47-54.
- _____ (1972) : Settlement Geography of Indian Desart.
- Sharma, H.S.(1982) : Perspective in Geomorphology. 4 Volms. (Ed.) Concept Publ. Co. N.Delhi.
- _____ (1980) : Ravine Erosion in India. Concept Publ. Co., New Delhi, 96 pp.
- Shreve, R.L. (1966) : Statistical Law of Stream Numbers, Jour. Geol. vol. 74, pp.17-37.
- Sinha, R.P.(1975) : Problem of Shifting cultivation in Meghalaya, efforts towards solution, in T. Mathew (ed.), Seminar on Tribal Economy, Shillong, NEHU, pp.187-92.
- Singh, L.R. (1958) : Rural Settlements in the Tarai Region of U.P., Nat Geog. Vol. II, pp.8-29.
- _____ (1958) : The Tarai Region of U.P. - A Study in Human Geography, Nat. Geog. vol.I pp.5-17.

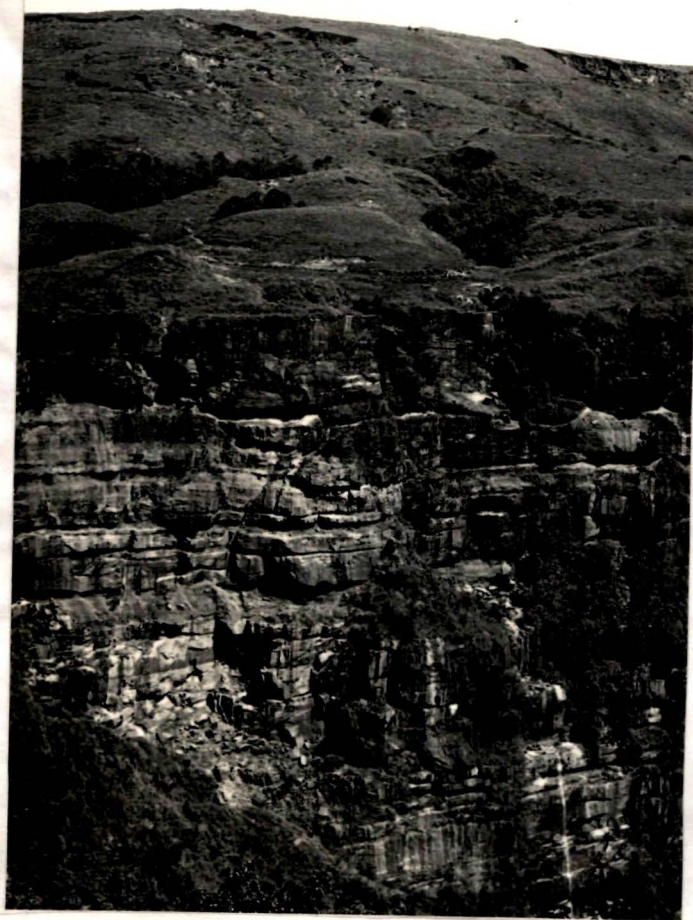
- Singh, D.K. and Sharma, H.N. (1968) : Sinuosity Index of Streams as a key to the Geomorphological character of a region. Prof. Pre-Symp. IGU, Gauhati.
- Singh, J.P. (1972) : Rural Settlements and house types in the Rilum of Khasi Hills, Meghalaya, in (R.L. Singh - Ed.) Rural Settlements in Monsoon Asia, Proc. IGU, Symp. Varanasi & Tokyo, NGSI, pp.398-404.
- Singh, R.L. (1961) : Meaning Objectives and scope of settlement Geography. The Nat. Geog. Jour. India, vol. 7(1), p.12.
- _____ (1955) : Evolution of settlements in the Middle Ganga valley, Nat. Geog. Jour. India, vol. 5(2), pp.69-114.
- _____ (1957) : Typical Rural Dwelling in the Umland of Benaras, The Nat. Geog. Jour. India, vol. 7(2), pp.51-64.
- Singh, R.P. (1968) : Geomorphology of Shillong Plateau of Assam, Proc. Pre-Cong. Symp. IGU, Gauhati, pp.1-9.
- _____, (1960) : Geomorphological evolution of the High land of Raj mahal, Nat. Geog. Jour. Vol. VI, (1).
- Singh, S. (1972) : Altimetric Analysis : A Morphometric technique Study, Nat. Geog. Allahabad, 7, pp.54-68.
- _____ (1974) : A Morphometric Study of the tributary basin of Upper reaches of the Belam River, Nat. Geog. 9, pp.31-204.
- _____ (1979) : A Morphometric study of average slopes of the small drainage basins of the Ranchi Plateau, Nat. Geog. Allahabad, 14(1).

- Singh, S. and Vats, P.C. (1979) : Geomorphic control on the rural settlements of Jodhpur dist., W. Rajasthan. Ajmer Geog. 6, pp.1-14.
- Small, R.J. () : The Study of landforms. Cambridge Univ. Press.
- Sparks, B.W. (1952) : Rates of operation of Geomorphological processes, Geog. Vol. 47, pp. 145-53.
- _____ (1960) : Geomorphology, London, Longmans, Green & Co., pp.371.
- Spate, O.H.K.(1952) : Geomorphological problem in India, A Plea for their more intensive Study. Indian Geog. Soc. A Silver Jubilee Souvenir, pp.181-85.
- Spate, O.H.K. and Learmonth, A.T.A.(1967) : India and Pakistan (3rd Ed.), Methuen and Co. Ltd.
- Strahler, A.N. (1952) : Dynamic basis of Geomorphology. Bull. Geol. Amer, Vol. 63, pp.923-38.
- _____ (1957) : Quantitative Analysis of Watershed Geomorphology. Trans. Amer. Geophy. Union, 38, pp.913-20.
- _____ (1964) : Quantitative Geomorphology of drainage basins and channel networks. In (Chow, V.T. Ed.), Handbook of Applied Hydrology IV, p.39 & IV, p.76.
- _____ (1960) : Physical Geography, (2nd Ed.) John Willey and Sons, New York.
- Synrem, H.K.(1976) : Social Structure of a Khasi village. N.E. Res. Bull, 7, pp.81-86.

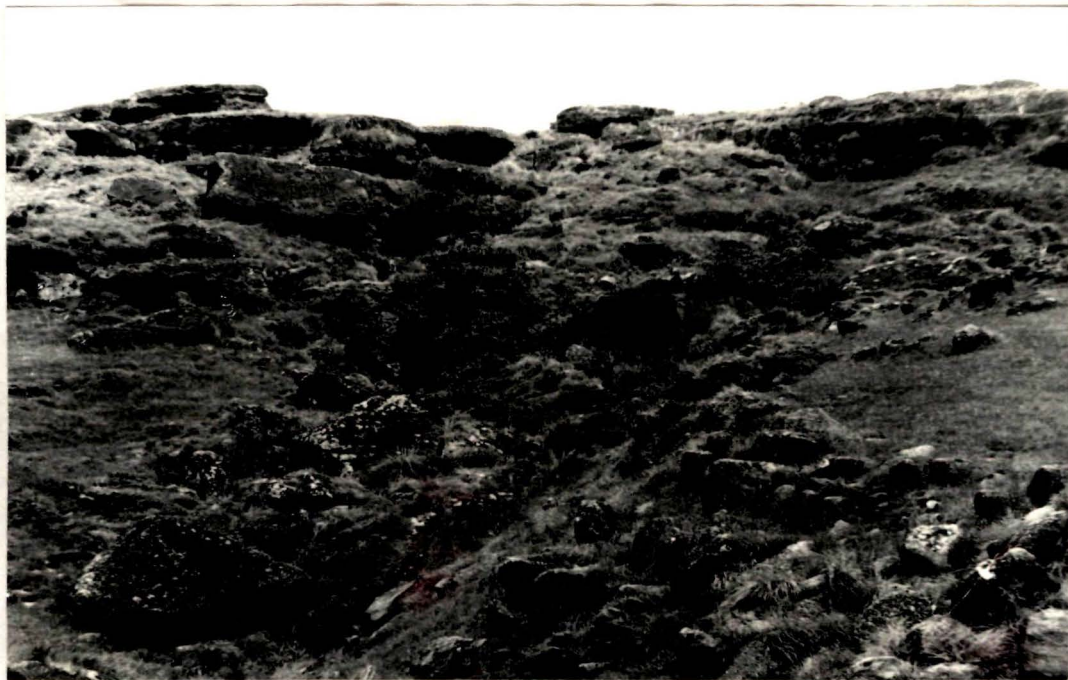
- Tamaskar, B.G. (1958) : The Jabera Basin: Its Geomorphology and Settlements, The Nat. Geog. Spl. No. Dec.
- Taher, M. (1971-72) : Man-Environment Relationship in the Cherrapunjee Region.
- Thornbury, W.D.(1961) : Principles of Geomorphology, John Willey and Sons, New York.
- _____ (1965) : Regional geomorphology of the United States. John Willey and Sons, New York.
- Thornes, J.B. and Brunsden, D. () : Geomorphology and Time, Methuen and Co., Ltd.
- Vaidyanadhan, R.(1964) : Recognition and Correlation of erosion surfaces in the southern part of Cuddapah Basin. Jour. Geol. Soc. India, Vol. 5, pp.121-27.
- _____ (1971) : Studies in Applied Geomorphology. Studies in earth Science, pp.318-21.
- _____, (1971) : Lineaments and their Importance in Landform Studies, Jour. Geog. Soc. India. I, 12 (3), pp.299-302.
- Rao, Ramanna, K.L.V. and Pradhasaradhi, T.J.
- Vats, P.C. and Singh, S. (1976) : Geomorphic influence on settlements : A Quantitative Approach, Deccan Geogs. 14(1), pp.27-33.
- Von Engel, O.D.(1942) : Geomorphology, New York, MacMillan and Co., 655 pp.
- Wadia, D.N.(1953) : Geology of India. MacMillan and Co. Ltd., New York.
- Waters, R.S.(1957) : Differential Weathering and erosion of old lands. Geog. Jour, Vol. 123, pp.503-509.

- Went Worth, C.K.(1930) : A Simplified method of determining the average slope of land surfaces. Am. Jour. Sci. Vol. 20, pp.184-194.
- West, W.D.(1964) and Choubey, V.D. : The Geomorphology of the country around Sagar and Katangi. Jour. Geol. Soc. India, voll. 5
- Woke, R.U. and Doornkamp, J.C. (1974) : Geomorphology in environmental management. An Introduction. Oxford.
- Wood, A. (1942) : Development of hillside slope, Proc. Geol. Asso. Vol. 53, pp.128-40.
- Wooldrige, S.W.(1958) : The trend of Geomorphology, Inst. Brit. Geog., Vol. 25, pp.29-36.
- Worcester, P.G. (1965) : A Text book of Geomorphology. E-W student ed. Affiliated E.W. Press Pvt. Ltd. N. Delhi.
- Young, A. (1963) : Some field observations of slope form and regolith and their relation to slope development. Inst. Brit. Geog., Vol. 32, pp.1-29.
- Zimba, D.T. (1977) : Geography of Meghalaya, Shillong. pp.67.

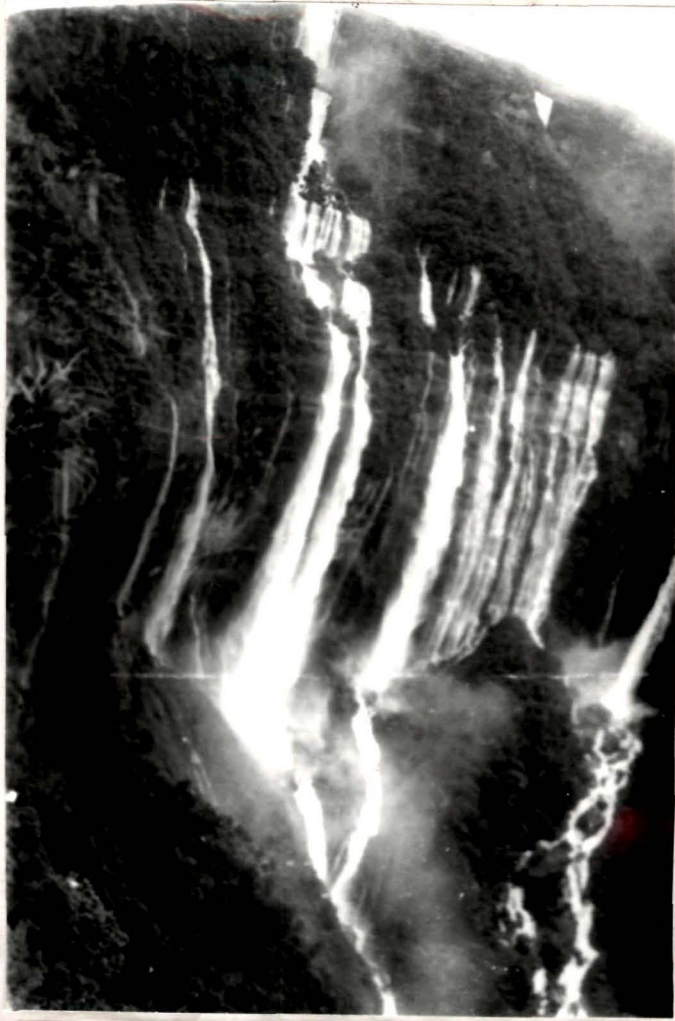
NEHU Library
 Acc. No. 101248
 Acc. by 10/2/86
 Class by _____
 Sub. Heading by _____
 Cata. by _____
 Transcribed by _____



Stratified horizontal sedimentary bed near Cherra Bazar. The upper section shows effects of solution, lower part is frost shattered



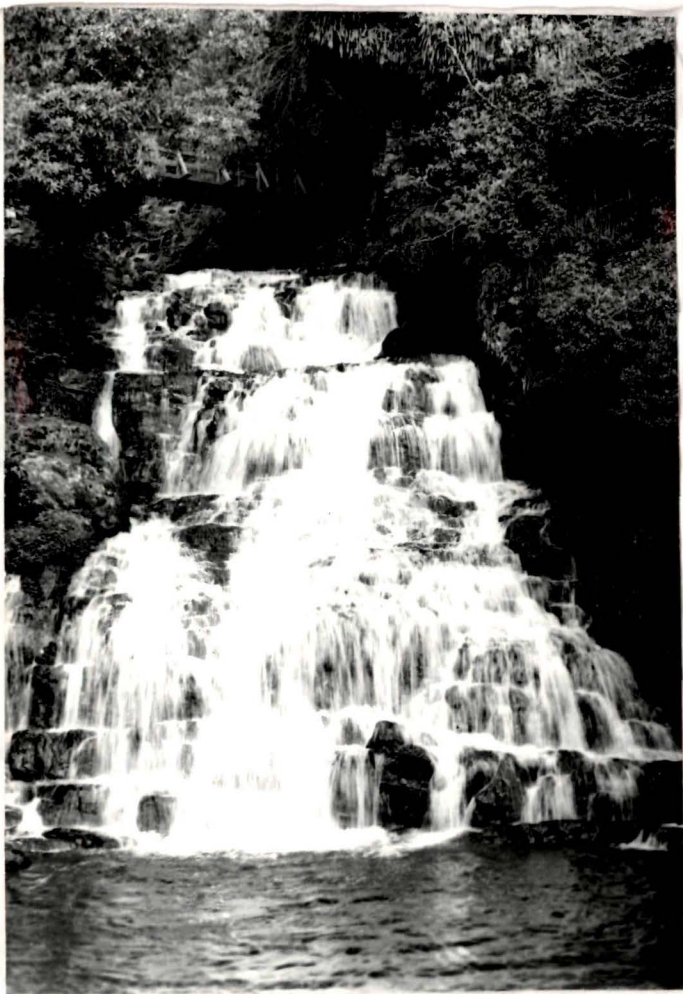
Exposed rocks due to intensive weathering and erosion



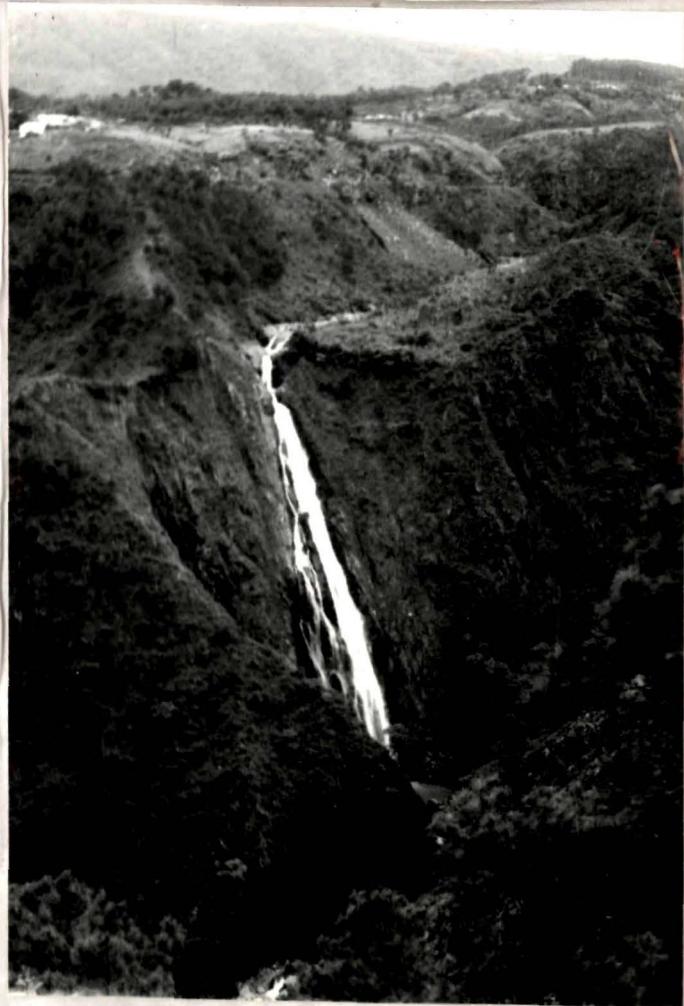
The Magnificent Mawsmai falls,
South of Cherrapunjee (348 mts)



The Yali falls, Garampani
(Jaintia Hills)



The Elephants falls (Upper Shillong)



The Bishop's falls (Shillong)
(121 mts.)



Action of physical weathering. Note the growth of grass along the fracture zone



A typical lime deposit inside Cherrapunjee cave looks like a huge water lily



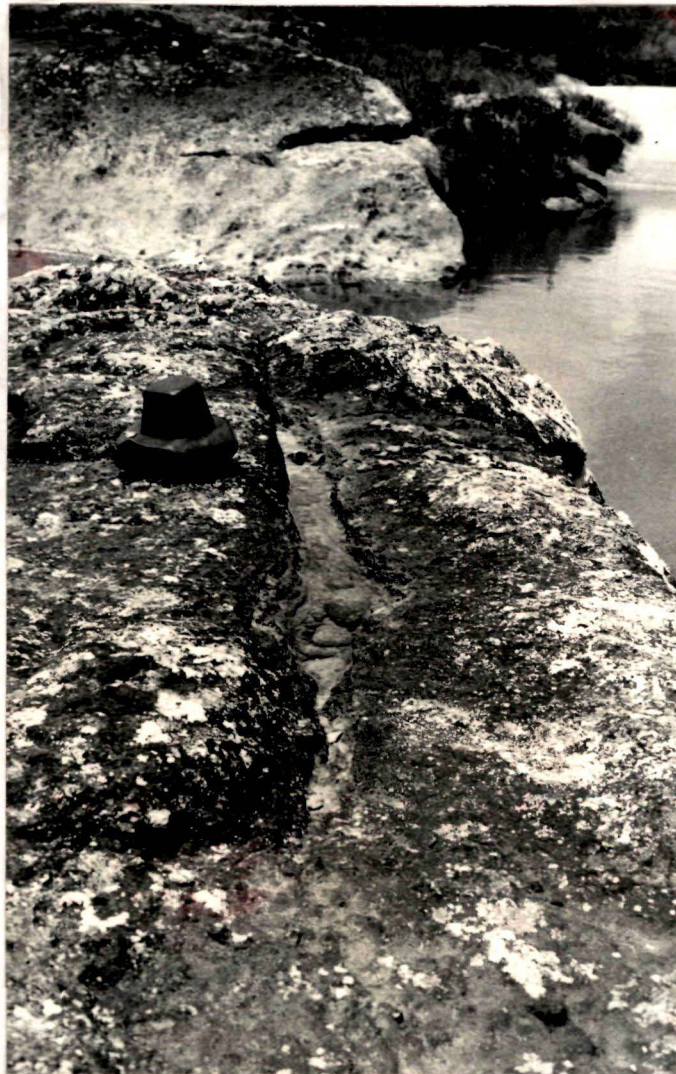
Stalagmite and stalagbite inside
Mawsynram cave



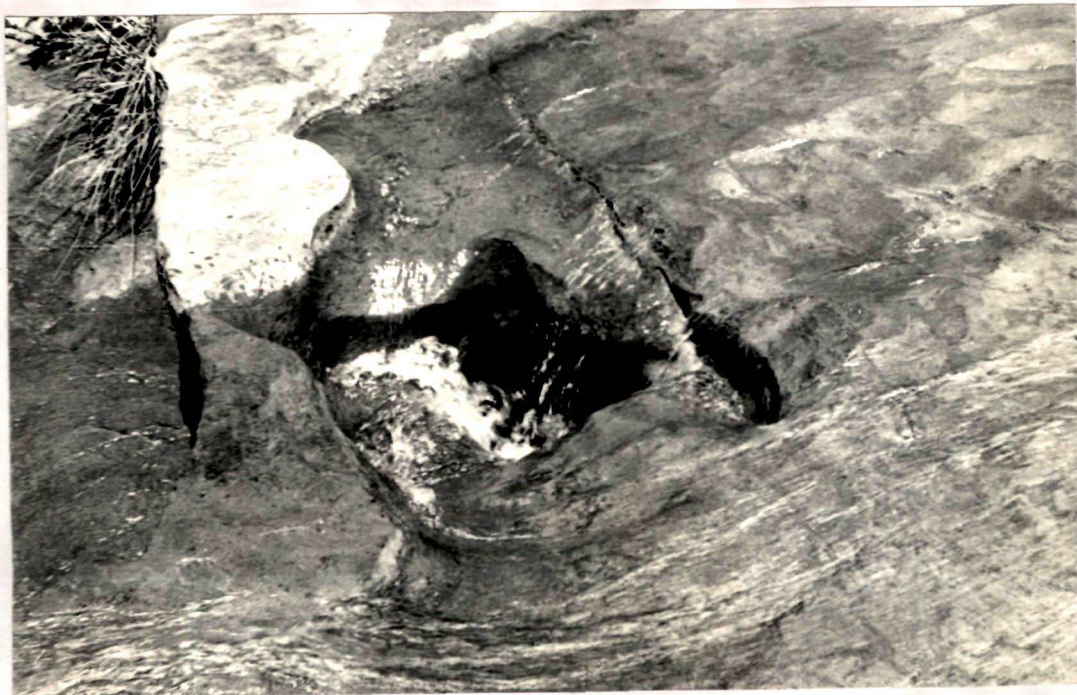
Stalagmite formation inside
Cherrapunjee cave



A product of chemical weathering
in Cherrapunjee area



Chemical weathering along the
joints



Pot hole drilling in carboniferous sandstone



Pot hole erosion of carboniferous sandstone forming the bed of stream Wah Lynkian near Cherrapunjee



Pot hole drilled material seen at the bottom



A pot hole - west of Cherrapunjee



Debris fall along Shillong-Cherra road.
(Photo taken 5 minutes after the fall)



Deformed Debris fall 15 Km. south
of Shillong along Shillong-Cherrapunjee
road



Rock sliding. Note the shape & size
of the rock pieces



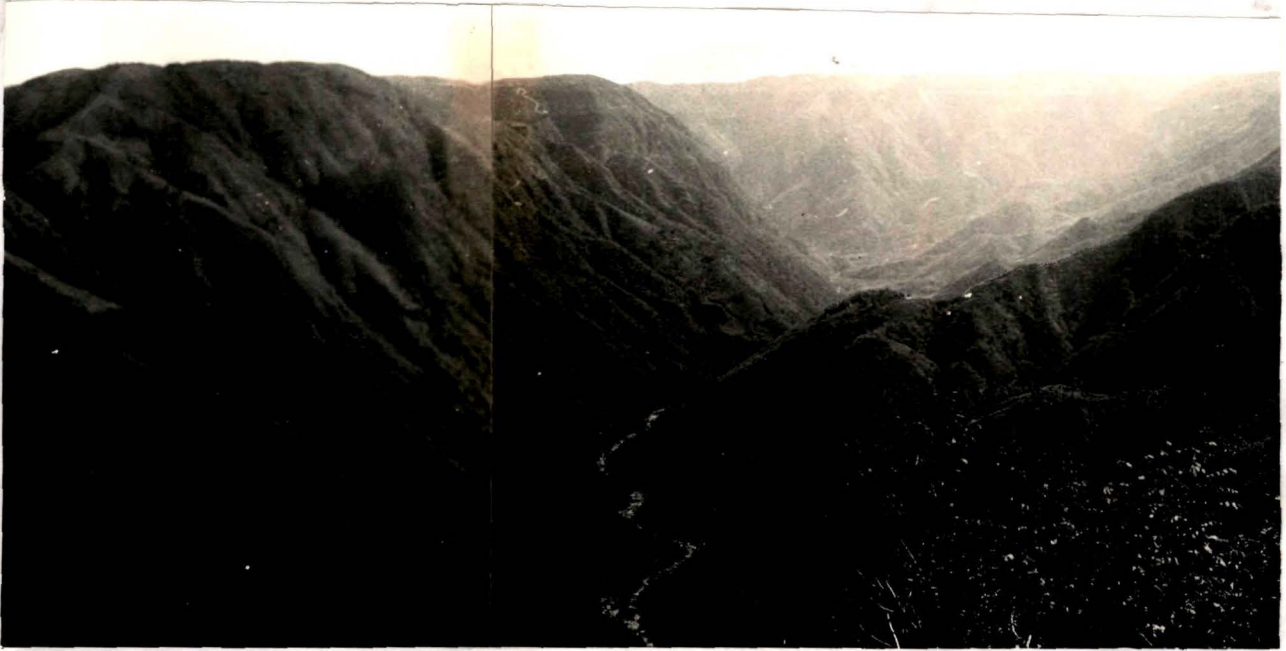
An exposed complex structure



Streams adjustment to structure
(Umsirpi Nala, south of Shillong)



Rill action on steep hill slope
East of Cherrapunjee



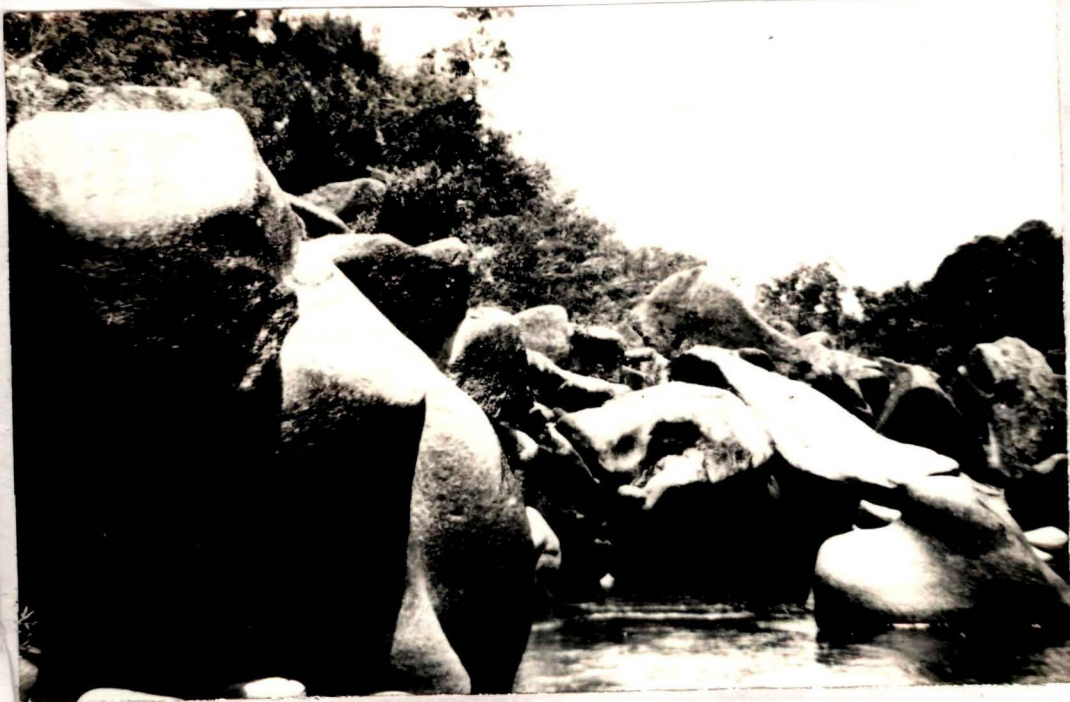
An youthful valley of Umsohryngkiew
river, East of Cherrapunjee



Upper Umiew river valley,
Note the exposed boulders on the
hill slope. Large scale felling of
trees and 'jhumming' is practised
on the slope



Residual boulders produced by
physical weathering



Fluvially eroded boulders on the
Upper Umiam river bed



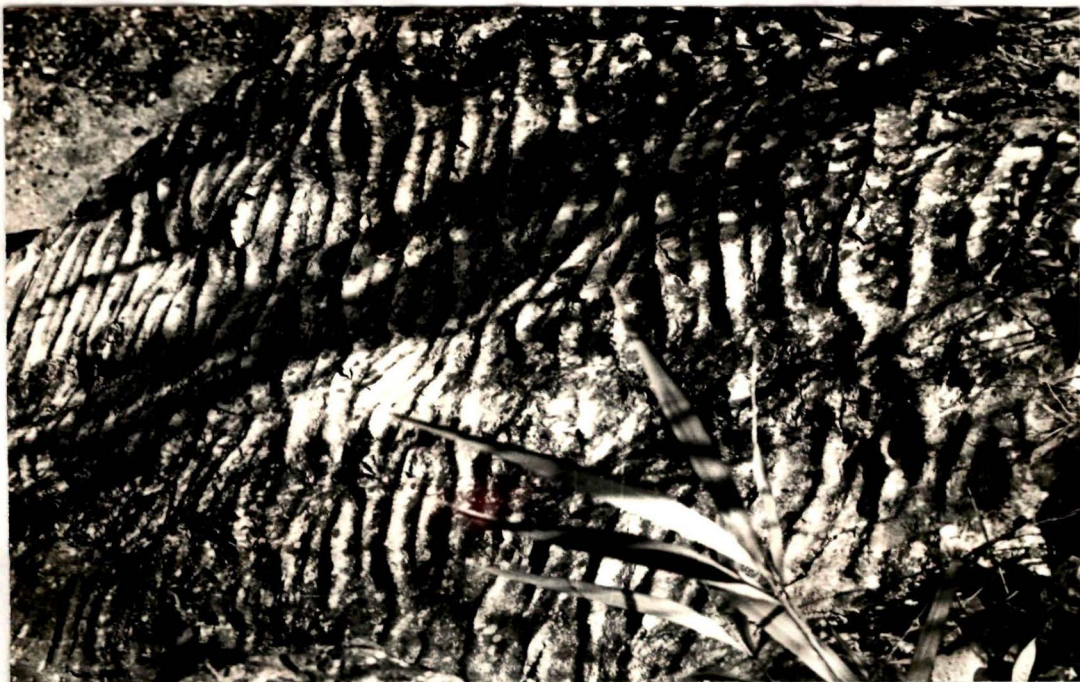
Derangement of boulder along the initial stage of stream bed. Note the square-cut size of the sedimentary rocks.



Wah Lynkian river meandering. In the background - the part which is devoid of vegetation is effected by sheet erosion.



An exposed granite boulder
North-east Khasi hills



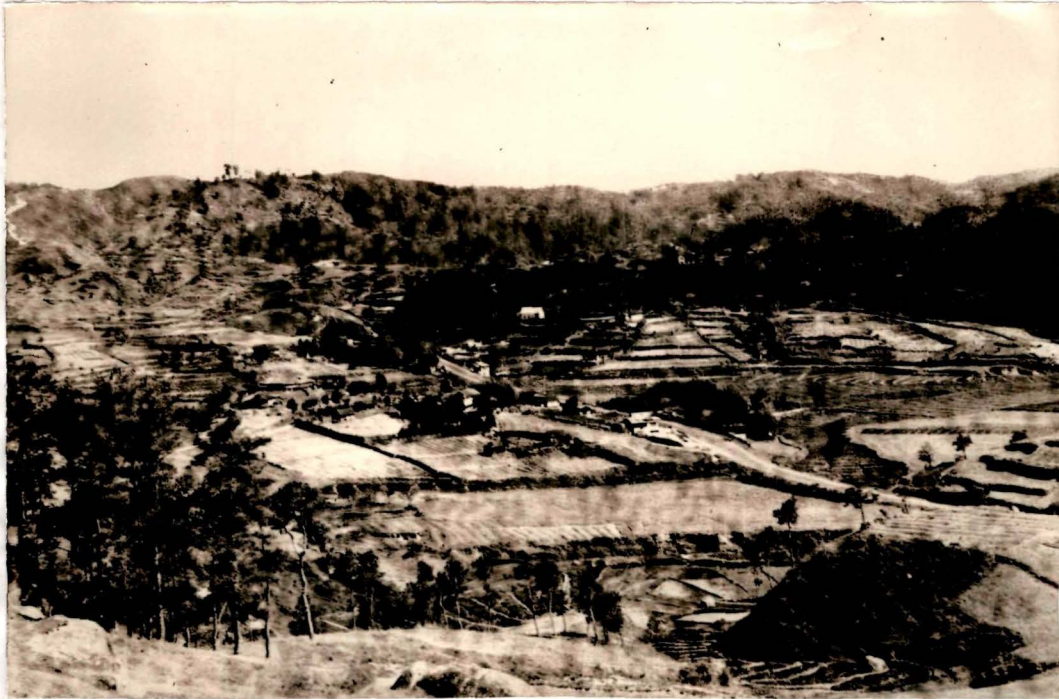
Ripple marks on an exposed boulder



Isolated households near cultivation sites. Umtngar village: Note the location of the house



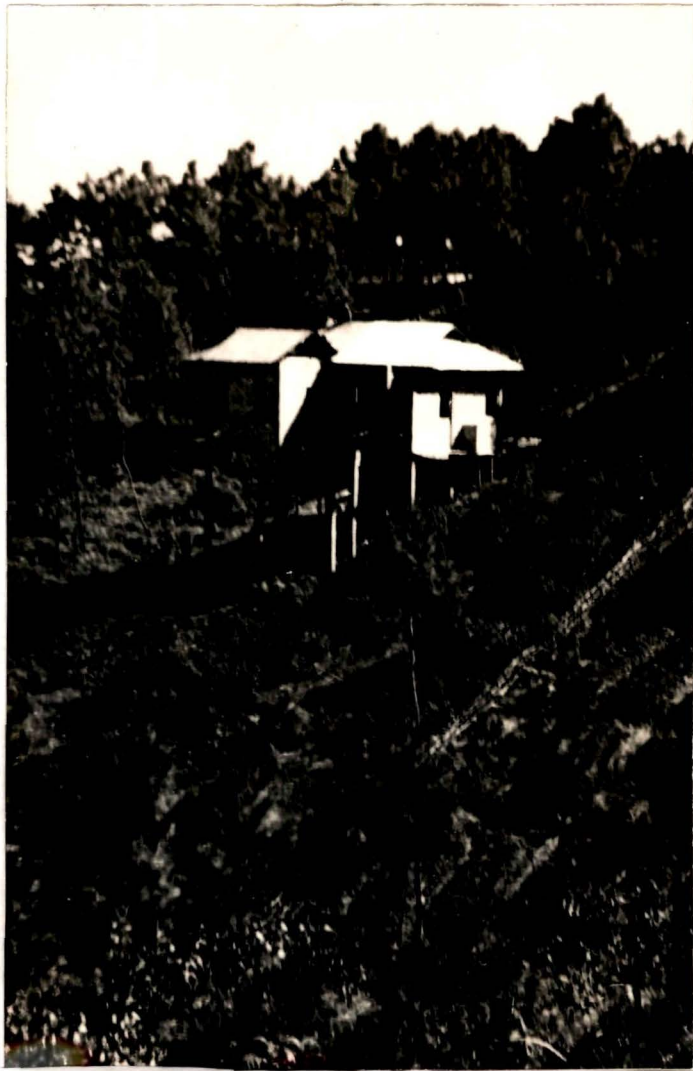
Dispersed clustered settlements near permanent cultivation sites North Khasi Hills



Dispersed clustered settlements
associated with 'jhumming' and
valley cultivation. Around Myllem



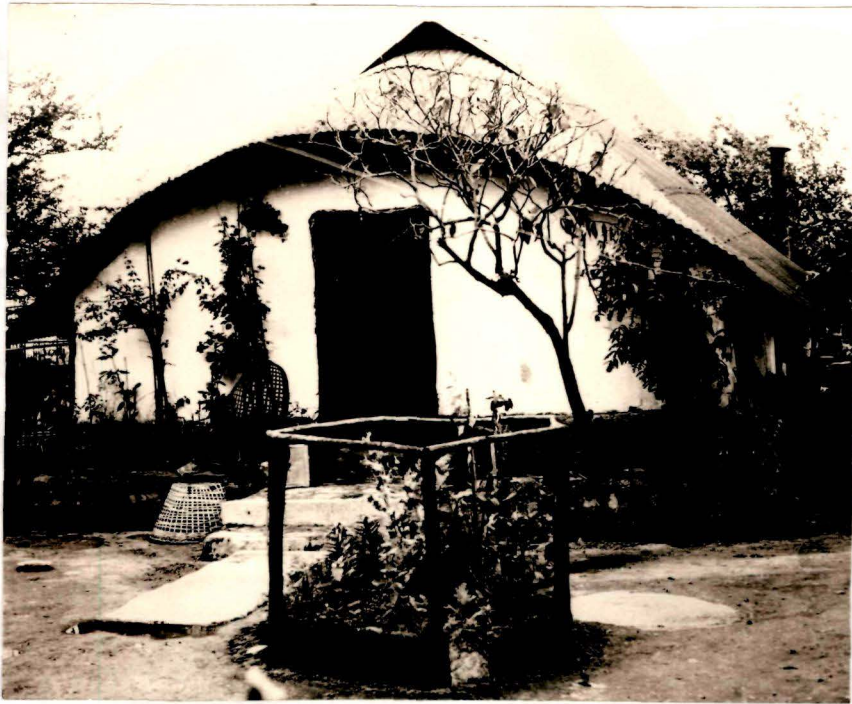
A linear settlement along Shillong-
Cherrapunjee road - Myllem



An isolated hill slope settlement near jhumland. Note the length of the pillars and the steepness of the hill slopes



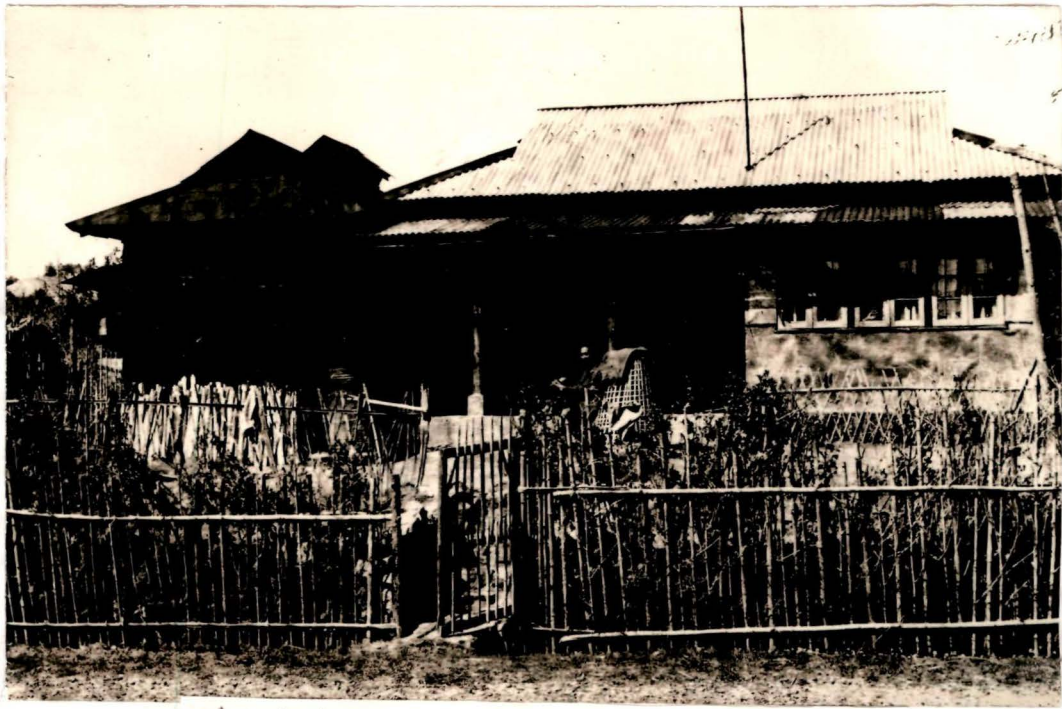
A valley settlement facing the Mawsmai falls, South Khasi Hills. Umschryngkiew river valley



A typical old Khasi house in Laitlyngkot village. Note the shape and building material



A typical Bhoi house in Umroi village (Northern Hills region)
Note the shape and building material



A mixture of old and modern house types in Myllem village. Left - old type, Right - developed Assam type. Note the variation in building material



A hill slope settlement(Assam type) under construction. Note the length of the pillars