

GEOMORPHIC STUDY OF MAWSYNRAM BLOCK,
MEGHALAYA

by

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DEPARTMENT OF GEOGRAPHY
SCHOOL OF ENVIRONMENTAL SCIENCES



Dissertation

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OF THE DEGREE OF
MASTER OF PHILOSOPHY

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28 September, 1984

C E R T I F I C A T E

This is to certify that the dissertation entitled 'Geomorphic Study of Mawsynram Block, Meghalaya', submitted by Mr. Girish Chandra Panda for the partial fulfilment of the degree of Master of Philosophy is a bonafide study to the best of my knowledge. All the quotations, extracts and ideas of other studies have been duly referred.

This dissertation may be sent to the examiners for necessary formalities and evaluation.

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DECLARATION

The material embodied in this dissertation is original and has not been submitted in part or full for any other diploma or degree of any University or Institute. The contents of this dissertation are true to the best of my knowledge and belief.

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INTRODUCTION

"Geomorphology is the study of the Earth surface. But this definition is so vague as to be almost meaningless. Instead it is more practical to see the land surface, and the soils from which landforms can rarely be separated, as part of the total environment. Within a dynamic system of interacting factors, geomorphology is best viewed from a balanced, total perspective and approached with an ecological bias".

KARL W. BUTZER

"Geomorphology from the Earth", 1976

The term 'Geomorphology' etymologically means (the Greek ge, 'earth'; morphos, 'Shape'; and logos, 'reason') the study of the Earth's shape, which has been subject to various interpretations. The status of 'Geomorphology as an autonomous discipline has been controverted, as the disciplines like Geology, Geodesy and Geophysics claim it to be inalienable part of their respective domains. In practice these sciences overlap, so that hard and fast definitions of Geomorphology is neither desirable nor practicable. The ambiguity relates to the various shades of meaning of the term consequent upon the varied definitions given by different scholars from time to time. It is not worthwhile on our part to be

a party to the controversy. It would suffice to say that Geomorphology in its widest sense is that branch of the 'earthsciences' which concerns itself with the development of the surface features of the Earth. In a more restrictive sense geomorphology is the science of those features whose shape is determined by the action of exogenetic processes i.e. of processes which originate outside the solid Earth. It is with this latter concept of geomorphology that we shall concern ourselves.

Geomorphology tells about the shapes of hills and valleys, the degree and frequency of slopes, the development of drainage patterns and the nature of material exposed in all available sections. But the study of geomorphology is not limited to this academic sphere only. In contemporary world it is being increasingly realized that almost in every aspect, an application of geomorphological principles could be rewarding. In the field of engineering geology; measures of soil control; soil science, economic geology; geohydrology; military geology; irrigation and for landuse and landscape planning could be mentioned as avenues which

could be well served and strengthened by geomorphological studies. In an agricultural country like India, the application of geomorphology in the fields of agriculture; horticulture; forest development; transport and communication network; settlement location; and selection of dam sites and aerodromes etc. may be of great significance. It may not be pertinent here to review the history of geomorphology as it has been undertaken by different scholars¹; rather, the main concern here is to examine the current trends of the discipline and get on with our investigation.

The study of this subject, which is concerned primarily with the form of the earth, is little more than one hundred years old. The early works in this field led to a variety of approaches giving rise to the development of several schools of thought. According to C.A.M. King (1966)² there are three major groups;

-
1. See-Thornbury, W.D., (1954, 1969) 'Principle of Geomorphology'. John Wiley and sons, New York.
Chorley, K.J., A.J. Dunn, and R.P. Beckinsale (1964). 'The History of the study of Landforms or the Development of Geomorphology'. Methuen and Co., London.
Fairbridge, R.W., ed. (1968). 'The Encyclopedia of Geomorphology'. Reinhold Publishing Corp., New York.
 2. King, C.A.M., 'Techniques in Geomorphology', Edward Arnold (Pub.) Ltd., 25 Hill Street, London W1X 3LL (1966) pp.7-11.

the first arising out of the work of 'Walter Penck' called as the 'Mobilistic view'; the second gives priority to the effects of climate in studying the characteristics of the landscape; the third is based on the idea of correlation by altitude and therefore, be termed as the 'eustic view'.

Following World War II, researches in geomorphology broke away from the traditional method, and the field of quantitative and dynamic geomorphology made a break through. Under the disciplinary impetus of R.E. Horton (1945)³, the description of drainage basins and 'channel networks' were transformed from a purely qualitative and descriptive study of W.M. Davis (1899)⁴ to a rigorous quantitative science. Horton's work was developed in details by A.N. Strahaler,

3. Horton, R.E. (1945): Erosional Development of streams and Their Drainage Basins. Hydro-physical Approach to quantitative Morphology "Geol. Soc. Am. Bull., Vol. 56, No. 3, pp. 275-370.

4. Davis, W.M. (1899a) 'The geographical Cycle'. Geogr. J. 14: 481-504.
(1899) b) 'The peneplain'. Am. Geol. 23: 207-239.

(1950, 1952, 1956, 1957)⁵ and his associates Melton, (1957)⁶; Morisawa, (1959)⁷ and Schumm, (1956)⁸. The application of the tools of mathematical-statistics to geomorphology became indispensable in making precise measurements and putting forward new hypotheses. But the conclusions drawn from mathematical calculations are not to be over emphasised in relation to data and assumptions upon which they are based. Landform characteristics are influenced by many processes and control factors, some of which are difficult to be analysed in terms of mathematical specifications. The role played by such factors as lithology, stratigraphy, structure; diastrophic history, and

-
5. Strahler, A.N., (1950): 'Equilibrium theory of Erosional slopes Approached by Frequency Distribution analysis' Dynamic basis of Geomorphology", Geol.Soc.Am.Bull.Vol. 63, pp.923-938.
(1956): 'quantitative slope analysis', Bull.Geol. Soc. Amer., Vol.67, pp.571-96.
(1957): 'quantitative Analysis of watershed Geomorphology", Am.Geog,Union., Transactions, Vol.38, pp.913-920.
 6. Melton, M.A., (1957): 'An analysis of the relations among elements of climate, surface properties, and geomorphology". Columbia Univ.Dept.of Geol., Tech.Rept.11, pp.1-102.
 7. Morisawa, M., (1959): 'Relation of quantitative geomorphology of stream flow in representative watersheds of the Appalachian plateau province", columb.Univ. Tech. Rep.No. 20.
 8. Schumm, S.A., (1956) 'Evolution & drainage systems and slopes in bedlands at Perth Amboy, "New Jersey. Bull. Geol.Soc.Am.67, 597-646.

climatic variations in the development of landforms can not be ignored. All of these relevant factors must be examined, and their impact on land features and processes must be analysed in order to understand the genesis of landform evolution.

The modern trend of geomorphology is not only towards a quantitative approach but also towards the studies of topographic forms. With availability of good quality of topographical maps and by the help of aerial photographs and landsatt imageries, precise mapping of observed and measured values is now possible. This has led to the progress of the study of landscape geometry or morphometry with the help of techniques based on hydrology (Horton) and hypsometric integral (Strahler). The broad categorizing of landform types and their assemblages in morphological mapping has been advanced by the Polish Academy of Sciences, the British Geomorphologic Research Group, Dylik(1953)⁹ (1961)¹⁰ Peltier (1950),¹¹ Tricart and Coillux

9. Dylik, J. (1953): 'Characters du developement de la geomorphologic Moderne', Bull. Soc. Sci., Letters Ldz. vol. 4, No. 1, pp. 1-40.

10. Budel, J. (1961): Morphogenese des Fest lands in Abhangigkeit V vol den Klimazoner", Naturmissetu Chaften, vol. 48.

11. Peltier, L.C., (1962): 'Area sampling for Terrain Analysis", Prof. Geog., vol. 15, pp-24-28.

12
(1954), Birot (1960), Hammond (1964)¹³ and Savigear
(1965)¹⁴.

The growth this science in India is rather recent and the whole credit of carving the ways for this branch of science goes to the geologists. Amongst the Geologists whose contributions are immensely valuable, mention may be made of A.M. Heron, D.N.Wadia, J.A.Dunn, W.D.West, S.C.Chattarjee, J.B.Aude, Arogyaswamy and Radhakrishna. At the early stage initiative was also taken by geographers like H.L.Chibber, S.P.Chatterjæ, S.C.Bose, R.P.Singh, E.Ahmad and K.Bagchi.

Geomorphological studies in India received new impetus with the works of young geologists and geographers since 1950. The scope of their geomorphological studies is now becoming wider. There is now emphasis on various aspects of geomorphology, from regional to coastal, fluvial, structural, climatic and applied

-
12. Tricart, J. and Cailleux, A., (1954) 'Le modele des chaines Pliss'ees. G.D.V.
 13. Birot, P., (1960) 'Le cycle d'erosion sous les differents climats". Curso de ates estudos geogr., lai de Janiero, Brazil.
 14. Hammond, E.H., (1964), 'Analysis of properties of Landform mapping", An.Am.Ass.Geog.Vol.54, pp.11-19.
 15. Savigear, R.A.G., (1965): 'A Technique of morphological mapping", An.Am.Geog., vol.55.p.514.
 16. See-Chatterjee, S.P.(1968:progress of Geomorphy in India,(Ind.Sc.cony.Ass; Calcutta.
Subramanyan, V(1967), Proceedings, seminar on Geom.Studies in India, Saugar Univ.
Vaidyanadhan, R.(1977):Recent Advances in Geomorphic studies of penninsular India:A Review, Ind.J.Earth Sc. (S.Roy Vol.)pp.13-35.

geomorphology. But most of the works have been done in the field of regional geomorphology with an emphasis to establish the denudation chronology of region and recognition of erosion surfaces, (R.P.Singh, 1956; E.Ahmed, 1958; Bagchi & Sengupta, 1958; R.K.Rai, 1969; Biswas, 1974; Vaidyanadhan, 1964,1971). The recent emphasis is on quantitative geomorphology of drainage basins by applying various morphometric techniques and measure to establish the interrelation of basin parameters. ¹⁷ Few recent studies related to channel characteristics, rills, and gullies, meanders, floods, slope profiles and characteristics in the field of fluvial geomorphology and slope analysis are encouraging. ¹⁸ Application of morphometric techniques in classification of landforms into morphological units of various order has been initiated by R.L.Singh (1976). Recent researchs in regional geomorphology incorporate the study of the

17. See: Singh & Kumar (1969), Pal (1972,73); Bhattacharya (1973), Kumar & Pandey (1975,77); Pandmaja (1975); Mukhopadhyay (1974), Sen (1977) Bagchi (1967); Singh & Srivastava (1975) Kumar (1975).

18. See: Singh (1958, 60 & 63), Ahmad (1958, 65); Bagchi & Sengupta (1958); Chibber (1953), Chatterjee (1940), Bose (1940), Satpathi (1970) Kumar (1968); Pathak (1968), N.P. Singh (1972) G.N. Singh (1977) Evan's (1970) Vaidyanadhan & R. Rao (1972) Munshi and Day (1965).

processes modifying the landscape.

Thus, Geomorphology can now be visualised as a landform-process - science and the main thrust of this micro-regional study is to elucidate this theme in the context of Geomorphic study of Mawsynram Block, East Khasi Hills district of Meghalaya.

Broad objectives of the study:

The present work, covering the south-western section of East Khasi Hills district of Meghalaya, is an exercise in regional geomorphology. The study explains the landform assemblage, their origin and classification. The area of study poses varied and complex problems associated with landform and landscape, and their explanation requires careful consideration of structural, historical, process and form approaches of geomorphological studies. The analytical treatment of the problems is based on both theoretical and observational methods of study. An attempt is made to evolve a rational approach by utilizing quantitative data as and when necessary to derive qualitative conclusions.

Choice of Region.

For an intensive micro-level geomorphological study a Block can be considered a feasible unit. It is being realised that a unit bigger than a Block will be too large for a meaningful study, as any planning for a region now-a-days involves a synthesis of knowledge concerning the geomorphology, lithology and geologic structure of that region. Many of the factors that determine the choice of a site for an industry, highways, railways, an air field; settlements, dam sites and agricultural landuse are largely influenced by geomorphic characteristics of the area concerned.

The Block, selected for present study, though an administrative unit, interestingly, more or less coincides with geological and physical features and possesses unique geomorphological characteristics. Besides this, it can safely be said that no intensive geomorphic study of this region has so far been done. Again this region is the world's Wettest with about 12000 mm. of rainfall annually, which results in the formation of strong fluviially dominated landforms.

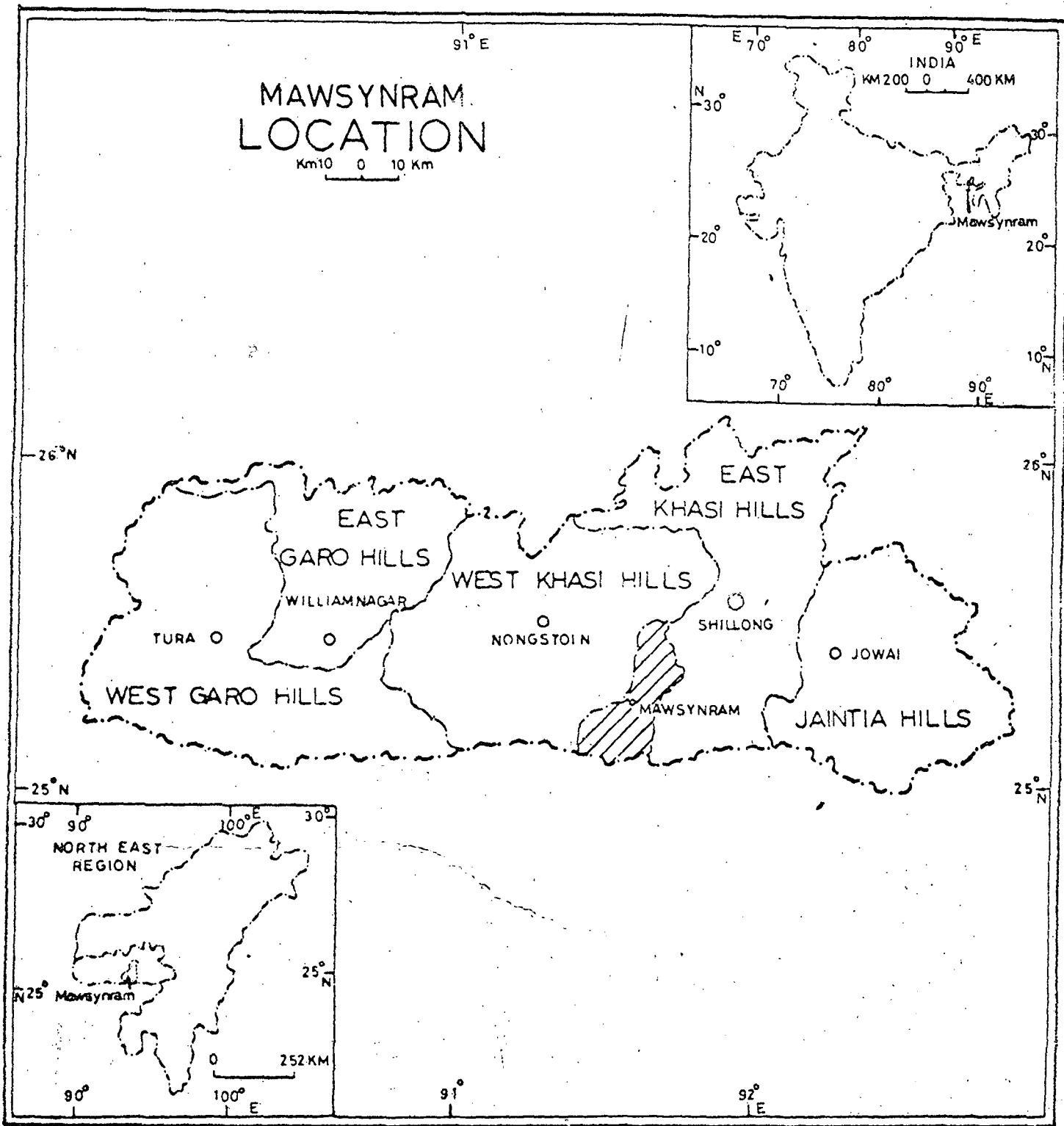


fig.1

Thus, keeping in mind the above mentioned characteristics of the region, the Mawsynram Block area has been selected for present micro-level geomorphic study.

Location:

Mawsynram Block area lies between $24^{\circ}57'$ N to $25^{\circ}27'$ N latitudes and $91^{\circ}26'$ E to $91^{\circ}43'$ E longitudes, which covers a territorial extension of 175.5 sq.mile, and forms a part of the southern hill region in East Khasi Hills district of Meghalaya (Fig.1).

The region is demarcated by Mairang Block and Umnagi River valley in North and West respectively, and in the East this region is separated from the Cherrapunjee platform by the Bagra of Umiew River valley and by Bangladesh plains to the south.

Salient features of the region:

The general slope of the study region is to the south ward direction into Bangladesh plains. Small areas lying between different contours (Fig.2), present a variety of morphogenetic features. On the eastern side it gradually slopes down to the valley of river Umiew or Bagra. Again in the western part, it gradually slopes

MAWSYNRAM
CONTOURS
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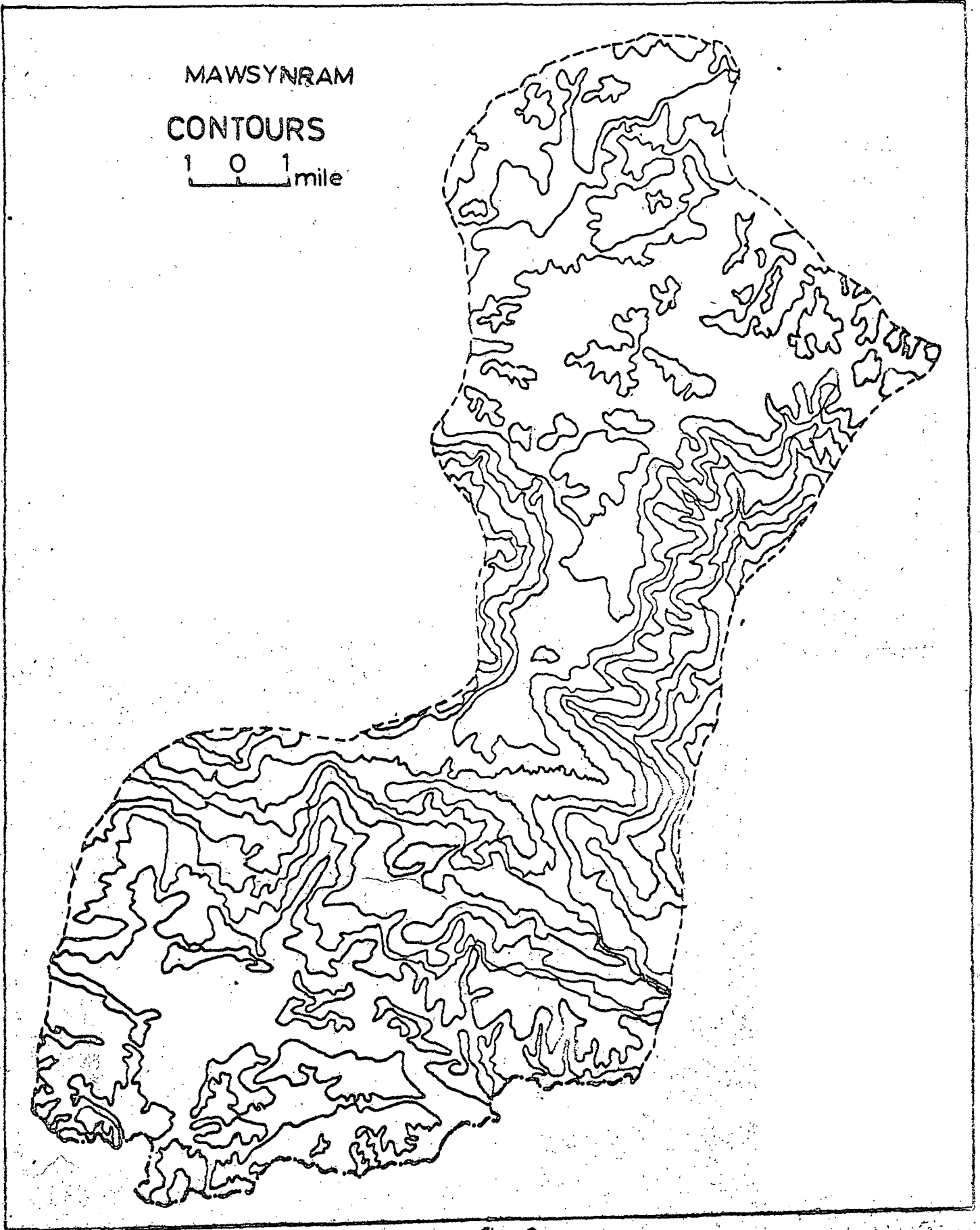


fig-2

down to valley of the river Umnagi and in the north it ascends gently towards the Shillong upland. Continuous weathering processes on the erosional scarps have led to the formation of Mawsynram structural platforms (1305 m). Its southern part is marked with a sudden lowering of the plateau surface to 3000 feet and it further gradually reduces up to a height of 150 feet near the Bangladesh plains. This southern margin of the lower plateau is a dissected hilly country with host of microlandforms, viz. gorges, escarpments, spurs, divided rolling uplands, low sand-hills and many swampy tracks of land. The area can, thus, be divided into two broad topographical units.

- (i) The Northern and central Plateau Region, and
- (ii) The southern dissected Terrain.

(i) The Northern and Central Plateau Region:

This plateau with surfaces higher than 4500 feet, represents the southern section of the Shillong plateau. Its graduated slope increases towards the northern part of the area under study. On the further south lies a vast structural platform on which stands Mawsynram village (1305 m.). This part of the central plateau is built up



of gently dipping sandstones of the Upper-Cretaceous Age, and over its edge are found many small water falls. Numerous residual hills of the Archaean and Eocene period are found scattered over the Mawsynram plateau. The most important among them are Mosingi (5800 feet), Symper (5827 feet) and Lumkyrphel (5892 feet). Some of them contain small limestone covers with narrow underground passages and characteristic cage deposits.

(ii) The Southern Dissected Terrain:

The southern dissected Terrain follows the southern scarp face of the Mawsynram structural platform (3000 feet) and extends towards the Bangladesh plains in south (150 feet). In fact, in this region the most striking feature is the abrupt fall in the elevation. The entire area is composed of Upper Cretaceous, Jurassic, Eocene, Oligo-miocene, Mio-pliocene and Recent sedimentary hills. The dissection has resulted in the formation of narrow hills and valleys. The streams such as the Umsaitkha, the Umkatang and the Umnokria have cut deep valleys through the Cretaceous (chalky) sand-stones and lime stones. In many places over its bed, older rocks like the gneiss and schists have been exposed.

Thus, the Mawsynram region presents a variety of landscapes characterized by scarps, rugged topography, long deep river valleys, water-falls and numerous rapids, residual hills (Monadnocks, firs etc.) gullies and other features like elongated ridges and many hill spurs projecting from higher tableland.

Earlier investigations:

As in the present work it is contemplated to study regional geomorphology, a brief review of researches done in this field is called for, particularly of those concerned with the Meghalaya plateau of the country.

The first ever work done on geomorphic aspects of this region is by S.P.Chattarjee in (1941)¹⁹. R.P.Singh (1968)²⁰ has presented the Geomorphology of Shillong plateau, Assam. N.C. Baruah (1968)²¹ threw light on the

19. Chattarjee, S.P., (1941); 'The Meghalaya Plateau'.

20. Singh, R.P., (1968): 'Geomorphology of Shillong Plateau of Assam', Proc. pre. Cong. Symp. IGU, Gauhati, pp. 1-9.

21. Baruah, N.C. (1968): 'Geomorphology of Barapani area in Meghalaya Plateau, Proc. Pre-cong: Symp. IGU, Gauhati, pp. 25-32.

'geomorphology of Barapani Area in Meghalaya Plateau. M.V.N. Murthy(1968)²² has presented one paper titled 'An outline Geomorphology Evolution of the Assam region' and attempts to trace the geomorphological evolution of the Assam Region including Meghalaya plateau since Archaean to recent time.

Some of the recent study have been undertaken by scholars such as M.Taher (1971-72)²³ on 'Man-Environment Relationship in the Cherapunjee Region;' S.N.Pattnaik (1979)²⁴ has discussed the general geomorphic characteristics of Meghalaya plateu and also analysed its influences on agricultural landuse. Rai et.al (1980)²⁵ in paper titled 'Hill slope and landuse around Shillong' has studied the nature and characteristics of different hills slope elements and their landuse pattern.Again

22.Murthy M.V.N.(1968) 'An outline of Geomorphological Evolution of the Assam Region, Proc.Pre.Cong.,Symp. (GU.Gauhati, pp.25-32).

23.Taher, M.(1971-72)'Man Environment relationship in the Cherrapunji Region".

24.Pattnaik,S.N.(1979). 'Geomorphology and Agriculture in Shillong plateau, Meghalaya'. Unpublished M.Phil. Dissertation, Department of Geography,NEHU,Shillong.

25.Rai et.al(1980)'Hill slopes landuse and soil Erosion around Shillong(Meghalaya),Seminar paper presented in NAGI, Chandigarh, India.

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Rai (1980) discussed the Morphometric analysis of Umran Basin of Meghalaya, and studied the geomorphology and rural settlements. In the next year (1981)²⁷ Panda and Rai have also presented one paper entitled 'Influence of landforms on location and distribution of rural settlements in Khasi and Jaintia Hills'. P. Panda (1983)²⁸ has also made a significant contribution in the field of Applied Geomorphology through his study of the 'Geomorphology and Rural settlements in Khasi and Jaintia hills, Meghalaya'. He has pointed out the location, housing structure and the distribution of rural settlements of the region have emerged under clear influence of the regional processes of landforms and their characteristic manifestations. Apart from these works the region still awaits unveiling of its morphological characters, particularly in micro-regional level.

Source of Materials and methods of Geomorphological

Analysis:

The proposed geomorphological study consists of four aspects.

-
26. Rai, R.K., (1980): 'Morphometric analysis of Umran Basin of Meghalaya', accepted for pub. in National Geographer.
 27. Panda, P.C. and Rai, R.K. (1981), 'influence of Landforms on location and distribution of rural settlements in Khasi and Jaintia Hills, Meghalaya'; National Geographer Vol. 40, No. 4.
 28. Panda, P.C. (1983). Geomorphology and Rural settlements in Khasi and Jaintia Hills, Meghalaya'. Unpublished PhD Dissertation, Deptt. of Geography, NEHU, Shillong.

(i) The collection and study of all relevant informations pertaining to the subject:

Topographical maps on one inch to a mile scale, No 78 0/7, 78 0/8, 78 0/11, 78 0/12 provided the basic information about the area under study. The amount, degree and intensity of slope, relief and dissection have been calculated from these toposheets. The literature available in this connection has been collected from both geology and Geomorphology. Various data regarding the rainfall and temperature have been collected from the meteorological data recording centre Mawsynram, and informations about soils and geology were collected from the source like ICAR Research complex for NEH Region, Shillong and Geological survey of India Shillong.

(ii) Field investigation:

Field work is an essential tool of geomorphological analysis. Various features of landforms and character of surface, not shown in map have been noted during field work of the study region. Informations concerning structure, rocks, soils, river beds, caves, meandering, vegetation, slope etc. have been noted for proper discussion and Analysis. Photographs and measurement have also been taken into consideration to express some of the significant aspects of its landscape.

(iii) Preparation of maps and diagrams:

This has been based on the various data extracted from one inch toposheets to be used for drawing maps to show slope, relative relief, intensity of slope, texture of drainage and landforms region maps. Isopleths have been employed to show texture and dissection index in maps. Apart from this many diagrams of long profiles, crossed valley sections, superimposed profiles, Hypsometric curve, and Altimetric graph etc. are prepared to help in visualizing the nature of landscape. The preparation further included the construction of slope profiles, and the data for the same have been collected through field observation and measurements.

(iv) Finally the Analysis of data and materials collected from field study and maps have been made. Various morphometric techniques are extensively applied on a micro-regional level to explain the evolution and characteristics of landscape. Besides this some of the statistical methods like correlation, significance test, regression analysis, linear and non-linear equations, scale ration, along with frequency graph have been used to arrive at fairly accurate results in landscape analysis. Such methods and techniques led not only to an ordered, systematic and

scientific portrayal of varied topographic expressions, but have also facilitated an understanding of the landforms (Singh, 1966).²⁹

Plan of work:

The scheme of micro-regional geomorphological work under study has been covered the following chapters:

The first chapter deals with the geology, tectonic and structural characteristics of rock formations. In first few pages, a brief geological account of the Shillong plateau has been given followed by a detailed discussion on Geology, tectonic and structure of the area under study. The important rocks are the gneisses complex, sylhet-Trap, Arkose (Glaucinite), Jainta Group, Garo Group, Dupi-Tila Group and Recent formations. The structural characteristics and tectonic events are no less significant than the lithology of the formations. The study area was particularly marked by tectonic disturbances especially during the precambrian times and during the Jurassic, Tertiary and later periods.

The second chapter examines the weathering and soil formations. In this chapter, factors which influence weathering and the intensity and impact of

29. Singh R.P.(1966):Geomorphological mapping in Applied Geography,proc.of the summer School, Dept.of Geog., B.H.U., P.261.

weathering on different parts of the study area have been discussed. An attempt has been also made to identify the different weathering zones of the area under study and some basic ideas about the nature and type of soils found on it, have also been discussed.

Then we enter into the manifold of geomorphology in the third chapter on 'Drainage and its Evolution', we have examined drainage systems of the study region from all the latest points of view and techniques giving particular emphasis to the quantitative aspects and their cartographic representation. In making an analysis of the rivers and valleys of the study region, an attempt has been made to explore the causes of the streams in their present courses and during geological past too.

The next chapter is on 'Morphometric Analysis of the six small drainage basins and their Geomorphic significance'. In this chapter the systematic description of the drainage basins geometry and their channel network have been discussed. Here too all the important morphometric techniques and quantitative methods have been employed.

The fifth chapter deals with slopes . The study of slopes has been recognised as an integral part of any geomorphological study. This study includes slope profile recognition of slope regions and their association with structure, process, and relief. Particular attention is given to a systematic treatment of these important aspects, due emphasis is placed on some practical applications of slope studies.

Finally an attempt has been made to classify the landform regions of study area on genetic basis. The select criteria used in defining the units were chosen from the fundamental and permanent characteristics of the landscape. In fact, this part contains the essence of the whole investigation, which is not only an integration of the geology, weathering, morphometric, slope and climatic backgrounds of the area, but also the development of geomorphic frame work on the basis of which the future investigations and planning can be undertaken.

CHAPTER - I

GEOLOGY, TECTONIC AND STRUCTURAL CHARACTERISTIC
OF ROCKS.

"The geologist examines the past for its own sake, inasmuch as geology is concerned with the history of the earth; the geographer examines the past only in so far as it illumines the present".

W.M.Davis
"Geographical Essays", 1909 p.253

Introduction:

The making of Mawsynram structural Platforms is linked up with the structural evolution of the Shillong plateau. So before going to discuss about the Geology, tectonic and structure of the area under study, it is very much essential to give a brief geological account of the Shillong Plateau.

The Shillong plateau is mainly constituted by the rocks of the pre-cambrian age acutely folded and steeply dipping with an over-turned fringe of Mesozoic and Tertiary Sediments¹. It is regarded as geologically part of the Indian peninsula, cut off there from by the intervening spread of the Ganges and the Brahmaputra

1. Stratigraphical position of the cherra sandstone, Assam, The Records of the Geological survey of India, Vol.IXXV.
Personal paper No-4, (1940), p.7.

alluvium. Its landscape evolution is closely linked with the Indian Peninsula. Its chronology seems to have similar sequence records as that of the Chotonagpur plateau including Rajmahal Highlands. A further resemblance is seen in the marine transgression which affected the southern shores of the plateau in cretaceous times and has left deposits, much of which lie undisturbed upon the older rocks, as do similar deposits, along the coromandel coast of the Peninsula.²

The plateau contains the ancient (Pre-cambrian) peneplaned surface, with marks of different cycles of denudation, in the central and northern part, it is hidden beneath the Mesozoic traps along the central southern fringe and Cretaceous Tertiary and Post-tertiary sediments over the Southern, South-eastern and south-western parts. The plateau also standing as a watershed between the surma valley of Bangladesh on the south and the Brahmaputra valley on the north.

2. SPATEO.H.K,(1967), India and Pakistan(3rd ed.) Methuen and Co.Ltd.pp.15.

Geological Investigation:

The first geological study on the region was made by T. Oldham (1859)³. The systematic geological mapping of the region was subsequently carried out in detail by H.B. Medlicott (1869)⁴, Godwin Austin (1869)⁵, La Tonche (1883, 1889)⁶ and F.R. Mallet (1875)⁷. Their accounts helped considerably in continuation of systematic mapping of different parts of the region by later workers viz. R.W. Palmer (1923)⁸; C.S. Fox (1936-38)⁹;

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3. Oldham, T., (1859) 'On Geological structure of a part of Khasi Hills". Mem.G.S.I. Vol. I, pp.99-210.
 4. Medlicott, H.B., (1869): 'Geological sketch of the Shillong Plateau", Mem.G.S.I. Vol.7, Pt. I, pp.151-207.
 5. Godwin Austin, H.H., (1869); 'Notes to accompany a Geological Map of a Portion of the Khasi Hills", Journ, A.S.B. Vol.38, Pt.2. 1869.
 6. La Touch, T.H.D. (1883): 'Cretaceous Coal measures in the Khasia - Hills", Rec.G.S.I. Vol.16, P.164-165. (1839): On Cherrapunji coalfield, Rec.G.S.I. Vol.20 pp.167-171.
 7. Mallet, F.R. (1875): 'Note on Coals Recently found near Moflang, Khasia Hills". Rec.G.S.I. Vol.8, Pt.3.
 8. Palmer, R.V., (1923): Geology of a part of the Khasi and Jaintia Hills. Rec.G.S.I. Vol.55, pt.2, pp.143-187.
 9. Fox, C.S., (1936-38): General Report, G.S.I. in Rec.G.S.I. Vol.69, Pt. I, pp.82-84, Vol.71, Pt. I, pp.81-86, Vol.72, Pt.1 pp.85-90, Vol.73, Pt. I, pp.75-80; Vol.74, pt.1., pp.55-63.

V.R.Khedkar and P.N.Mukherji (1938-39)¹⁰ and A.M.N. Ghosh (1936-39)¹¹, which led to the establishment of the stratigraphic sequence of different rock suits of the region.

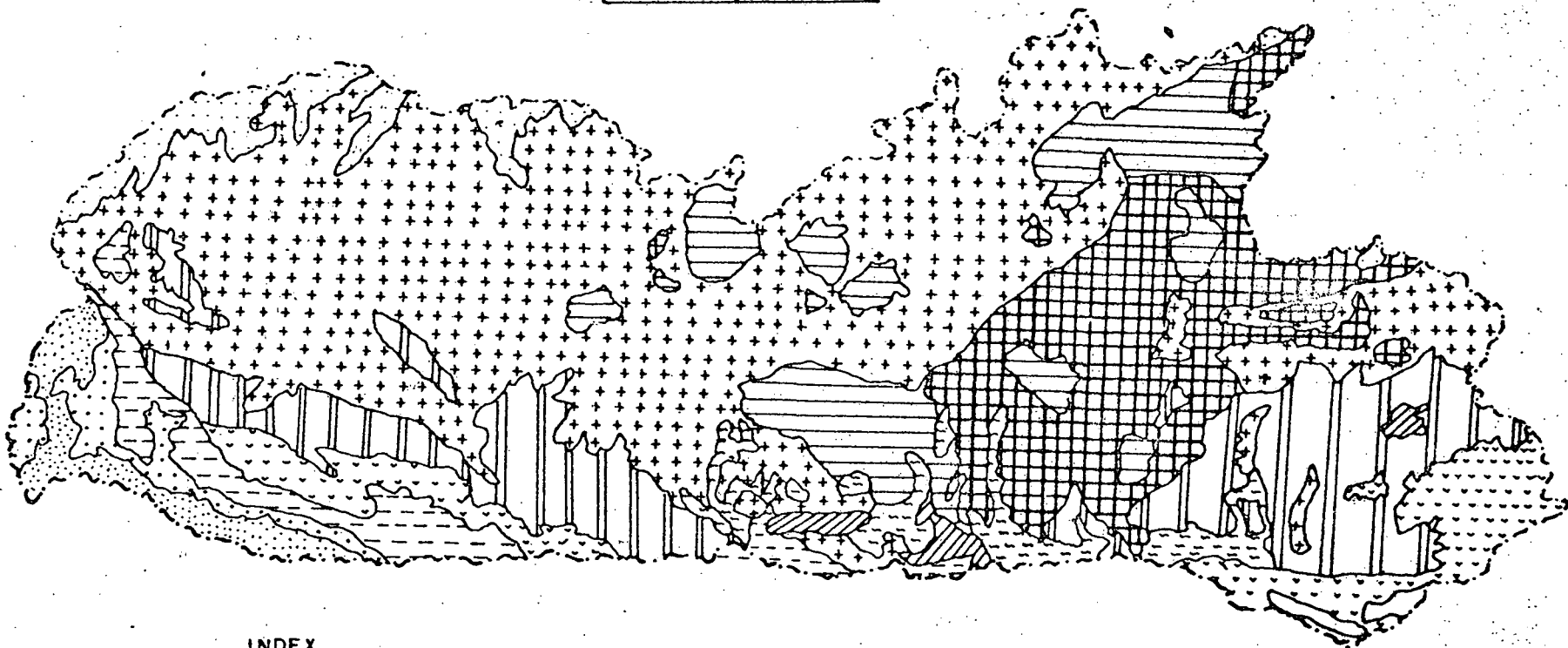
The self sediments over the southern part of the plateau have been systematically mapped by A.C.Goswami, M.K.Das, S.C.Talukdar, A.C.Bhattacharya, G.Barman, B.K. Duaran, C.Chakravarti, B.D.Adhikari, K.K.Sen and S.K. Srivastava during the field seasons from 1961-62 to 1972-73.¹² Their work led to the delineation of different litho-stratigraphic units of the Tertiary self Sediments (as given in the table - I(1) and their sedimentological history. The recent investigations along the southern Khasi Hills (Talukdar 1966-67) and 67-68¹³ Threw new light on the sylhet trap volcanism and on the composition and type of the lava flows.

The whole of Meghalaya is occupied, if one looks at the given Map (Fig.-3) by the following rock groups

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10. Khedkar, V.R.; (1938-39) and Mukherji, P.N., (1938-39) Unpublished progress Report of G.S.I., Assam.
 11. Ghosh, A.M.N., (1936-39): General Report, G.S.I. in Rec. G.S.I. Vol. 71, Pt. I; Vol. 72, Pt. I; Vol. 73, Pt. I, Vol. 74 Pt. I.
 12. Unpublished Progress Reports of the Assam Circle, G.S.I. for the field seasons from 1961-62 to 1972-73.
 13. Talukdar, S.C., (1966-68): "Stratigraphic Revision of the Cretaceous-Tertiary Sediments of North East India" Unpublished paper read in the Seminar on Geology, of North East India, held at Shillong in 1967.

MEGHALAYA GEOLOGY

Km 25 0 25 Km



INDEX












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|---|--|--|--|
|  | ALLUVIUM (RECENT) |  | GNISS WITH OLD INLIERS
(ARCHAEAN-MID PROTEROZOIC) |
|  | DUPITILA SERIES (PLIESTOCENE) |  | KHASI GROUP (UPPER CRETACEOUS) |
|  | TIPAM SERIES CHENGAPARA FORMATION
GARO HILLS (PLIOCENE) |  | SYLHET TRAPS (LOWER CRETACEOUS) |
|  | SURMA SERIES (MIOCENE) |  | GRANITES (UPPER PROTOZOIC) |
|  | SIMSANG FORMATION (OLIGOCENE) |  | SHILLONG GROUPS (MIDDLE PROTEROZOIC) |
|  | JAINTIA SERIES (EOCENE) | | |

FIG-3

of different geological periods as follows:-

1. Archean Gneissic Complex.
2. Shillong Group of rocks.
3. Lower Gondwana rocks
4. Sylhet Traps
5. Cretaceous-Tertiary sediments.

The general stratigraphic sequence of the formation is given below:

TABLE -I(1)

Geological Age	Group name	Formation name	Rock Types
1. Recent	Newer Alluvium	(Unclassified)	Sand, silt and clays.
-	Thickness (not known)	(unconformity)	
2. Pleistocene	Older alluvium	(unclassified)	Sand, clay, pebble, gravel and boulder deposits.
&	(thickness not known)	(unconformity)	
3. Mio-Pliocene		(unclassified)	Mottled clays Feldspathic sand stone & conglomerate
4. Oligo-Miocene	Garó Group	Chengapara formation (700 m)	Sand, Silty stone clay, Marl.
		Baghmara formation (630 m)	Felspathic sand stone, pebble, conglomerate, clay silt clay.
		Kopili formation (500 m)	Shale, Sand stone

5. Eocene	Jaintia Group	Simsang formation (1150 m)	Silt stone-sand stone alternation sand.
		Shella formation (600 m)	Alternation of sand stone limestone.
		Langpar formation (100 m)	Calcareous, Shale, sand stone, Lime stone.
6. Upper- cretaceous	Khasi Group	Mahadek formation (150 m)	Arkose (glauconitic)
		Bottom Conglomerate (25 m)	Conglomerate, arkose
		Jadkata formation (140 m)	Sand stone Conglomerate alternation.
		(unconformity)	Basalt, Alkalibasalt, Rhyolite, Alid, Tuff.
7. Jurassic (2)	Sylhet Trap (600 m)	(Unconformity)	
8. Pre- Cambrian		Intrusives (Acid and basic) Shillong Group	Porphyritic & coarse granites, Pegmatite, aplite, quartz vein epidiorite, diorite, basalt, Quartzite, Phyllite, conglomerate
		Unconformity	
9. Archaean		Geneissic complex	Biotite-gneiss, biotite-hornblende gneiss, granite gneiss, migmatite, mica schist, sillimanite, Quartz Schist, Bio- tite-granulite Amphibolite, Pyroxene granulite etc.

Source: Geology and mineral Resources of the states of India, Part IV Miscellaneous publications No. 30, Geological Survey of India, Dec. 1974, p. 69-79.

Geological setting of the area under study:

As a part of Shillong plateau, Mawsynram region also consists of very ancient Archaean and Shillong Series rocks expose in large parts along the northern and south-western portion. These are similar to the rocks exposed in the rest of the Garo, Khasi, Jaintia and Mikir Hills, and also like peninsula in Bengal and Bihar of which it was a part at one time. These rocks form the basements for very much younger Tertiary sediments along the southern part of the Mawsynram and that of its neighbouring areas too.

The region to the north and central part of Mawsynram experienced peneplanation resulting in the formation of flat levelled surface, one of the most remarkable sights even today. A spectacular feature of the drainage in the South-Mawsynram area is the deep gorges, which is the result of the relatively greater upliftment of this block, head ward erosion massive along joints by antecedent stream and the control exercised by the well-jointed Cretaceous-Tertiary sand-stone cover.

14. Geology and Mineral Resources of the states of India
Miscellaneous publication No-30, Part. IV(GSI)p.69.

The present physiographic configuration of the region has taken shape only during geologically recent times, however it is the ultimate result of events that took place through the geological past.

Considering the General Geological succession of Shillong Plateau we can derive the sequence of lithological units of the study area as follows (Fig.4).

TABLE - I(11)

Geological age	Group name	Formation name	Rock types
1. Recent	Newer Alluvium (Thickness not known)	(unclassified)	Sand, Silt and clay.
Unconformity			
2. Mio-pliocene	Dupi Tila Group (1050m)	(unclassified)	Mottled clays, felds, Pathic, sand stone and conglomerate
unconformity			
3. Oligo-Miocene	Garro Group	Chengepara Formation (700m)	Sand, Silt stone, clay, Marl, pebble, conglomerate
4. Eocene	Jaintia Group	Kopili formation (500m)	Shale, sand stone, Marl sand.
		Sheila formation (600m)	Alternation of sand stone limestone
		Langpar formation (100m)	Calcareous shale, sand stone, lime stone.

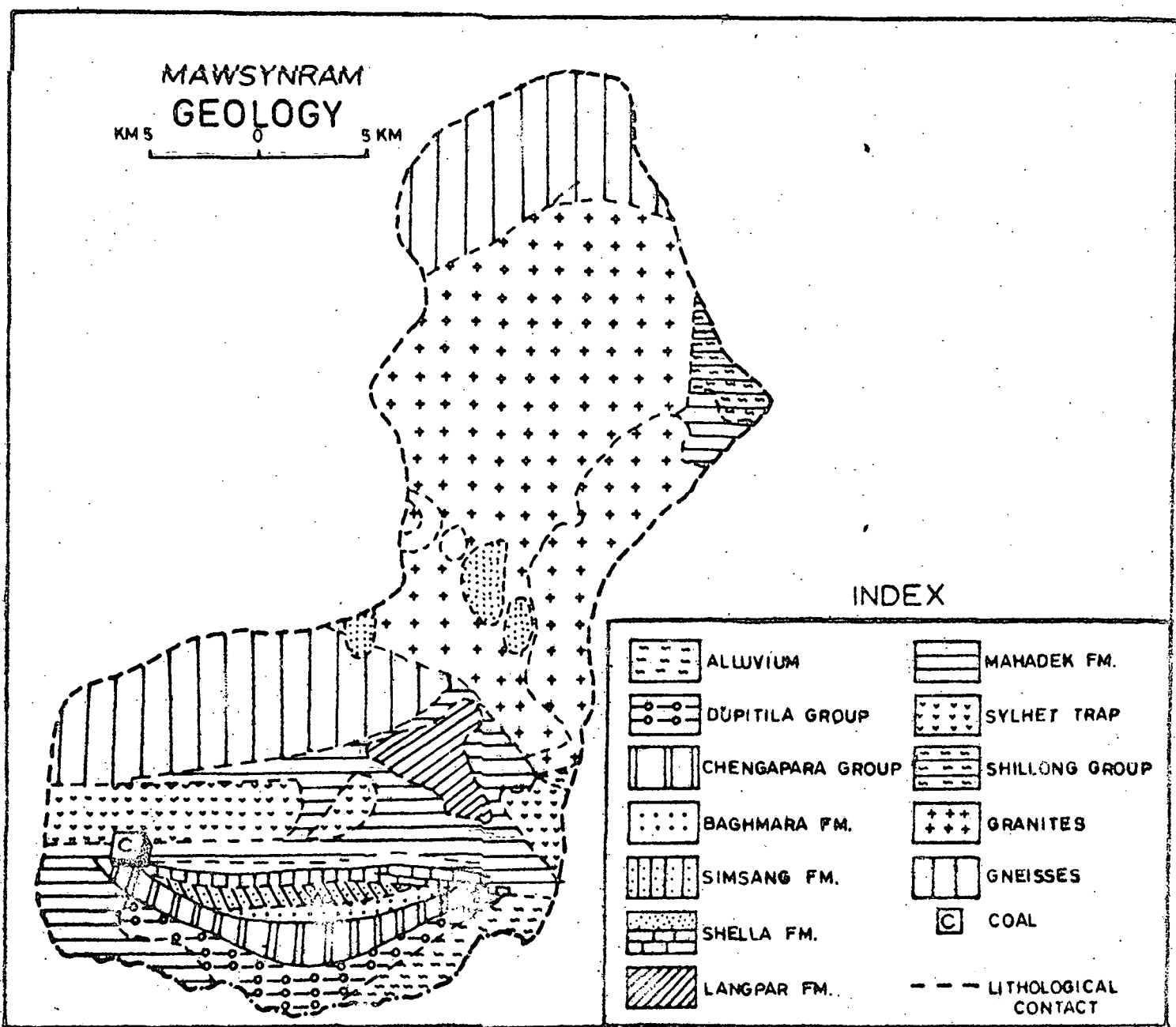


fig-4

5. Upper-cretaceous	Khasi group	Mahadek formation(150m) unconformity	Arkose(glaucous)
6. Jurassic(?)	Sylhet-Trap (600m)	unconformity	Basalt, alkali, basalt, rhyolite, acid tuff.
7. Pre-combrian		Shillong group unconformity	Quartzite, Phyllite, conglomerate
8. Archaean		Gneissic complex	Biotite-gneiss, biotite-hornblende gneiss, granite gneiss, migmatite, mica-schist, Biotite-granulite-amphibolite, pyrosene-granulite, etc.

Archaean

The Archaean gneissic complex is exposed in the extreme north and south western parts of the Mawsynram Block. The rocks are believed to be the north-eastern extension of the Indian peninsular Block, separated from it by the Garo Rajmahal trough fault. This gneissic complex consists of gray and pink Mica-gneissic, at places traversed by quartzite veins. The rocks are composed predominantly of para and orthogneisses, Migmatites and meta sedimentary bands. Rock types come under this complex has been given in the Table-I(ii). The contact between the Archaean Metamorphics and the Shillong series runs in a general N.E.S.W. direction.

Shillong Group

The Shillong Group of rocks is predominantly composed of quartzite, usually friable, with subordinate phyllite, quartz-sericite schist, conglomerate etc. are exposed these rocks. These rocks generally strike in a N.E.S.W. direction and is therefore regarded as homotaxial with Dharwar formations of the rest of India. These rocks are composed in the extreme north-eastern parts of the Mawsynram Block, which is the south-western extension of the central Shillong group of Meghalaya plateau. These rocks generally strike in NE-SW and dip either south-east or south. Current bedding is commonly noticed in these rocks. The mildly folded sediments have suffered low grade metamorphism and are dissected by numerous faults along which the different rocks apparently moved up and down at various times during the Tertiary period. These rocks are intruded by ultramafic and acidic sills and dykes.

Khasi Green stone and mylonite granite:

Essentially, Khasi green stone is an epidiorite and consists of augite and plagioclase. In Mawsynram Block, it is specially developed in between Maoplong and Saoarim. The green stone acquires the amphibolitic

composition when it comes in contact with the younger granite. These rocks also bear the intrusive relationship with the Shillong series. The granite intrusive along the axial region of the Shillong group of rocks around Myllem is termed as myllem granite. Megascopically it is porphyritic and flesh coloured. Microscopic studies show that Microcline, quartz, orthoclase and biotite are the essential mineral constituents of the rock type. The age of the granite does not show any sign of crustal movement like that of older gneisses. It fixes its upper age limit as pre-sylhet or pre-Rajmahal trap.

The sylhet Trap:

Along the southern margin of Mawsynram Occurs the trap rocks, exposed in a narrow E.W. strip, known as sylhet trap, that could be seen occurring at about 15 Kms away from Mawsynram on the way to Balat, along the road cuttings and also near Shella. The sylhet traps are of the nature of plateau (flood) Basalts, which runs in a E.W. strip 80 Km long and 4 Km wide along the southern border of the Shillong plateau, the Maximum exposed thickness is 550-600M. They apparently over lie the eroded pre-cambrian 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 exposing the traps and sills. The flexure in the Therriaghat-Shellia sector with its E.W axis changes along its trace westward (along the Balat and Khasimora of Mawsynram) high angle reverse fault through normal and vertical faults (Dauki-fault) and marks the exposed limit of the Sylhet traps to the south. To the north in southern Mawsynram traps are in contact with the gneissess, granites or Shillong Group of rocks along an E.W. Fault termed Raibah fault; immediately south of this fault the traps dip at 10° - 35° along the monocline or at 50° against the Dauki fault (e.g. Umagi river section, west of Mawsynram) Literally they plunge together with the sediments south west along the Jadukata river, to the east; the east exposure of the traps is seen in the Dauki River.

The Sylhet Traps comprise predominantly basalts and minor alkalibasalts (nepheline tephrite) rhyolites and acid tuffs. The basalt occur as flows and are 5-7m in average thickness. Andesites are absent. The alkali basalts occur as flows in the Umies gorge. South East of Mawsynram, near tyngner ($25^{\circ} 14'3''$ $91^{\circ}36'30''$) Rhyolites

also occur associated with acid tuffs. (vitric tuff, lithic lapicla) in the umiew gorge. Both within the flows and also in the immediately adjoining Archaean rocks to the north, basalt dykes are common; within the trap area the dyke occurs as swarms. The sylhet trap is supposed to correspond with the Rajmahal trap, which continues below the Bengal alluvium, and hence the trap is supposed to be of Jurassic age.

Cretaceous - Tertiary Sediments:

The Cretaceous-Tertiary Sediments occupying the Southern part of the Mawsynram are thick and extensive and are considered to be physically continuous with the cretaceous Tertiary Sediments of the Bengal Plain. These Sediments are affected mostly by basement controlled faults.

The Sediments are mainly sandstones and slate (mud stone), except for the three well defined fossiliferous limestone, occurs as (i) discrete outliers and (ii) a continuous narrow belt fringing the southern margin of the Mawsynram block bordering the Bangladesh plains. Here the Sediments are divided into two groups (a) Khasi Group and (b) The Jaintia Group. The Khasi

group is a distinct arenaceous facies consisting of the oldest Jadukata Formation, followed by the predominantly conglomeratic mahadek formation, of which the later formation only occur in the southern margin of Mawsynram. The Jaintia Group is a Crataceous facies (shelf facies) and has been divided into three formations, viz. the langpar, the shella and the kopili Formations.

Khasi Group

(1) Mahadek formations:- The Jadukata Formation and the bottom conglomerate Formation are overlain in turn by a coarse arkose, usually glauconitic which is termed as mahadek formation on the southern Mawsynram, north of Raibah fault. The maximum exposed thickness of the mahadek formation is 150 m.

(i) The Jaintia Group

(i) The langpar formation:- The langpar formation of the Jaintia group overlies the Mahadek Formation. These rocks are seen on the Mawsynram-~~Bynku~~ road sides at about 5 Km from Mawsynram Twon. The rocks consist 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 (600m thick) represented by the alternating limestone and sandstone sequence.

(ii) The Shella formation:

The Shella formation consists of three sandstone and limestone members beginning with a sandstone over the langpar formation. These have been designed successively the lower (Therria sandstone/Lakadong limestone) middle (Lakadong/sandstone/umlatdeh limestone), Upper (Narpur sandstone/Prang limestone/siju limestone and Sylhet sand stone/limestone member in eastern part of plateau looking westward along the cliff face below Mawsynram ($25^{\circ}18' - 19^{\circ}35'$) the lower sand stone band of the Cretaceous can be seen thinning in a northerly direction.

(ii) The Kopili Formation:

The Kopili formation cover lies the Shella formation and is about 500 m in thickness. The rocks are alternations of thin sand stone and Shale with rare thin fossiliferous bands of limestone. The basal part comprises a dark horison with scattered phosphatic nodules in southern part of Mawsynram it occurs as crecent shape in a East-west direction.

Garro Group(i) The Changapara Formation:

This formation overlying conformably the Baghmara formation consists of poorly-cemented, fine-grained, micaceous sand, blue to brown silt-stone and clays with a few thin beds at its base. East of Dareng river in Mawsynram block ($25^{\circ}19'-90^{\circ}30'$, both the Changapara and the overlying Dupi-Tila Group beneath the alluvium, when it reappears in the extreme South West of Mawsynram block near Balat ($25^{\circ}13'-91^{\circ}22'$) an erosional unconformity can be seen.

The Dupi-Tila Group consists of alternations of coarse felspathic sandstone with lenses and beds of pebbles of vein quartz and sandy molted clay. This group also mainly represent deltaic types.

Quaternary and Recent Deposits

Recent Alluvium:

Recent Alluvium is found along the Southern foot hill region of Mawsynram. The Alluvium consists of fine silty sand and light to dark greyish clay with rare pockets and layers of coarse sand. The fine sand at places contains abundant minute flakes of Micca.

GEOLOGICAL HISTORY:

The Archean basement of Mawsynram region including Shillong Plateau, a remnant of the north easterly extension of the Indian Peninsula, remained a land-mass experiencing earth movements leading to complete folding and fracturing of the ancient rocks till Precambrian times, when the north eastern part of Mawsynram covering eastern Khasi and central Jaintia hills, developed into a trough over which the sediments of Shillong Group of rocks were laid down. The sediments, later uplifted and folded, experienced low grade metamorphism as a result of granitic (Myllem granites) and basic/ultrabasic (Khasi green stone) intrusions.

During the Post Pre-cambrian, the area to the north and central part of Mawsynram experienced peneplanation resulting in the formation of a flat levelled surface, preserved over this plateau even today. By the end of Jurassic period about 150 millions years ago, the southern margin of Mawsynram experienced plateau volcanism through east-west fissures i.e. Raibah fault along with the southern block foundered and the northern block rose. Not long after the cessation of volcanism, the rest of

15. Murthy M.V.N (1968) op; cit., pp. 25-32

sinking of southern block increased resulting in the invasion of the sea and deposition of the upper-cretaceous sediments about 10 million years ago. The movement was evidently rapid first and slowed down until and during Eocene times, about 60 million years ago, when the area had reached to stable conditions and fossiliferous calcareous formation at the Jaintia Group began to be deposited.

During Paleocene times large part of the Shillong plateau covering the Mawsynram was still experiencing upliftment of the northern block resulting into the deposition of only the oldest (lower sylhet) sandstone and limestone beds over the plateau. The younger sylhet formation comprises three distinct, successively younger limestone bands, interbedded with coal-bearing sandstones are exposed along the southern fringe of the Mawsynram. This is evident because the area to the north was experiencing uplift while the area to the south continued to sink, since then, the sedimentation continued uninterruptedly over the submerged southern part of Mawsynram. Including South and South eastern fringe of Khasi and Jaintia Hills, till the end of

Oligocene when the Barail range to the South of Jaintia Hills stood up as a landmass.¹⁶

During lower Miocene (about 25 million years ago) sedimentation continued uninterruptedly over the south and western part of Garo Hills and the Southern fringe of the Khasi Hills (along the South Mawsynram), 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 resulting into the formation of land-locked shallow water lacustrine basins along southern fringe of Khasi and Garo Hills. The pliocene (Dupitila) were deposited in these basins, which occurs along extreme southern fringe of Mawsynram. The sub-Recent older Alluvium deposits found along the southern boarder are fluviatile deposits along old river valley.

The deep gorges in the south Mawsynram is the result of the relatively greater uplift of this block headward erosion massive along joints by antecedent streams, and the control exercised by well-jointed Cretaceous Tertiary Sandstone cover West of Mawsynram

16. Dutta.S.K., Palaeo-geography of the Assam plateau, Directorate of Geology and Mining Deptt., Shillong, Assam.

platform 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 small stream valleys on the extreme northern margin of Mawsynram (North of watershed lines) represent headward erosion along the joints, especially favoured by the absence of thick sedimentary cover in the south.

The story of the Geological evolution of the Mawsynram region is thus one of uplift and down-sinking in different parts during the past 100 million years, which has produced the present spectacular physiographic configuration of the region.

STRUCTURE AND TECTONICS

The Mawsynram region is a part of Shillong Massif. The central and southern parts are true plateau, capped by Mesozoic-Tertiary rocks and underlain by Mesozoic flood basalts (The sylhet Traps) and polycyclic precambrian gneisses, meta-sedimentaries (The Shillong Group) and plutons. Further North, only the Pre-cambrians crop out constituting upland.

The southern margin of the Mawsynram plateau is a sharp fracture zone, formerly considered (Evens 1964) a strike slip fault but recently (Murthy etc. as 1969) demonstrated to be a vertical reverse fault belt secondary fractured associated with this system. The northern limits of the region is upto southern watershed zone of the Shillong plateau.

A detailed study of the geology of the region is yet to be made, but geological structures occurring in the rocks are studied by geologists. It is generally believed that Shillong plateau along with Mawsynram region is an autochthon of Crystalline rocks that constitute the foreland spur of the Indian shield and it has been overthrust from the N-W by the Himalayas and from S-E by the Naga Hills. The general structural trend of the crystalline rocks of it is N-E S-W, but a variation of it occurs in the south and western part of Mawsynram along the Garo Hills, where the trend is E-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 more

17
 metamorphosed rocks. Both folded and mineral lineations are seen. The plunge of the lineations is moderate to steep, but at places it becomes vertical or nearly so. A good example of this is a fold at Mairang (extreme north of Mawsynram) area, where lensoid bodies of massive sillimanite occur in the core and its immediate portions of the flanks of the plunges.

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, 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. These structural relations between the rocks of the Shillong series and myllem granite are seen around Mawphlong, situated at the North-eastern corner of Mawsynram region.

The Sylhet Traps, the effusion of which marked the first major tectonic event during the Jurassic period occur along a narrow strip, exposed in gorges of Bagra

17. Singh R.P., (1968): op.cit., pp.1-9.

river along the south-eastern margin of Mawsynram plateau. Their contact with the crystallines to the north is a fault, the Raibah fault, which apparently determined the limits of the traps during the effusion.

The Dauki Lineament:

In the southern fringe of Meghalaya, the predominant structural lineament is the Dauki fault which comprises at least four E-W running usually normal faults and at places becoming reverse faults. Each of these faults exhibit different geometric fault types along their trace. In the southern fringe of Mawsynram one of these four faults (Dauki fault-II, from Balat to Khasimara.) branches off from Dauki fault-I longitude $91^{\circ}25'$ and from west to east it could be traced as a high angle reverse to vertical fault and further east it passes into a monocline. In all the faults of Dauki system the northern side is up thrown with basement rocks and the sedimentary capping at a higher topography level.⁷ The amount of topographic and/or stratigraphic displacement is great, the structural relief on either side of the Dauki fault system ranges up to 13,000 mts.

18. Chakrabarti, C. (1977) "The Dauki lineament along the southern part of the Meghalaya plateau. Misc. Publ. No. 31. Geological Survey of India, pp. 92-93.

A rectilinear drainage pattern in NE-SW, NW-SE directions is a distinctive feature of the Mawsynram region. 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 region along with Shillong plateau during Upper Tertiary period.

CHAPTER - II

WEATHERING AND SOIL FORMATION

"The atmosphere's work on rock is slow, but ubiquitous and ultimately triumphant."

JEROME WYCKOFF,
Rock, Time and Landforms.

Introduction:

No Geomorphic studies has supported the concept of a small region, like Mawsynram, within which an extensive group of distinctive Weathering process occurs. We also do not believe that the transformation sequence or the synthesis mechanisms observed in our present study area is essentially different from those occurring over other part of Shillong plateau. Nevertheless, the characteristics of the weathering products found in Mawsynram region are marked to be distinctive, and has also recognised weathering types in different parts according to the dominance of particular minerals. Further more, depths of rock decay are frequently held to be greater in the Mawsynram than elsewhere. This view must also be accepted with caution because deep weathering as a phenomena is not confined to Mawsynram, within the Mawsynram region itself, characteristic of weathering depths vary greatly, particularly with the humidity of climate but also in response to many other factors. Some of the major factors

contributing to the rate and course of weathering are listed below:

- (i) Climatic factors;
- (ii) Biotic factors;
- (iii) Geomorphic factors;
- (iv) Geological factors;
- (v) Chronologic factors.

From the study of above factors some very general predictions may be made, but the large number of variables involved makes detailed prediction of weathering very difficult. However it is clear that the southern margin of Mawsynram is one within which many of these factors operate to favour deep chemical decay of rocks, while in the northern part the effect of physical and thermal weathering is more marked. As an area with moderate temperature and world's highest rainfall, it promotes the weathering processes, and a large part of northern Mawsynram, around Mawpholong and Nongpung is dominated by ancient crystalline massifs and sedimentary basins. More or less stable landsurface of late Tertiary.¹ Thus provides a geological and geomorphic basis favouring deep penetration of weathering, and through decomposition of rocks.

1. Singh, R.P.(1968) op.cit.,pp.1-9.

Climatic forces, particularly precipitation and temperature, directly or indirectly influence kinds of weathering. Comparatively in dry and cold regions of northern Mawsynram, Physical weathering is more important than chemical or biological weathering conditions are optimum for heating, cooling, and frost action in moist, moderate hot regions of southern Mawsynra,, conditions favour chemical and biological weathering. The greater the effective precipitation and temperature the greater the amount and degree of chemical and biological weathering. So realising the role played by climate on weathering processes of any region, it is very much essential to give a brief climatic account of our study area, before going to discuss the various types of weathering and its products.

CLIMATE:

Situated between the rain shadow part of Shillong plateau, in the north and Bangladesh plains in the South, Mawsynram block experiences extremely varied climatic conditions mainly caused by altitude and aspect. In general the climate of Mawsynram is quite different from the adjoining Shillong plateau region of Garo, Khasi

and Jaintia hills by comparatively heavier precipitation and shorter and less oppressive summers. The heavy rainfall and Altitudinal zoning of the climate are two important characteristics of the climate of Mawsynram. The Southern sandy foot hill tracts experience hot and sub-humid tropical climate. With the increase in altitude towards north the climate changes from rainy, cool, temperate to little bit rainy, cold temperate. Thus most significant factor controlling the climate of Mawsynram are south west monsoon and altitude. Based on the principle of Lapse rate the areas lying below (600m) 1000 feet above sea level have not and moist tropical climate. The areas above 1000 feet but below 5000 feet above sea level experience rainy, cool-temperate climate. Higher up the climate is rainy, cold temperate up to an elevation of 6500 feet. The second most important factor affecting the climate of Mawsynram region is Monsoonal heavy rainfall. The south facing slopes in this region are heaviest rainfall areas of the world today. The north facing slopes fall in the rain shadow area of Shillong Plateau and thus are comparatively dry. Because of slanting rays of the sun falling on the northern slopes these are comparatively colder also. (areas North of Nongspung).

Climate no doubt consists of many elements like temperature, pressure, humidity, winds, rainfall, snow, Fog, moist, Frost, clouds, vegetation etc. Yet for our present purpose the elements of rainfall, temperature, humidity, vegetation, are described here.

TEMPERATURE:

With the exception of Balat and Shella areas normal monthly maximum temperature is recorded in this Block. The highest monthly maximum temperature is observed in the month of May. There after, onset of rainy season brings down the temperature. The temperature continues to fall with the break of rains and the lowest monthly temperature is recorded in January. As already stated the temperature changes with altitude, during the month of may normal monthly maximum temperature is 35°C at Balat and 30°C at Mawsynram village. The places like Mawphlang, Jakrem experience even less in this time. Similarly in the month of January the normal minimum temperature is recorded to the tune of 8.5°C at Balat and 5.8°C at Mawsynram. The temperature at Mawphlang, Jakrem, and Welloi, during this period however is around 5.5°C . As far as annual range of temperature is concerned the places at higher altitudes (Northern part of Mawsynram) observe lower range as compared to the places at low altitudes (Southern Margin of Mawsynram) experiencing higher range.

The mean maximum in this area is highest in the month of July (24.0°C) and August (24.7°C) and lowest in the month of January (15.6°C). The same month, recorded the highest and lowest minimum temperatures also. The mean minimum temperature varies from 6.3°C in January to 18.1°C in July. The table II shows the variations between monthly maximum and minimum is very high in the month of January, when maximum is 15.6°C and minimum is 6.3°C. From may to September the range between monthly maximum and minimum temperature seems to be narrowing down and again is raised towards December, (Fig-5).

TABLE -II(i)

	Jan	Feb.	March	April	May	June
Max C°	15.6	17.0	21.5	23.8	23.1	23.7
Min C°	6.3	6.4	10.5	14.1	15.5	17.0
	July	Aug.	Sept.	Oct.	Nov.	Dec.
Max C°	24.0	24.7	23.6	21.8	19.9	16.5
Min C°	18.1	17.8	16.6	13.0	7.9	6.5

Source: Metrological data recording centre, Mawsynram, Meghalaya, 1982.

In weathering processes the effect of average annual temperature and monthly average temperature is quite significant. The mechanical disintegration of rocks are frequent during high-temperature. The alternate heating and cooling during day and night helps the mechanical disintegration of rock easily.

The above data shows that the daily maximum is highest in the month of August (24.7°C). As the temperature plays the important role in mechanical weathering, from the temperature distribution, it could be considered that the mechanical weathering shows generally greater impact in the month of May to August in Mawsynram Block area. However temperature alone does not control the rate of weathering, and quite apart from the topographic factor, Humidity and the supply of groundwater and of organic matter are of particular importance.

HUMIDITY:

It is the relative humidity at a place that affects the amount and process of precipitation at that place. The amount and incidences of atmosphere precipitation determines the mode of weathering and even the characteristics of rock decomposition.

High atmospheric humidities, generally associated with abundant rainfall, favours chemical decomposition by the action of water infiltrating below the surface. In areas of humid climate like Mawsynram, the weathered mantle is generally deep, out-crop of bed rock are rare even on the steep slopes and in areas of resistant rock, the products of decomposition form an almost continuous mantle, which marks the irregularities beneath the solum and softens all the landforms. In Mawsynram around limestone area, humidity plays most important role, by giving a helping hand for chemical decomposition on the exposed rock mass. In many respects it is the availability of water as the principal chemical reagent involved in weathering processes that becomes most critical, especially within humid tropical climate like Mawsynram-region.

RAINFALL:

Generally the amount of rainfall received increases from the southern foothill tract of Mawsynram towards the mountainous area according to relief. The amount of rainfall decreases on further north due to the effect of rain shadow. The rain begins to fall by the third-week of April and continues right upto the end of September

after which it gradually diminishes. The maximum rainfall occurs over the Cherapunji and Mawsynram platforms receive the average 12,000mm of rainfall annually. It is the wettest spot of the world.

It is clear from the above discussion that there is a marked variation between the southern and northern parts of Mawsynram block as far as rainfall is concerned. The rainfall at Mawsynram and Cherapunji which is located in the structural platform in the south is as high as 13,923mm. and 11,418.7mm respectively. While Shillong being located 50 Km. to the north with a rainshadow effect gets only 2417.3mm, (Fig.5). The high rainfall in Mawsynram-Cherapunji 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 mts. Which just cuts like a peninsula into the surrounding gorges about 600 mts deep on either side and as a result the monsoon having reached the heads of the gorges ascends vertically upwards and causes heavy rainfall.

RAINFALL AND TEMPERATURE

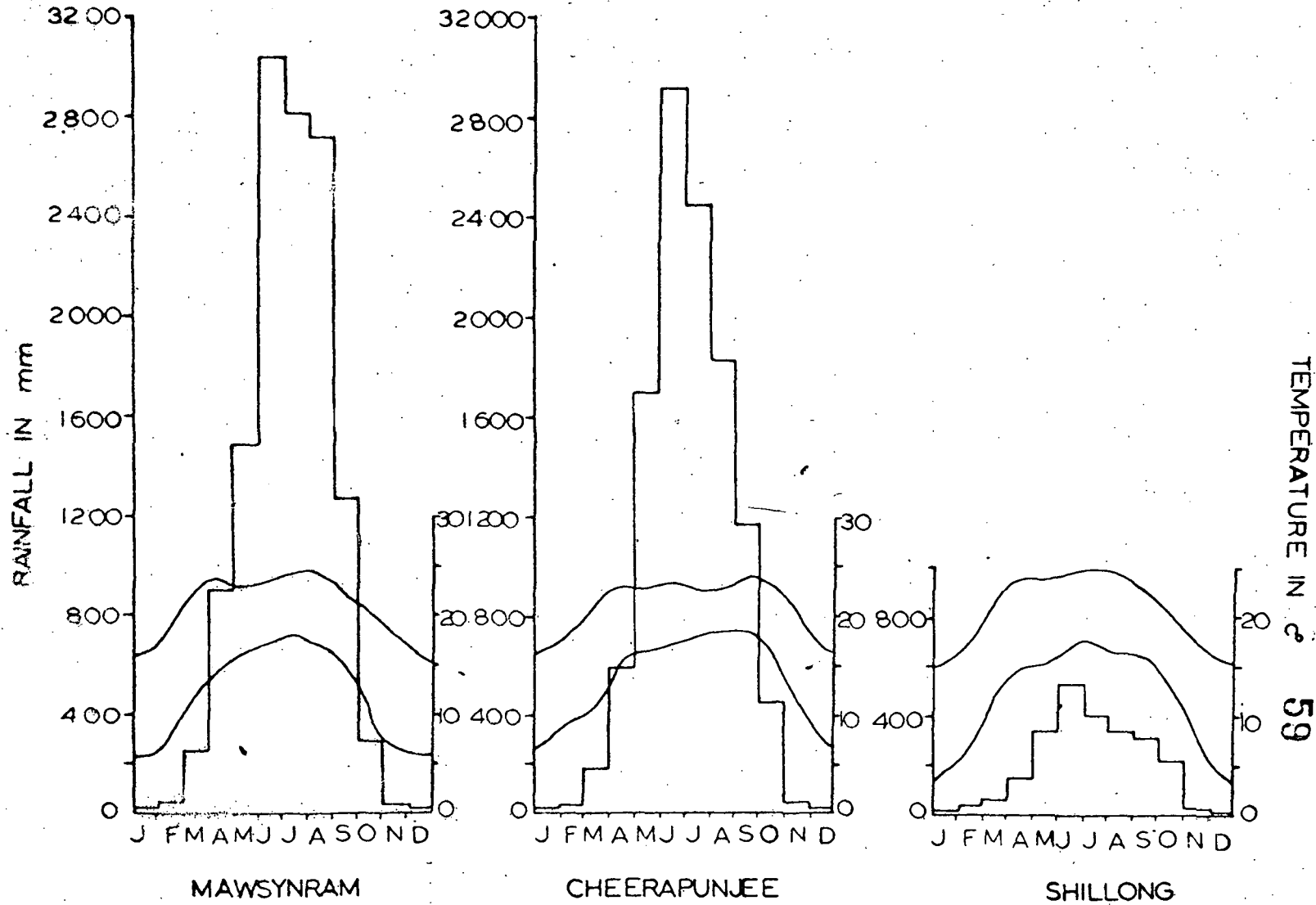


fig-5

TABLE - II (ii)
(Rainfall in mm.)

	Jan.	Feb.	Mar.	Apr.	May	June
*Mawsynram	17.00	43.8	247.56	895.02	1484.05	3035.3
Cherapunji	19.8	37.3	178.9	605.2	1705.1	2921.5
Shillong	15.2	28.5	59.4	136.4	325.4	544.6
	July	Aug.	Sept.	Oct.	Nov.	Dec.
*Mawsynram	2813.4	2745.00	1277.00	299.00	32.00	3.3
Cherapunji	2456 .7	1827.5	1167.7	447.4	46.7	4.9
Shillong	396.9	334.6	314.9	220.2	34.9	6.3

The factors of climate such as temperature, humidity and rainfall determine not only the fluvial processes but also the rate at which weathering withers by chemical or mechanical processes. As the area under study is a Block, which has been considered as a feasible unit, for a detailed and intensive field observations. The researcher has done a vast field observations and finally selected some most important regions, which has been

*Source: from metrological data recording centre, Mawsynram, 1982.

affected by the processes of weathering severely. The selected regions are; Mawsynram limestone area, Mawphlong Kaolin rock area, and foot hills area around Balat. During field observations, the researcher, tried to identify those weathering areas where climatic factors might have played a significant role.

WEATHERING

The weathered rind beneath the land surface, part of any landform, is a result of the physico chemical alternation of rocks or sediments. The group of processes responsible for such alternation is called weathering, which requires interaction between mineral matter and atmospheric agents such as temperature, wind, pressure and water.

Rocks of similar chemical and mineralogical composition may react very differently to the same weathering environment. For example, coarse grained granite, weather more rapidly than fine grained granites. Weathering requires the presence of water, and hence rock structure is important because it largely controls penetration of water into rocks. Porosity data for the common rocks are given in Table II (iii).

TABIE - II(iii)

Rock type	Prosity in %	Unconsolida- ted	Prosity
Granite	1.00	Clay	45.1
Basalt	1.00	Silt	40
Shale	18.00	Sand	35
Sand stone	18.00	Grand	25
Lime stone	10.00	-	-

Source: Leopold, L.B., et.al., Fluvial processes in geomorphology, p.101.

For the sake of convenience, depending on the operative factors, we may classify weathering processes as physical, chemical and biological. All of these pfocesses undoubtedly take place contemporaneously, but one of them may be dominant as a site of a particular time. As we have already mentioned the whole of Mawsynram structural platform experiences heavy seasonal rain and moderate temperature during monsoon and summer months, this region becomes very much prone to the weathering processes. Assisted by heavy rain fall and moderate temperature it forms an important medium to dissolve the minerals and hold them in solution during the process of weathering and transportation over the area under study.

Physical or Mechanical Weathering

Physical weathering is the change of consolidated rock to unconsolidated matter that is caused by physical forces acting on rock in place. This type of weathering is brought by two main processes, temperature change and crystallisation. To these might be added, as a lesser effect, the action of plants roots in the purely mechanical sense.

Thornbury (1971)² and Sparks (1972)³ have recognised various processes as mechanical of these, however, only slaking and weathering caused by temperature, are noticed in this area. Wetting and drying cause alternate swelling and shrinking and generate stresses that cause breakdown of material. This process is known as slaking. In the limestone area and the Mylliem granite area of Mawphong, this type of weathering dominates. Mainly the cretaceous Tertiary sediments show this type of mechanical weathering. During the fieldwork the researcher has observed, the disintegration of the fine grained sandstones into a number of large pieces of different size, around welloi (Plate-1). A large variation in diurnal and monthly rainfall in this region helps the process of slaking.

2. Thornbury, W.D., (1971) 'Principles of Geomorphology', 3rd ed. John Wiley & Sons, New York.

3. Sparks, W.B., (1972) 'Geomorphology', Longmans, London, p.41.

Temperature changes due to natural causes are no longer believed to be very effective in rock breakdown. Black Welder (1969) has pointed out that a good deal of thermal expansion and contraction of rock is caused by forest fires, which cause non uniform heating of rocks. In Mawsynram, areas of high altitude, around welloi, Nongphung, Mawphlong extensive jhum cultivation is practised, shows spalls and flakes of rocks which are produced due to exfoliation caused by unequal heating and cooling. When temperature fluctuates, the mineral grains composing rocks alternately expand and contract. Because of the slow penetration of heat into the depth of a rock, the surface layer expand more than those with in. The frequent result is the appearance of cracks parallel to the surface of rock blocks, and desquamation of the latter.

On the steep slopes of high mountains, thermal weathering is more intense, where the air is more transparent, and insolation stronger than in the adjacent lowlands. Again the practice of jhuming in hill slopes further accelerated it. The rock fragments produced by weathering are readily removed from the slopes by gravity. This results in accumulation of hill sides waste or talus at the foot of mountain slopes. In our study area such types of weathering has been observed around the village Mawphlong, welloi, Nongsphung,

Mirang, Mawsynram etc. over the old jhum cultivating areas. (Plate -2)

The mechanical action of external agents also break down rocks and sediments. Tree roots growing in cracks dry rock apart, dividing it into small pieces (Plate-3). Ants, termites and other burrowing creatures tear apart unconsolidated sediments and soils. The mechanical destruction of rocks by Biological agents may be observed practically in all climatic zones.

All of these physical processes increase the specific surface of a material. When particles are broken into very small sizes, electrical bonds are broken, which leaves unsatisfied electrical charges on the particles. These particles, whose charges are able to attract or absorb opposite charges, are then ready for chemical processing.

Chemical weathering

Chemical weathering is the change in the chemical composition of rock and sediments that is caused by atmospheric agents, namely water and gases. Four basic kinds of changes take place; additions, removals, transfers and transformations (simonson, 1959)⁴.

⁴.Simonson, R.W., (1959) 'Outline of a generalized theory of soil genesis'. Soil Sci. Soc. Am. Proc. 23:152-170.

The simplest kind of addition is hydration, which is the chemical combination of water with a particular mineral. As our study area is the world's wettest spot, the impact of water on weathering is profound. Complete dissolution of minerals in water is observed in salt bearing series, in Jypsums, limestones and dolomites etc. It is with these rocks the formation of karst, sinks and cavaties are associated. Water enriched with free carbon dioxide dissolves limestones and it relatively readily redeposits the dissolved carbonate of lime. The cave deposits are found in Mawsynram limestone topography ($25^{\circ}19'$, $91^{\circ}35'$) is through this process.

One of the most striking karst features are cave. Such caves are generally long, winding passages, but they may also be in the form of big rooms. The Mawjymbuin cave* near Mawsynram village is almost 137 feet long with walls 135 feet apart and a ceiling 15.5 feet high, (plate-4). Another important cave, locally known as 'Jaleaiaw' cave is also located 8 kms. away from the Mawsynram town, on the Lawbah road.

There are several theories regarding the development of caves. These can be classified as to 'phreatic,' 'vadose' and 'water table' theories, corresponding to the

* The researcher has measured the length, width and height of the Mawjymbuin cave, during field study.

ground water zone in which the cave is assumed to be created. For the study of genesis of the Mawsynram limestone cave, the phreatic theory, proposed by Ground(1910)⁵ is seems to be not fit, as the researcher during field studies, observed, that the Mawjymbuin cave is situated above the water table (vadose zone). Again it is also observed that the leaching occurs mostly in channels through which the atmospheric water flows to the ground water table of this region. So the possibilities of Mawjymbuin cave formation is supported by the vadose theory of Matson (1909)⁶ then any other one.

The researcher has also marked some unique development of stalactite and stalagmite deposits inside the Mawjymbuin cave(plate-5). After moving few yards inside, at the centre of the cave a huge stalactite is hanging on the roof about 3.6 feet long and 4.2 feet in circumference (plate-6) and just opposite to it, on the floor, a stalagmite of 4 feet high and 7.9 feet circumference is found, which appear like the shape of a sivalinga (plate -7). During the Hindu festival of sivaratri, the local people visit and worship inside the cave. It has also been noticed that the entire roof of the Mawjymbuin cave is being severely affected by chemical weathering (plate-8).

5. Ground, A. (1910) 'Pencks Geogr'. Abu 9, 345

6. Matson, G. C. (1909) U.S. Geol. Surv. Water supply, pal. 233-42.

In Mawsynram region there are innumerable areas where karst features are present but do not dominate the landscape. This may be a result of the topographic youthfulness of the karst features, but more commonly it is attributable to the absence of one or more of the essential conditions essential to ideal karst development. The entire southern half of Mawsynram from east to west is characterised by extensive limestone formations, but the features assemblage is too incomplete for it to be classed as a major karst area. This region is terraineous, rocky and full of steep slopes. They are some sort of 'terra-in-cognita' so far. They may well contain karst features of great importance, which are yet to be discovered.

An example of simple transformation is the oxidation of granite-gneiss surface of the areas, is indicated by red-yellow surface layers of residual soil. Oxidatrous process is found in Mawsynram platform, particularly in the areas where, hornblende rock structures are found. These rock structures contain ferrous iron which rapidly oxidizes under surface conditions, coating the mineral with a brown crust. The researcher has marked such a typical oxidation of hornblende rock structure area between the Mawsynram village and Mawsynram P.W.D. office (Plate - 9) oxidation process also found active in bank of the river Umnagi, east of

Mawsynram where sedimentary rocks, such as sandstones, clays, often show a brown colourization, indicating that the minerals underwent oxidation and turned into hydroxide.

It is the hydrogenion of water that is the most powerful agent of chemical weathering. Naturally whatever is dissolved in the water affect the chemical reactions that occur. The major dissolved constituents are sulfate, bicarbonate, chloride, nitrate, calcium, sodium, magnesium, hydrogenions and potassium.

The product of chemical weathering may form a new mineral (the synthesis mechanism) or remain as residue when other constituents are removed (the residue mechanism. Jackson and Sherman 1953)⁷. Synthesis involves additions and transformations but residue results mainly from removals and transfer. Water is the main transfer agent in both of these weathering processes, and its activity is fundamentally important.

Areas which have undergone by chemical weathering through removals and transfers (dissolution and hydrolysis) of Mawsynram structural platform area are as follows:

- (1) Mawsynram area ($25^{\circ}19' = 91^{\circ}36'$) along the stream, north of village Mawsynram.

7. Ruhe, Robert V. (1975) 'Geomorphology', Geomorphic processes and Surficial Geology. Houghton Mifflin Company, Boston Atlanta Dallas Geneva, Illinois Hopewell, New Jersey, Palo Alto London

- (ii) Langrin area; at Chargaon, which is the extension of Mawsynram area.
- (iii) Shella area; situated in South-eastern ($25^{\circ}11' = 91^{\circ}38'$) corner of Mawsynram block. Here four limestone beds-inter-bedded with sand stone have the total thickness of 415 metres. The area covered is about 0.36 Sq. Km.
- (iv) Langaon area ($25^{\circ}10' = 91^{\circ}15'$) along the southern border of the Mawsynram platform. The limestone becoming to the Shella formation of the Jaintia Group (Eocene).

The above mentioned calcareous rocks (essentially the limestone) of different parts of the study area consists of either chemically precipitated calcium carbonate or the remains of invetebrate organisms composed of the same material. They are very much susceptible to the action of carbondioxide and humus acids and weather into a variety of forms. As the rocks are permeabmble, either because of major joint system or because of the presence of a multitude or minor cracks, there is a very large surface available for weathering.

San-ches Furtado (1968)⁸ points out that Kaolinite deposits dominate in the area of high humidity, particularly produced under the conditions of free drainage and slight acidity of ground water. He also found that granites in such regions associated with kaolinite deposits. As our present study area is a region of great rainfall, there is a sufficient reason to believe that the ancient Archaean and Shillong series rocks, which have been exposed in large parts along the northern and south-western portion of Mawsynram Block; are more susceptible to chemical weathering. The area where kaolin deposits marked is:

Mawphlang area of Mawsynram;

Where isolated out crops of the kaolin deposits occur in an area of six kms from Mawngap small patches of these deposits scattered all over the area varying 175 Sq.mts to 1550 sq.mts in area. Abundant biotite and potash feldsper shows that these areas have been affected by sever chemical weathering. Weathering of these rock blocks causes a slow rounding of the corners of the blocks, and the development of peculiar shapes partially rounded

8. Thomas, M.F., Tropical Geomorphology; A study of Weathering and landform Development in Warm climates, pp.25. Pub. Macmillan press Ltd. 1974.

boulders. Such features well developed in Mawphlong and Mawsynram village are known as tors (Plate-10). A considerable amount of this weathering may take a place underground, and the tors may be formed before they are exposed by erosion (Linton, 1955⁹).

On the southern part of Mawsynram the sylhet traps are exposed in a narrow E.W.Strip. They comprise predominantly basalts and minor alkali basalts rholites and acid tuffs. These rocks are susceptible to water, which undergoes the process of hydration. The Umiew gorge, south East of Mawsynram, near. Tyngner ($25^{\circ}14'3''=91^{\circ}36'3''$) is the region of such intensive chemical weathering.

Biological Weathering

A critical role in weathering processes may be played by both living organisms and by organic compounds resulting from the decay of plant materials. However the quantitative importance of these factors is as yet difficult to assess. The cyclong of nutrients within the vegetation cover is one aspect of this problem, and it has been suggested that the deep rooting trees or the heavy rain forest are capable of removing important quantities of dissolved

9. Spark, B.W., (1972). op.cit.p.41

mineral matter from considerable depths (Lovering 1959¹⁰ quotes depth of from 10 to 30 m. as not uncommon).

The researcher during the field observation has marked the following types of vegetation in different parts of study area.

(i) Northern Mawsynram: particularly around Mawphlang, Jekrem; The entire area is gay with sprinkled bushes of *Rhododendron formosum* and other important species such as *Rhododendron arboreum*, *pyrus pashia*, *Gentiana. Quadrifaria*, etc. Apart from this the sacred grove *castanopsis kurui*, *quercus griofit hii* etc. Occupy the basin of a swacer shaped depression with the hill-slopping.

(ii) Central Mawsynram, around the Mawsynram village:-

There is a marked difference in the species composition between northern and central Mawsynram forest. Here species like *Engilhardtia - Spicata*; *Drimycarpur recemosus*, *sysginm cummunii*, *Elacocarpus Spp.* *clerodendron clerodendron Spp.* etc. are dominating.

10. Thomas, M.F., (1974) op.cit., p.25-26.

(iii) Southern fringe of Mawsynram:
from Balat to Shella :

Here the long leaf plants are generally found. The dominating species of this region are Anthouphalus kadamba, Artheanpus uplesa, Duabhanga Sonnensoides, Euria accuminata, Schima wallichii, casiafistula and castro-nopsis roxbur-ghiana.

As a result of periodic leaf fall from the above mentioned trees, and of the decay of woody material, much of this is returning to the surface layers of the soil of this region. These plants accumulate considerable quantities of major elements such as Si, Al, Ca and Fe, during growth. Each year such forests contribute to the surface between 10 and 20 tons of dry matter per acre. Using 16 tons as average, lowering thought that 0.4 ton of silica would be contributed to each acre per year. Over a long period this process amounts to the removal of important quantities of silica from some depth below the land surface. Because of this fact, the soils of this area is highly acidic and P.H. value is generally between 4 and 6 but may be as low as 3.5 in pine forests.

11. Thomas, M.F. (1972) op.cit. p.25-26

12. Ramakrishnan, P.S. and et. al., (1981). Slash and burn agriculture in northeastern India. in: Fire Regimes and Ecosystem properties, U.S. Reptt. of Agric. Gen. Tech. Report, WO 26, pp-583-587, Washington.

Open to shifting cultivation (jhum) practice in Mawsynram region, the burning of the slashed material destroys the vegetative cover of the area. Subsequently, it leads to the failure of the protective root system of the vegetation, which become very much prone to the processes of weathering. In Mawsynram, since about 90% of the rain comes during the monsoon period, it is reasonable to assure that most losses of surface soil occur during this period. Again as the rainfall is very great but evaporation is low, chemical weathering is probably of greater importance than physical weathering, as the rocks are almost always moist at ground level.

Weathering, then, is a complex phenomenon, involving a variety of processes and being influenced by a number of factors, the most important of which are lithological and climatic. No hard and fast rules can be laid down about exactly how different rocks will weather, as so much depends upon minute differences in lithology and process, one can really only tell how a rock will weather when one has seen it weathered. Doubts and differences of opinion exist about the efficacy of the processes of weathering and it will be many years before even some of the doubts are resolved, as weathering is such a difficult process to study.

Soils:

A physical, chemical, biological, and mineral weathering progresses, alternation of rocks and sediments develops threedimensionally beneath the land surface. The intensity of weathering decreases in each succeeding lower layer. A weathering zone is an altered layer that differs physically, chemically and mineralogically from the layers adjacent to it and that extends beneath the land surface. Weathering zones can be used to study not only weathering per se but also geomorphic and stratigraphic relations.¹³ Another pertinent use is the fit of soils to the zones. Specific soils of the soil envelope fit specific zones and thickness of zones.

For our study purposes a soil may be considered as a unit formed at the earth's surface possessing distinctive zones or horizons characterized by difference in Minerology, organic content, texture, and structure. Although pedologists and geologists sometimes differ in the definition of a soil, geomorphologists are concerned with the entire weathered zone from surface down to unweathered bed rock.

To understand the nature and type of soils found on different weather zones of the Mawsynram, We must have

13. Ruhe, Robert, V. (1975) op. cit. p. 33-41.

some basic ideas about the factors that affect the formation of soil. Pedologists generally list climate, parent material, biotata, and relief as fundamental factors of soil formation. Because soil properties change, time is also very important.

The soil formation factors in our present study are not considered individually. It has been described along with the type and properties of soils in succeeding sections. We have already discussed extensively in our earlier weathering section about the various factors of weathering processes, which have also a substantial effect on soil formation in the region concerned. The soils of Mawsynram may be broadly grouped into hill soils and plain alluvium. In some places, we find red loamy soil, fine silt constituting the major fractions. They are also characterised by a very high organic matter and nitrogen content. At other places, we find minimum clay to fairly heavy clay. The soils of the paddy lands around Mawphlang and Welloi are heavy loams and contain a fairly large amount of organic matter.

Analysis of soil

The Indian Council of Agricultural Research complex for NEH Region, of Meghalaya, have carried out sample

soil testing of different places of Meghalaya, including Mawsynram region. A perusal of the above soil test summary data suggests that the entire soil of Mawsynram are deficient in available phosphorus. The low availability of phosphorus in these soils might be due to strongly acidic soil reaction and presence of considerable amount of exchangeable Al in these soils. The content of organic carbon was rated to be high in most of soils of this region. The possible reasons for higher organic matter content may be thick forest vegetations high rainfall and low temperature .

The soil reaction varies from strongly acidic to acidic in nature. Generally, the soils of higher altitudes and belonging to high rainfall areas are strongly acidic (northern part of Mawsynram). The reason of low PH may be assigned to the leaching of the bases from the exchange complex under the prevailing high rainfall (12,000mm) and hilly topography of this region. About 95% of the soils of this region is acidic in nature.

Very meagre information is available regarding the status of micronutrients in these soils. Soils from different altitudes of Mawsynram region ranging from 100 to 1900 m above the mean sea level here analysed for micronutrients.

14. Prasad, R.N, Soil Science, Proceedings of Workshop on Agricultural research complex for N.E.H. Region, Shillong India (1981) pp.89-107.

The contents of total zinc, copper and manganese varied from 10 to 47.25 PPM, 17.0 ppm and 110.0 to 770.0 ppm respectively. The amounts of DTPA extractable zinc, copper and manganese range from 0.72 to 3.28 PPM, 0.6 to 2.8 PPM and 3.0 to 162 PPM respectively. The contents of both total and available zinc and copper did not show any definite trend with the change in altitude and toposequence. However, the content of available manganese in the soils of higher and lower altitudes was almost 50% in the valley land as compared to the slopy land. The information about the content of boron and molybdenum is very scanty. The prevailing high rainfall through out the year in Mawsynram and hilly topography are congenial for lower availability of both boron and Mulybdenum.

Jhum and Soil Properties

The practice of jhum, which is prevalent in this region, affects the soil properties. Burning causes changes in the soil properties:

15. Ibid., pp. 39-107, (1981)

TABLE II (iv) *
EFFECTS OF BURNING ON THE SOIL PROPERTIES.

Soil Properties	Before	After
PH	5.1	5.5
Organic carbon(%)	1.32	1.05
Available P ₂ O ₅ (kg/ha)	3.30	3.31
Available K ₂ O(kg/H _a)	2.19	5.70
Exch. Ca (Meg%)	7.15	9.46

Increase in PH is related to increase in the content of available potash and exchangeable Ca. Burning causes appreciable increase in the levels of available potash and increase in its content depends on the amount and type of burning materials available. Nutrient status of the soil is further subject to alternation due to enormous soil and nutrient losses. In course of erosion, the surface soil is likely to be detruncated and the sub-soil poor in fertility gets exposed to the surface.

Occurrence and distribution of acid soils in Mawsynram region.

The Mawsynram region displays extreme variation in climate, vegetation and physiography. Conditions conducive

*Source: ICAR Research Complex for NEH Region, Shillong, 1982, Meghalaya, India.

for the formation of acid soils in this region are high rainfall coupled with high temperature (at the lower altitude, southern extreme margin of study area, around Balat and Shella, high amount of decomposed and undecomposed organic matters associated with low temperatures at higher altitudes and hilly topography (around Mawphalong, Nongpung, Jakrem and Welloi). These encourage the loss of alkali and alkaline earth metals from the soils.

Characteristics of acid soils:

Besides hydrogen, exchangeable, it is also present in the exchange complex of the soils. It varies from 0.05 to 2.8 Meg% in the soils of Mawsynram. Its contents were found to be more at higher altitude (0.80 meg%) than the lower altitude (0.04 meg%). Iron may also play role similar to aluminum in soil acidity of this region.

The soil of this region contains fairly high amount of organic matter. However, the rate of mineralisation is slow due to highly acidic soils reaction, low temperature, low amount of calcium in these soils.

The content of organic matter increased linearly with the altitude. The valley soils are generally higher in organic carbon than the adjoining uplands.

The study on the effect of topography of potassium in Mawsynram region soils, it was found that the contents of water soluble and exchangeable K were higher in the upland soils than the corresponding low lands. The regions for the lower contents may be related to the lower clay content and leaching in the valley soils. It was also observed that the total content of potassium increased with increase in altitude. Excepting water soluble and exchangeable in the low lands.¹⁶ Variation due to altitude may be related to different geological formation from ancient Archaean gneissic complex to recent sediments of the soils. The soils of north eastern part of Mawsynram around Mawphlang has developed from the granite, Where as the Shillong group of rock is the dominating parent material at welloi and around Mawsynram village of central plateau area.

16. Prasad, R.N.(1981) op.cit, pp.91-93.

Identification of clay minerals in the
soils of Mawsynram region.

Clay is the most active part of the mineral soil mass and is the seat of most of the chemical and physio-chemical reactions. The property of soils viz. swelling, plasticity, moisture, retentions, nutrient fixation and release, buffering capacity etc. are mainly dependent to a large extent on the nature and quantity of clay minerals. Attempt was made to separate clay, Salt and sand fractions from 30 soil samples collected from different altitudes and toposequence (upland and valley land) of East Khasi Hills, including Mawsynram region, of Meghalaya. The results indicate that mica, Kaolinite, chlorite, vermiculite, are some of the important minerals present in these soils.¹⁷

Soil landscapes

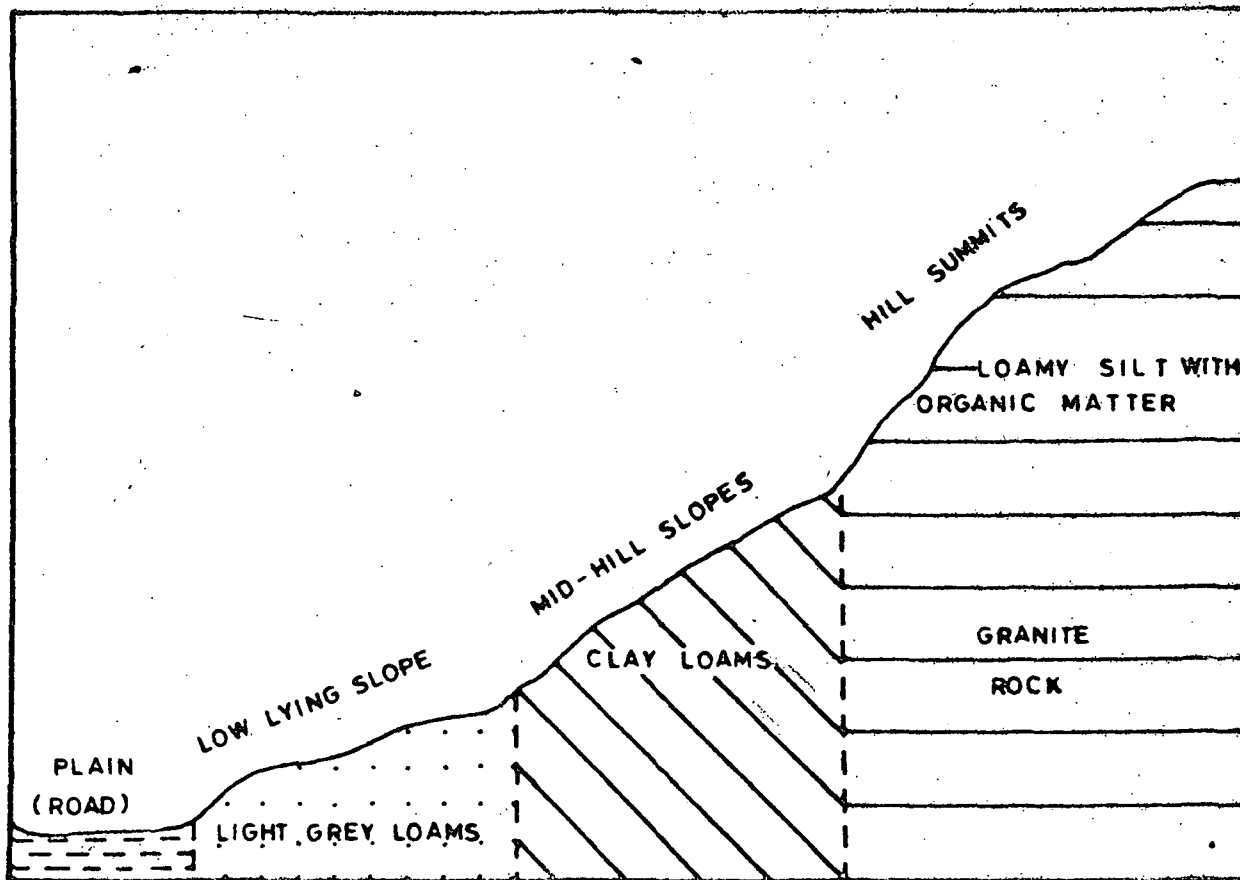
If soils are part of the landscape, the pattern of soils on the ground is the soil landscape. It may be small and occupy an ancient Archaean gneisses of granite surface over Mawphlang, north east portion of Mawsynram

17. Ibid.,(1981), pp.94-96.

region (Fig.6). This soil landscape is called a soil association area. There dominant soils, loamy silt with high organic matter and nitrogen content, clay and loams, light grey loams, are on hill summits, hill slopes, and low lying closed depressions in the water logged landscape, such as pattern of soil sequences originating from the same parent-material but which vary with topography i.e. relief and drainage is termed soil catena. A soil catena is a physiographic complex of soils or sequence of soils between the crests of hills and the floors of adjacent depressions or drainage ways, whose profile change from point to point in the traverse depending on conditions of drainage and past history of land surface. These are the facts fundamental to soil geomorphology.

Thus, the weathering of rock and the formation of soil prepares the land scape for erosion and transport and deposition of eroded debris. The Mawsynram region as a whole is a potential area susceptible to

18. Ruhe, Robert V., (1975) op.cit. pp.42-43.



A SOIL CATENA.
 (Near Mawphlang)

fig-6

large scale soil erosion. Soil erosion by Geological and Geomorphological factors and as a result of human activity is taking place at an alarming rate. Blockage of roads and drainage systems due to land slides, prevalence of shifting cultivation, deep turbid water flowing in the streams, because of heavy rainfall during monsoon period and disappearing of vegetation cover in certain pockets are indicative of the seriousness of soil erosion problem.

CHAPTER - III

DRAINAGE AND ITS EVOLUTION

"All these varied and wonderful processes, by which water mightily alters the appearance of the earth's surface, have been in operation since the most remote antiquity".

AGRICOLA, 1546

INTRODUCTION:

The significance of drainage in the evolution of the landscape, has long fascinated geomorphologists, hydrologists and geologists. 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 in them and to the rivers by which the waste is washed along the channel in the valley floor, (W.M.Davis, 1900). In this connection our present discussion about the drainage and its Evolution have been very much in use in understanding the geomorphological character of the region concerned.

The Mawsynram block area is drained by the rivers Umnagi, Umiew or Bagra and Umparsumai. These rivers discharge their water through various deep channels into the Bangladesh Plain. The Umnagi collects its feeders like the Umiyngkhol, Umnongspung, Ummānrat and

Phud-symper. The Umit and Umsawrata excavating their courses, unite with the Umnagi in its lower course along the south-western part of Mawsynram block. The Umiew or Bagra, having its source in Smith area, south of Shillong city, enters in the area under study near east of Tanglang village and after travelling along the eastern margin of Mawsynram, block, finally reached the Bangladesh Plain near Shella. It collects several streams on its left and right banks. The Umparsumai is the most important river of south Mawsynram.

In making an analysis of the rivers and valleys of Mawsynram, an attempt is being made to seek the causes of the location of the streams in their present courses and to go back, if possible to the early date. The story of the drainage and landscape evolution of the Shillong plateau has been discussed earlier by Evans (1964)¹ and R.P.Singh (1968)², they have expressed their views of massive headward erosion along the joints by antecedent streams, and the control exercised by the well-jointed cretaceous-Tertiary sand stone cover. Further south of

1. Evans, (1964) Oil India, A brochure for 22nd I.G.C., India, New Delhi.

2. Singh, R.P. (1968) op.cit. Gauhati, p.1-9.

study area the consequent streams are mostly controlled by the structures (monoclines and faults) in the sediments. The present form of drainage pattern was attained through different geological events since Mesozoic to present day (described in chapter-1, on structure and tectonics) as indicated by the polycyclic erosional surface at various levels.

The natural history of a river, its morphology and growth, will be treated in relation to its geological structure, and varying activities in different stages. The revival of the river's lost energy will be examined as it enters a new cycle of life.

II- Drainage Divides

The drainage divides delineate macro and micro river basins and enlist various orders of streams which ultimately describe the drainage network. The major drainage axis runs in a zigzag fashion from north to south. The primary divide outlines, the Umnagi and the Umiew or Bagra basins. The secondary divides mark the Umiyngkhol, Umnongspung, Phud symper, Umkynrem, Umsaikha, Umduma, Umjangut, Umktang and Umnokria basins (Fig.7).

MAWSYNRAM
DRAINAGE DIVIDES

0 mile



fig-7

A glance at the drainage divides map (Fig.7) of Mawsynram would reveal that the drainage system of this area is to a great extent directed by the structural platform zone, extended from north to south, which act as the watershed, from where the various small streams, flow down in a east and west direction towards Bagra and Umnagi river valley.

The area under study has low undulating divides in its northern part but in the southern portion, it has deep dissected section of divides. On the basis of their nature character and expressions the divides fall under two categories:

- (i) Former accentuated divides with undulating Character, and
- (ii) Young divides dominating the landscape in form, feature and number.

The divides of the former type generally occupy the ancient (pre-cambrian) polycyclic surface in the northern part. Second category of divides occurs on scarps, southern dissected tract over the Cretaceous-Tertiary and Post-Tertiary surface. The pattern of

divides protrays drainage patterns³. Thus the pattern of divides has equal significance to the pattern of drainage.

III- River Basins

The drainage divides have outlined macro and micro river basins. These basins, to a large extent, span over Archaean gneissic complex with acid and basic intrusives, Shillong group of rocks, Lower Gondwanan rocks, Sylhet Traps and Cretaceous-Tertiary sediments. The alignment of the major and minor joints control the drainage lines of Mawsynram. The study of the drainage maps shows that the drainage pattern in the region represents a most spectacular feature revealing extraordinary straight courses of the streams, evidently along joints and faults⁴. The magnificent gorges scooped out by the streams, such as Umpursumai, Umnokria, Umktang and Umsaitkha in the southern part of Mawsynram are the result of massive headward erosion by antecedent streams, along joints of the sedimentary rocks over the block, experiencing relatively greater uplift during

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3. Kumar, A. (1979) Geomorphology of Simdega and its adjoining area, Bihar. The National Geographical Society of India, Banaras Hindu University, Varanasi, Pub.No.22, p.23-42.
 4. Mathur, L.P. & Evans, (1964) 'Oil in India', International Geological Congress. Twenty Second Session, India, New Dehi.

Tertiary period. The northern part of Mawsynram, devoid of any sedimentary cover, is marked by long incisive valleys of ummanrat, umjangut and phudsymper, formed due to headward erosion along joints in the gneissic rocks and granites. The limestone covered country over the southern Mawsynram represent a typical karst topography, cut deeply by the short tributaries of umnagi and Bagra river.

I-The Umnagi Basin

The Umnagi river basin is the most extensive and by far the most important. This river system rises from the southern slope of Sohieng at an altitude of 6053 feet (at $25^{\circ}29'N$ $91^{\circ}43'E$), flowing to south west it runs along the northern and western part of the study area. This river enters Mawsynram region after receiving several tributaries from the granite country of Mawphlang. It is united with the Umnongspung at an altitude of 4580 feet. The other tributaries, Umjarang, Phudsymper and Phudstew join with the river Umnagi at an altitude of 4500 feet, 4000 feet, and 3290 feet respectively. In the south-western part of Mawsynram, at an altitude of 645, 525, 203 and 150 feet, the feeder streams such as

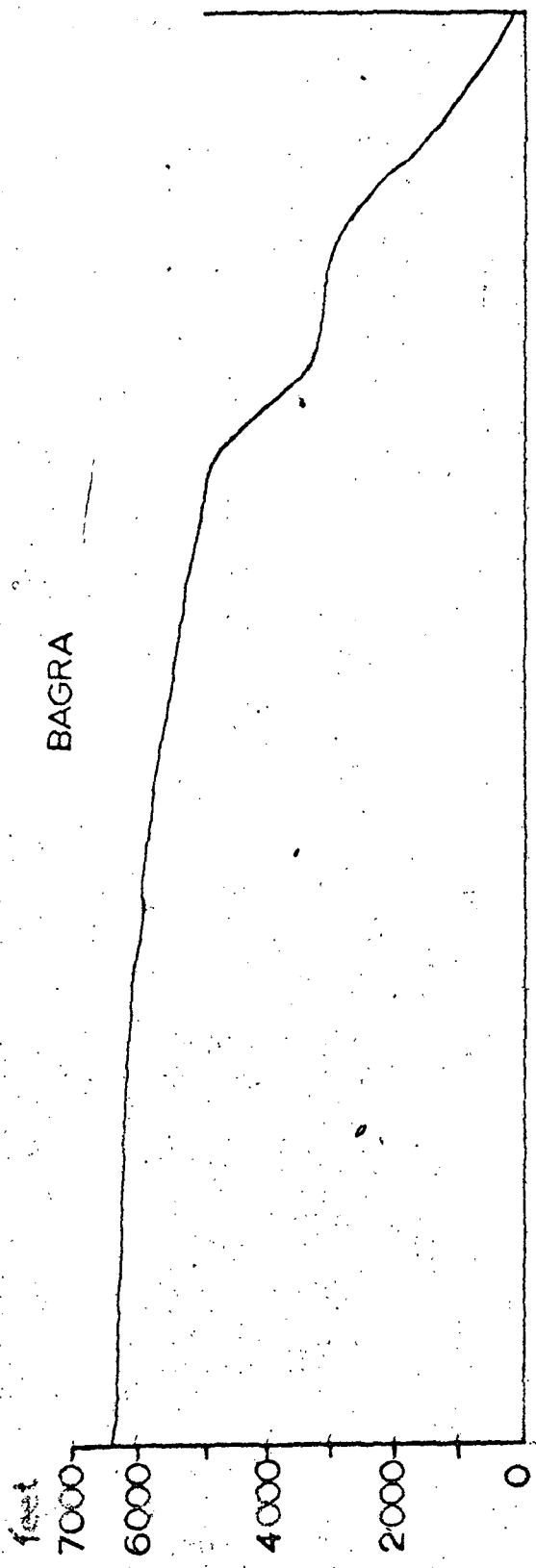
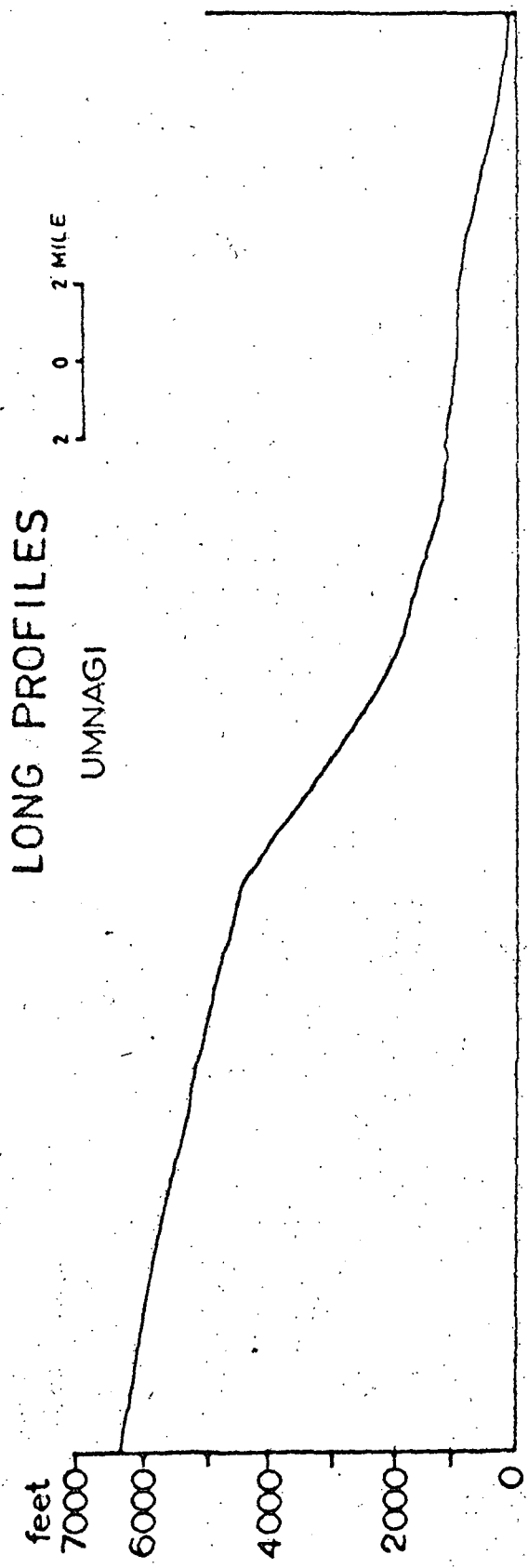


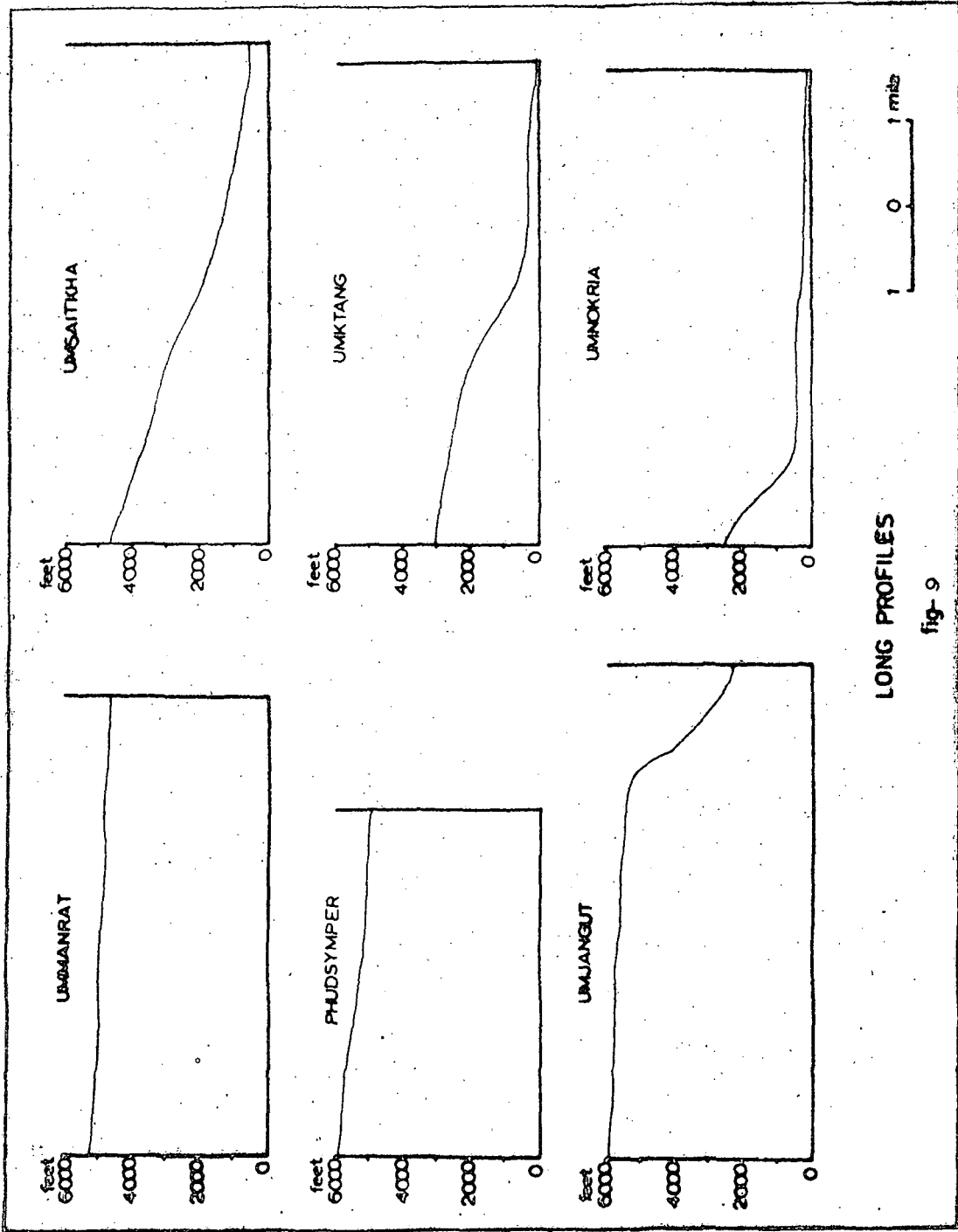
fig-8

Umlt, UmsaUrata, Umjajuh and phud shylla have joined in the lower course of the river Umnagi, and finally near Kathalbari it has reached the Bangladesh plain.

The Umnagi meanders infrequently being admirably controlled by the joints over the granite-gneiss surface of Mawphlang and Nongsoung and reveals some of the depositional (Plate-11) and erosional marks wherever it takes a significant direction, joint direction guides the course of the Umnagi (Plate-12) and its feeders. The consequent stream of south are mostly controlled by the structures-faults and monoclines in the sedimentary rocks surface. The long profile of the Umnagi (Fig-8) shows one significant break-in-slope at 4550 feet, where it dissects the scarps.

(i) Ummanrat Basin

The Ummanrat is a major tributary of the Umnagi. It rises in the north extreme part of Mawsynram and flows in south-western direction over the Shillong group of rocks and Archaean gnisses complex rock surface of sohphoh. At sohphoh village the ummanrat join with umnagi and has formed a larger stream at an altitude of 4687 feet. Its long profile (Fig-9) shows very



gentle slope from its origin upto mouth.

(ii) Umiarang Basin

This stream rises in Jakrem area and flows towards north-east direction and has joined with the Umnagi at an height of 4716 feet. A hot spring is marked, just few kms. away from the main river Umnagi, over its bed.

(iii) Phudsymper Basin

Most of its feeders have their sources at an altitude of 5827 feet over the gneissis complex surface around symper peak and has formed a radial pattern of drainage. This small stream drained the hearts of Mawsynram region and then passes, through Mawlynu and Mawhiang villages and join the Umnagi, forming deep gorges at junction, at an elevation of 4000 ft. The long profile of Phudsymper (Fig-9) shows no significant breaks-in-slope, and it carves out a deep gorge near its mouth.

2. The Umiew or Bagra Basin

The Umiew or Bagra basin is an extensive valley of the northern Cherrapunji Plateau. This river rises from the southern slope of Smith area, at an

elevation of 6094 ft., enters the study area near Tanglang village and flows further south along the eastern margin of Mawsynram, by cutting deep valleys through the creataceous (chalky) sandstone and limestones. In many places older rocks like the gneiss and schists have been exposed along its bed. The basin of Umiew or Bagra river has separated the Mawsynram region from the Cherapunji platform and finally reached the Bangladesh plain near Shella.

The feeders of the Umiew form a drainage net in relation to the granite and sedimentary joints. The important tributaries of this river system, which have mostly drained the entire eastern and north eastern part of Mawsynram are: Umduma, Umjngut, Umkynrem and Umsaitkha. The long profile of the Umiew shows (Fig-8) two important break in slope, at an elevation of 5000ft. and 3050 ft., where it carves out deep gorges and the nick point is marked by beautiful water falls.

(1) Umjngut Basin

The Umjngut rises from southern slope of painsanngut village at an altitude of 5735 ft. over the Archaean gneisses complex surface of Nonglewai

area. This stream drained the north-eastern part of study area and after flowing towards south it meets the trunk river Umiew at an elevation of 2215 ft. The long profile (Fig-9) of Umjugut shows a significant break in slope at a height of 4800 ft. A beautiful waterfall is marked in its mouth just before meeting Umiew.

(ii) Umkynrem Basin

This stream originates from the Laitmawsiang village at an altitude of 5513 ft. over the Shillong group rocks and Archaean gneissic complex rocks surface of central Mawsynram region. After flowing through the villages such as Mawlynu and Saitshilliah, it has formed a deep gorge before joining the Umiew at a height of 1750 ft.

(iii) Umsitkha Basin

This is a small stream basin, which originates along the eastern slope of Mawsynram village at an elevation of 5000 ft. The long profile of the Umsaitkha (Fig-9) shows two important breaks-in-slope, at an height of 3000 ft. and 1500 ft. where it dissects the

scarps. The nick point is marked by a waterfall, 2 km south of Mawsynram, near P.W.D., I.B. The lower scarp also registers a nick point which is marked by another small water fall of 120 ft. The stream finally meets with Umiew near the village Sinei at an elevation of 504 ft.

3. Umparsumai Basin

This drainage basin is the most important basin of the southern part of the study area. It rises in southern slope of Mawsynram village at an altitude of 4500 ft., flows in the south east direction, along the steep slope of the terrain. It has formed two waterfalls of 120 ft. and 150 ft. in its upper reaches, at escarpment facing Bangladesh plain. The Umparsumai meanders over the older alluvium surface for a short distance, before reaching the plain of Bangladesh near katrang village at a height of 410 ft. The Umnokria is most important tributary of this river. The long profile of this stream shows a significant break in slope at a height of 1000 ft. (Fig.9).

4. Umktang Basin

It is a small basin, situated east of Umparsumai basin in south Mawsynram region. Umktang originates from



Mawlyngbna area, at an elevation of 3078 ft., flows towards south over the older alluvium surface of Mawdon region and finally reached Bangladesh Plain near Hat Mawdon, West of Shella Bazar, at an altitude of only 50 ft. Its long profile(Fig-9) shows one important break-in-slope at a height of 2000 ft., where a small water fall is marked.

If one looks at the drainage map of study area (Fig.7)*, it reveals that there are many other small streams of Umnagi, Umiew and Umparsuma; whose courses are controlled by the geological structure and in many places in upper reaches of these rivers, they have adopted very awkward course to avoid the resistant Archaean gneissic complex rocks and Shillong group rocks surface. The main river Umnagi and Umiew seem to be in old stage of cycle of erosion in their upper reaches but youthful in the lower stages.

IV- Pattern of Drainage

An outline of the macro and micro basins defines the varying orders of stream system, but an analysis of the composition of each type of basin brings out distinctly the pattern of drainage. Drainage patterns refers

*Please see the drainage divides map(Fig.7) as the drainage map of Mawsynram.

to the particular plan or design which the individual stream-courses collectively form. 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 evolutions.⁵

The drainage map of Mawsynram (Fig.7) reveals the following four types of drainage pattern (viz,

- (i) Rectilinear pattern ;
- (ii) Radial pattern ;
- (iii) Semi-dendritic pattern;
- (iv) Parallel pattern;

(i) Rectilinear pattern

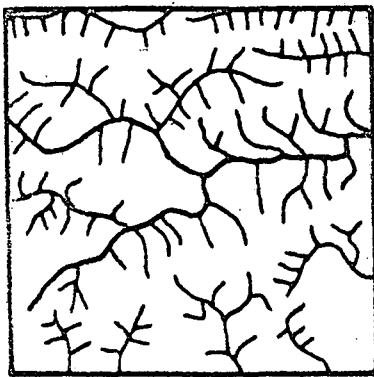
In rectilinear pattern, stream bends and junctions are approximately at right angles. A system of well developed joints, fracture zones or small faults may give rise to such a drainage pattern (Fig.10).

If we examine the drainage map of Mawsynram (Fig.7)* we find the northern tip and extreme south portion of study area is dominated by well-developed

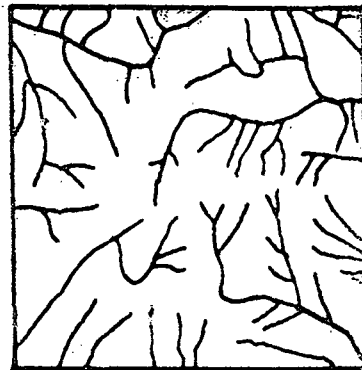
5. Zernitz, E.R., (1931): Drainage pattern and their significance' J. Geol, Vol, 40, pp. 498-521.

* Please see the drainage divides map (Fig.7) as the drainage map of Mawsynram.

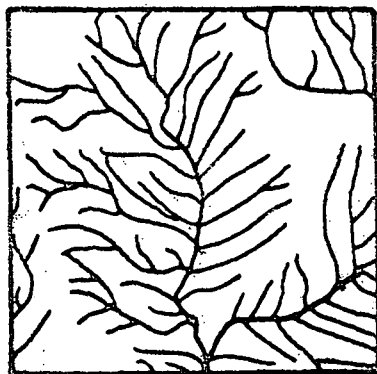
DRAINAGE PATTERN



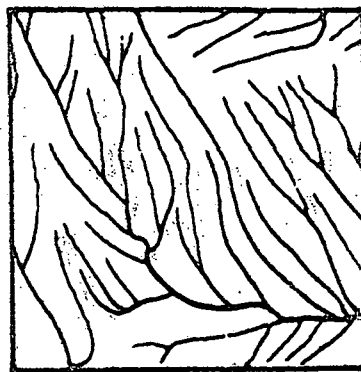
Rectilinear



Radial



Semi dendritic



Parallel

0 ——— 1 mile

source: Toposheet No 78⁰/₈ 78⁰/₁₁ 78⁰/₁₂

fig-10

rectilinear drainage pattern, by stream Ummanrat and its tributaries and Umparsumai and its tributaries. Some of them appear to represent faults, many of them are master joints and fractures and whole pattern has been developed due to uplift of this region along with Shillong plateau during Tertiary period.

(ii) Radial Pattern

In this pattern, streams extend outward along radial from a common centre like the ribs of a fan. This type of drainage pattern develops on flanks of domes and volcanoes, where there is no effect of differing rock resistance.⁶

In Mawsynram, most prominent areas of such pattern (Fig.10) are situated in the central part where the stream phudsymper and its tributaries drain areas around isolated symper peak (5827 ft). This pattern has developed here because the characteristics of the underlying rocks around symper peak are uniform and the relief consists of isolated hills of great heights. A few prominent radial patterns are also found in south-eastern part of Mawsynram.

6. Schumm, S.A. (1973) Fluvial Geomorphology in river mechanics River Morphology (Ed.)

(iii) Semi-dendritic pattern

The dendritic drainage pattern is like that of limbs branching from the trunk of a tree.

Small streams in eastern Mawsynram for example Umjngut and Umkynrem belong to this category (Fig.16). As our study area underlies a very complex geological structures and a large part is covered with very steep slope, there are a few well developed dendritic drainage pattern marked. This type of drainage pattern develops, where geological structure is simpler and particularly over the surface of horizontal, uniformly erodible sediments or uniformly resistant crystalline rocks with gentle regional slope.

(iv) Parallel pattern:

In the parallel pattern, main streams have parallel courses as to tributaries. Parallel landforms such as sandstone ridges and steep regional slope play a significant role in the development of such pattern.

In our area under study, the slope increases from north to south and finally in the extreme south, the slope is very steep forming an escarpment facing the

Bangladesh Plain. A few parallel pattern of drainage are notice in the southern part, which flows parallel along the steep slope of the terrain. The Umsaitkha stream and its tributaries in the south display a typical parallel drainage pattern (Fig. 10).

(v) Stream Frequency (FS)

Stream frequency shows the number of streams per unit area. This is one of the most important morphometric analysis of the drainage basins. Horton (1945)⁷ defines drainage frequency as the total number of streams in a drainage basin divided by the areas of drainage basin.

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

Whose, 'FS' is the stream frequency, 'N' is total number of streams in a unit area, and 'A' is the unit area.

From the one inch topographic sheets

$$(NO-78/\frac{0}{7}, 78 \frac{10}{18}, 78 \frac{0}{11}, 78 \frac{0}{12})$$

a drainage map of the Mawsynram region is prepared and and it is then divided into one inch grids north-south

2. Horton, R.E. (1945) op.cit. pp.275-350.

and east-west, representing an area each block one Sq. miles on the surface. The total number of stream crossings are counted for each Sq. which represent the number of stream per one sq. miles. For the preparation of a isopleth map, to study the spatial variation of stream frequency over the surface at different parts of the study region, all these figures are grouped into following five categories:

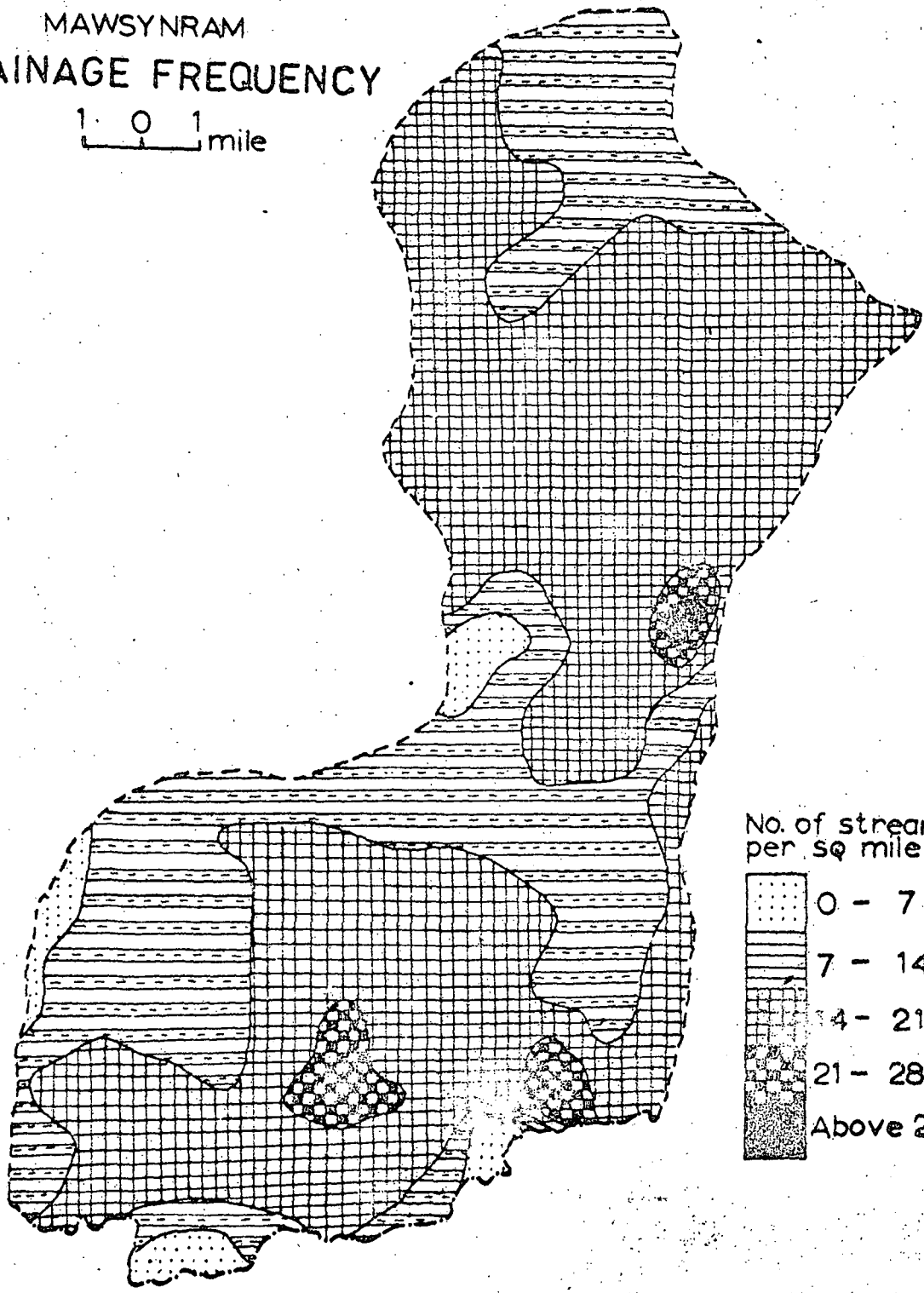
TABLE III(1)

Sl No.	Texture	Stream category	Frequency
1.	Coarse	7	Low
2.	Moderately coarse	7-14	moderately low
3.	Medium	14-21	Moderate
4.	Fine	21-28	High
5.	Very Fine	28	Very High

An examination of isopleth map of stream frequency (Fig.11) would reveal that more than half of the study area is covered by the category of moderate stream frequency, i.e. 14-21 streams per sq.mile, in the north-western and central parts of the region. The next most

MAWSYNRAM
DRAINAGE FREQUENCY

1 0 1 mile



No. of streams per sq mile

[Stippled pattern]	0 - 7
[Horizontal lines]	7 - 14
[Vertical lines]	14 - 21
[Fine grid]	21 - 28
[Dense grid]	Above 28

fig-11

important, moderately low category, (7-14) streams per sq.mile, occupy the extreme northern and southern margin of Mawsynram. The areas of high and very high, 21-28 and above, stream frequency per sq.mile lie in the central and southern part of region in two major patches delinked from areas of moderate stream frequency. The low stream frequency per sq.mile is found in extreme south and south-western belt of the study area.

From the isopleth drainage frequency map of Mawsynram region, it is clear that the central and north-eastern part has a higher frequency than that of the north-western and south-western part. In the former, an extensive area of 21 to 28 and above drainage frequency per sq.mile is marked along the eastern slopes, but in the plateau region its number has drop down to 14-21. This higher frequency may be attributed to the high rainfall and the lithological and structural characteristics of the Archaean complex, the Shillong group of rocks and Cretaceous-Tertiary sediments, having sufficient relief and areas of dissection along the Mawsynram eastern scarp, and the Umiew of Barga basin. To large extent rainfall plays a major role in the

development of streams. As this part of the Mawsynram receives heavy rains for around 222 days (more than 12,000 mm) in a year, it influences directly the quantity and character of run off. Heavy rainfall throughout the year is perhaps, the most important single factor influencing the drainage frequency of the area under study.

Permeability of the mantle rock and relief also to some extent play important role in the development of drainage frequency. Greater relief along the Mawsynram structural platform presents favourable conditions for the development of numerous streams towards the Umiew and Umnagi river basin in the eastern and western direction. The hard granite surface over the Mawphlang area does not allow large amount of percolation and hence surface runoff is high, and a large number of small streams originate over its surface, join the main river Umnagi and Umew or Bagra.

In the middle of umparsumai basin, a small pocket of high frequency is marked (21 to 28 streams per sq.mile) this may be attributed to that region which has a plateau like topography, with a great relief along the scarp face.

In the southern extreme margin of the Mawsynram, near Bangladesh Plain, the stream frequency is between 7 to 14 and even below 7 per sq.mile. This is mainly due to the lack of relief (average 250 feet) and the presence of highly permeable rocks of the Cretaceous-Tertiary sediments.

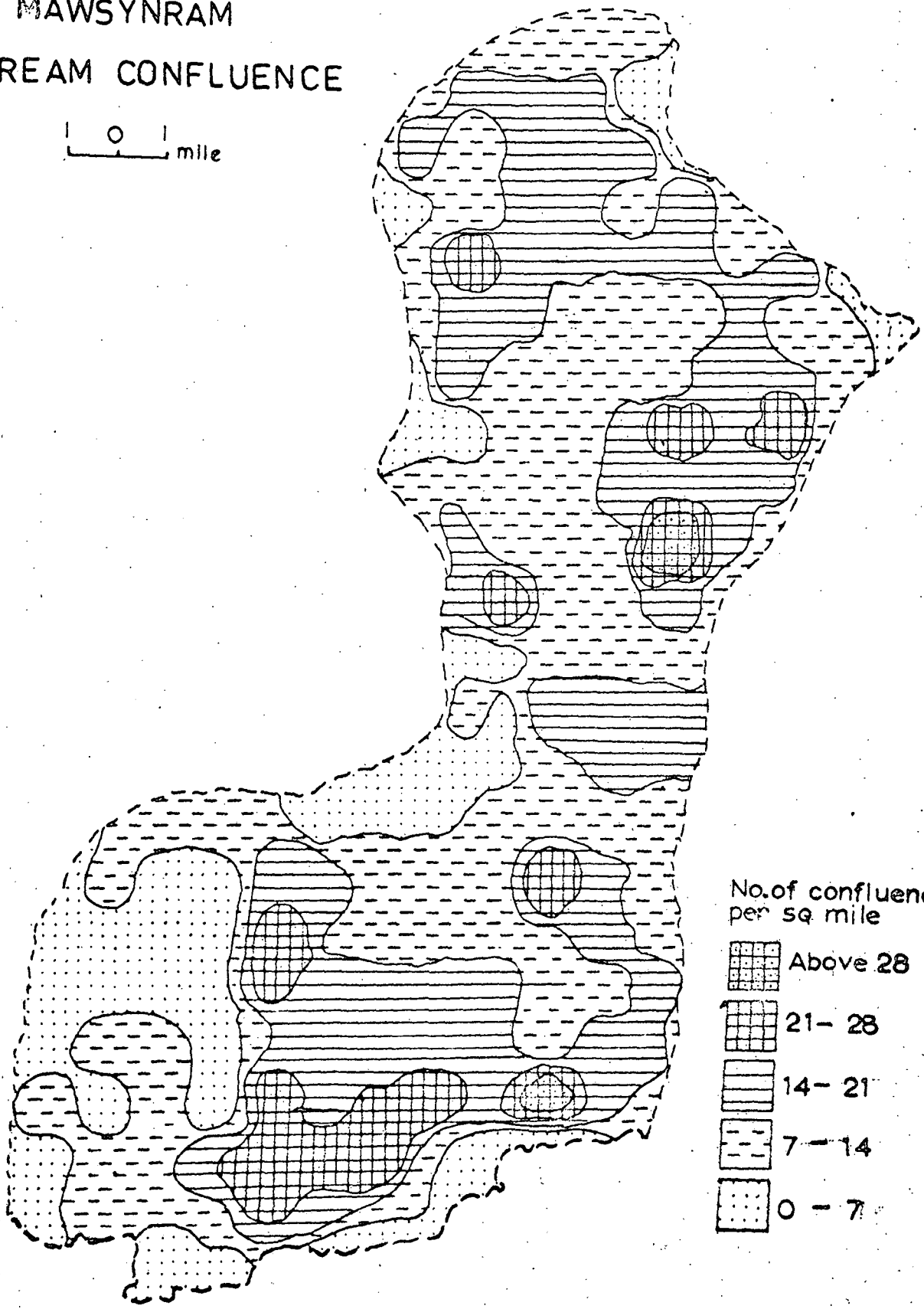
(vi) Stream confluence point

The growth of drainage basin records the evolving number of stream channels which unite to form confluence points. The distribution of confluences per unit (Fig.12) along with the earlier discussed distribution of the number of streams (Fig.11) expresses the phases of evolution. The distribution map of stream confluence have been prepared for Mawsynram region by using isopleth techniques to bring out their genetic planning for forming drainagenets. The confluences and stream sources has been counted in one sq.mile, from the one inch toposheets and their respective figures have been inserted to draw isopleths.

The greater the number of stream source and confluence, the greater is the drainage dissection. The isopleth map showing stream confluence density(Fig.12)

MAWSYNRAM STREAM CONFLUENCE

1 0 1
|-----|
mile



No. of confluence per sq mile

	Above 28
	21-28
	14-21
	7-14
	0-7

fig-12

express five density categories. The number of confluence per sq.mile is above 28 in first category and their minimum number is less than 7 in the fifth category. The maximum number of confluences per sq.mile is located in the north-eastern fringe. Other four categories lie around them. The isopleth map indicates the trend and pattern of each of the five categories, grouped in three major density categories viz. maximum, moderate and minimum density of confluence points.

The north-central undulating country of Mawsynram, the areas around nongspung, welloi etc. have a density of 7 to 14 confluences per sq.mile. The area of highest density of confluences per sq. mile are two in number and lie on north-eastern and south-eastern margins near mosingi and Mawdon respectively. The density of 21 to 28 lie in several small pockets on north-eastern, north-western and south-western part of the study area. The maximum stream confluences per-sq.mile are observed in southern and south western fringe.

TABLE III(ii)DENSITY OF CONFLUENCE

Categories	No. of confluence	Confluence category
i	Above 28	Maximum
ii	21- 28	
iii	14- 21	Intermediate
iv	7- 14	Minimum
v	below 7	

The confluence of streams concentrates along the valleys of umnagi and Umeiw or along the ridges and scarps of Mawsynram structural platform. Due to steep slope, stream gains good velocity which is required for the effective removal of debris from the foot slope. The minimum number of confluences reveal less dissected parts towards extreme south, near Bangladesh plain. The intermediate number of confluences per sq. mile defines dissection, better span of excavation and lengths. The master stream like Umnagi, Umeiw, Umparsumai and Umktang etc. have accordant confluences and they all are showing youthfull features like long deep gorges, potholes, and water falls.

vii-Drainage Texture

Drainage texture implies the relative spacing of drainage lines. Horton (1945)⁸ states what we commonly refer to as drainage texture really includes both stream frequency and drainage density. Stream frequency of Mawsynram region has been shown by isopleth (Fig.11). This map showing number of streams per sq. mile. The isopleth trace the trends of the density categories of the number of streams per sq.mile.

Their density categories numbering five can be summed up into five categories viz. very fine, fine, moderately coarse, and coarse texture of drainage (Table III(1)).

The area of very fine and fine texture of drainage seems to concentrate in the north-eastern part of the region along with high stream frequency, i.e. 21 to 28 and above stream per sq. mile. The area of medium drainage texture, lie in the north-western and central part of Mawsynram region, with a stream frequency of 14 to 21 stream per sq.mile. The area lying in southern and south-western parts of region is marked by moderately coarse and coarse texture of drainage,

8. Horton, R.E.(1945) op.cit.,pp.275-350.

with a very low frequency of streams per sq.mile, i.e., 7 to 14 and below 7.

The above study establishes the following facts:

- (a) The number of streams and confluences coincide with that of drainage texture.
- (b) The relation between stream and confluences is obvious in the area of radial drainage system, particularly around the Phudsymper peak (5827 ft.) of the study area.
- (c) In radial pattern, where number of streams are many, the number of confluences may remain few or nil. This type of contrast is found over Phudsymper peak(5827 ft) of central Mawsynram plateau and primarily over the granite domes areas of Mawphlang.
- (d) The high dissected areas of east, north-eastern and South-western parts of Mawsynram is marked by large number of streams and confluences. The feeders in these areas has formed deep gorges
- (e) Fine drainage texture corresponds to the areas of high relief. The areas of low-relief, in

southern extreme parts of Mawsynram, close to Bangladesh plain, are the areas of coarse drainage texture.

The study of stream frequency and confluence, expresses the influence of lithology, structure, climate and slope on drainage texture. Its further analysis leads to the study of the drainage density.

viii- Drainage Density (Index of texture of dissection)

Horton (1945)⁹ defined drainage density as the total length of the stream (L) in a given drainage basin divided by the area of the basin (A). The drainage density then is simply a length per unit.

Using the above formula, the drainage map of Mawsynram region is divided into one inch grids, north-south and east-west, representing each grid one sq. mile on the surface. The total length of streams are measured for each grid, which represent the length of streams per sq. mile. Then a isopleth map of drainage density is prepared which tract the trends of the drainage density categories per unit area.

9. Horten, R.E., (1945) o.cit. pp. 275-350

An analysis of the isopleth map (Fig.13) showing index of texture of dissection per sq. mile shows the distribution of drainage density. Its implication is further revealed when it is compared to the stream frequency map showing number of stream per sq. mile. The isopleth map traces the tendency of each five category. To avoid complications and elaborate description only three major categories of drainage density viz. high, moderate and low are being accepted for analysis.

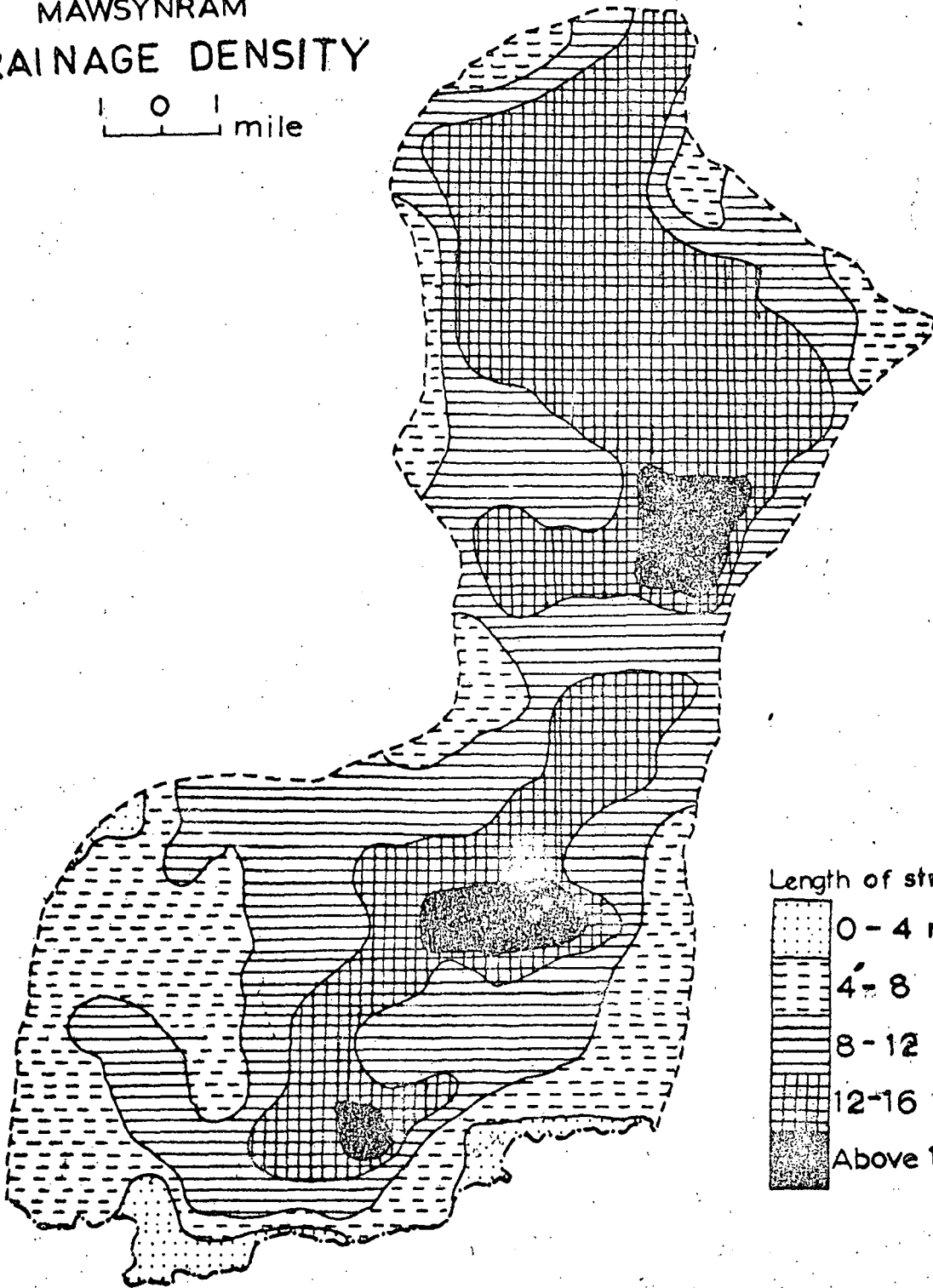
TABLE III(iii)

Sl No.	Categories of stream length(in km)	Drainage Density or Texture of dissection category.
1.	below 4	Low
2.	4 - 8	
3.	8 - 12	Moderate
4.	12 - 16	High
5.	above 16	

High drainage density of texture of dissection finds expression in north-eastern, south-eastern and central part of the area under study. They are scattered over the scarps along the eastern slope towards the Umiew river valley. They show a density of 12 to 16 or more kms.

MAWSYNRAM DRAINAGE DENSITY

0 | mile



Length of streams per square mile

- 0 - 4 mile
- 4 - 8
- 8 - 12
- 12 - 16
- Above 16

fig-13

drainage length per sq.mile lie over the south-western, western and south-eastern of the region and arranges in the adjacent area of high drainage density. The low drainage density category confined mostly to the lower relief surface of Balat, Mawdon, Kathalbari and south-western corner of study region. This represented lower basins of rivers and low lying surface near Bangladesh Plain.

The stream frequency map (Fig.11) and density map (Fig-13) combinedly further reveals the following facts:

(i) The areas of high stream frequency with 21 to 28 and above number of stream per sq.mile coincides with the areas of stream length with 12 to 16 kms and above per sq.mile, indicating high drainage density or texture of dissection.

(ii) The lands with 14 to 21 number of streams per sq.miles and 8 to 12 kms. stream length per sq.mile showing moderate drainage density or texture of dissection.

(iii) Below 7 and 7 to 12 number of streams per sq.mile with below 4 and 4 to 8 kms. of stream length per sq.mile areas revealing low drainage density or texture of dissection.

(iv) drainage density is related to the number of streams and confluences in the study area.

Climatic elements like precipitation determines directly the quality and character of run-off. The Mawsynram region registers annual rainfall of over 12,000mm. The greater per centage of rainfall runs off immediately creating many surface drainage lines. Soil is also another factor to control surface runoff. Permeability of the mantle rock is most dominant factor that influences the drainage texture. The granite and gneiss complex impermeable terrains of a area are characterized by fine drainage texture. Initial relief rock structures, rock-massiveness, joints and fault-infested terrain also control the drainage texture. High relief promotes the excavation of river valleys favouring the development of numerous headward eroding streams, particularly around the plateau region of Mawsynram, is very much distinct from the map. The eastern scarps facts of plateau is responsible for the development of countless drainage exhibiting fine drainage texture.

ix. Denudation Chronology

The history of the major rivers in Shillong Plateau, including the present study area have concerned geomorphologist and geologists since a long time and

this interest persists to the present. Here an analysis of drainage system in relation to the present framework of Mawsynram region helps us to prepare a denudation Chronology of the recent past. If we project our systematic knowledge of the drainage organization in any morphological segment, it may be possible to set out a chronological development of drainage from the pre-cambrian till today. The ancient mountains act as base to reconstruct the probable profile of the then morphology, where we can not only prepare the model of drainage upon the structure, but can also trace the denudation chronology to represent its morphological history.

The primary solidified landmass of Mawsynram during Pre-cambrian period was uneven where initial drainage might have evolved. The primary eroded materials were deposited in the initial troughs. The Archaean earth movements corrugated the sedimentary layers and converted them into complex folded structures. The Mawsynram Plateau dips steeply on its southern border. The denudation chronology of the Mawsynram region thus, took a concrete shape in sympathy with folded structures. The drainage plain was more or less similar to the

10

drainage organisation of the tertiary fold mountain.

The Umnagi and Umiew or Barga with some of its tributaries and streams might have remained as Archean river. The geographical cycle seems to have been intervened by the pre-cambrian emission. This effusion might have been marked by the following drainage features:

- (i) Many truncated streams such as umnagi and umiew or Bagra appeared over the former surface without their source drainage.
- (ii) Cooled lava surface constituted a hybrid of the stream organisation. These evolving stream either form the new feeders of the truncated rivers or some of them carved out their independent valleys.

The drainage history of the area might have undergone a great modification with the peninsular India, when it wandered from its ancient anchorage with super continent of Gondwana land to be tucked in to Asia. In the new environment the land scape story was outlined and defined with the change in the boundary of land and sea.

The Jurassic emission finds its expression in the southern part of the area. This emission is popularly known as Sylhet trap which no doubt brought a modification in the former drainage by burying topography. During this period the drainage might have modified in the following manner.

- (i) The Southern small streams of Mawsynram, such as Umnokria, Umktang, Umparsuma and Umsaitkha with their tributaries were buried.
- (ii) The large rivers like Umnagi and Umiew or Bagra remained as truncated streams either in source regions or also in the remaining streams.
- (iii) The cooled lava formed a structural surface over which new drainage lines evolved.
- (iv) Cycle thus initiated by this Jurassic intervention might not have run its full course as marine transgression brought change.

The Southern extreme part of Mawsynram plateau recorded marine transgression during the Cretaceous period, which seems to have affected the previous drainage cycle in following manner:

- (i) The river valleys such as Umnagi, Umiew or Bagra, Upparsumai, Umkatang and Umsaikha were drowned outlining the coasting of that period.
- (ii) The aggradational features like delta formation on the junction of land and sea, flood plain along the above mentioned river valleys might have been registered. As now its remnants found along Balat to Shella on Southern part of Mawsynram region.

The marine regression began and marine tongues, bays and bights again appeared as land of low relief in south. The landscape cycle initiated with this change in the level was marked by the following noted features:

- (i) The former rivers extended their courses over the newly emerged surface.
- (ii) Some consequent streams of umnagi and umiew or Bagra might have also been initiated.
- (iii) The older rivers like umnagi and Bagra might have excavated new valleys in the old one and with the progress of cycle the outstanding features were gradually obliterated.

The one dominating fact to influence Mawsynram region denudation chronology is epeirogenetic event of the Tertiary period, which has formed the present morphology and drainage systems. The changes that might have took place during this period is as follows:

(i) The southern scarp section of Mawsynram rise steeply and comes under the sway of the summer monsoons, recording high precipitations in this region.

(ii) Elevated peneplain has remained an average elevation between 1350 to 1800 mts. above sea level.

(iii) Each break-in-slope expresses useful features. River valleys of umnagi, Umiew or Bagra, Phudsymper and Umparsumai etc. bound in water falls, rapids, imposing gorge pot-holes, discordant Junctions mark such breaks.

(iv) The deep engravings of the recent periods the undulating peneplains with graded river valleys dominate the central Mawsynram structural platform.

(v) The Umnagi, Umiew or Bagra, Umkatang, Umparsumai, Umnokria, Umsaitkha and host of other small streams dissect its south-eastern, souther and south-western part.

The Tertiary Landscape cycles explain most of the elements of landscape outlined above. The Mawsynram plateau presents a polygenetic landscape which defines peneplains at different altitude. Many of the subdued hills appeared with the uplift and formed axis of new drainage line. The radial pattern of drainage over granite surface of symper-peak(5827 ft) at central Mawsynram region stands a contrast to the semi-dendritic drainage pattern eastern region. The southern extreme part is dominated by rectilinear drainage pattern, which has developed with master and minor joints and the whole pattern has been developed due to uplift of this region during the Tertiary period. On the basis of the above discussion it can be concluded that the river systems of Mawsynram region have probably been stable at least during the late Tertiary and perhaps little bit earlier. There is no doubt that the phases of denudation chronology of the study region are not one but consists of several chapters. The simplest and therefore first hypothesis we should adopt is that the past resembled the present, and thus we should use

observation and interpretation of the present as fully as we may in reconstruction of the past, and only go beyond it when its capacity to explain is exhausted.

(Jones, 1976, p.11¹¹). Thus only through the complex denudation chronology study, we will be able to assess the antiquity of the present river systems and complicated landscape evolution of the Mawsynram region.

11. Bishop Paul(1982):"Stability or change: A Riview of lands on Ancient Drainage in Eastern New South Wales", Australian Geographer, Vol.15.pp.219-229.

CHAPTER - IV

MORPHOMETRIC ANALYSIS OF THE SIX SMALL DRAINAGE
BASINS AND THEIR GEOMORPHIC SIGNIFICANCE

"When you can measure what you are speaking about and express it in numbers, you know something about it, but when you can not express it in numbers your knowledge is of a meagre and unsatisfactory kind".

LORD KELVIN

INTRODUCTION

'Morphometry' refers to the measurement of the shape or geometry of the landform elements in the context of 'Geomorphology'. The need for the study of the drainage basins through 'Morphometric Analysis' has been derived from the two main sources i.e. firstly, to provide an empirical description of the inherent characteristics and to describe the form from relationships of the Morphological systems and secondly, to analyse the underlying inter-relationships of the landforms and processes associated within the basins. (Doornkamp and King, 1971).¹

Since the second world war, Morphometry has entered a new phase - the phases of micro-Morphometry which is concerned with the intensive study of the

1. Doornkamp, J.C. & King, C.A.M.: Numerical Analysis in Geomorphology - An Introduction. Edward Arnold Ltd., London. 1971. pp. 18.

small morphological units e.g. drainage basins. The drainage basin is a fundamental geomorphic unit of the land, and all flow of surface water is governed by its properties. By analysing various properties of a drainage basin, the degree of internal adjustment which has taken place among different properties and the stages of basin development can be established.

The present study is based on the fundamental hypothesis that the system of landforms evolving from the same geomorphic processes under similar climatic conditions and geologic material, possess a high degree of geometrical similarity which is manifested in the morphometric properties of the drainage basins. On the contrary, the lack of geometrical similarity in the drainage basins may result from the geological heterogeneity or climatic variations which tend to distort the basin Morphometry.

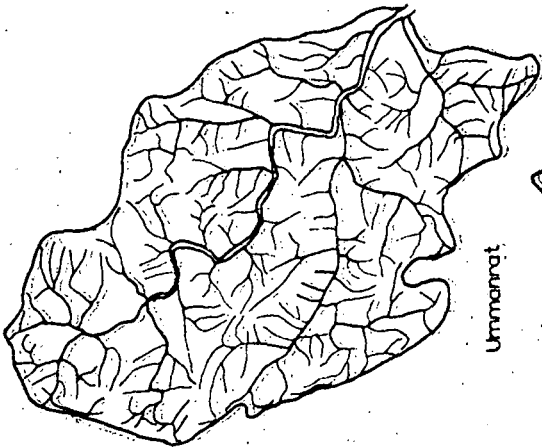
METHODOLOGY

The systematic description of the geometry of the drainage basins and their channel network constitute the measurement of the:

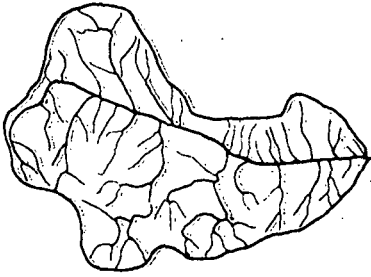
- (i) Linear aspects of the channel network,
- (ii) Areal aspects of the drainage basins and
- (iii) Relief or gradient aspects of the drainage basins and channel networks.

The first two properties are planimetric where as the third one reveals the vertical inequalities of the drainage basin forms. In the present study, an attempt has been made towards the evaluation of the geomorphic significance of the drainage basins of six small streams of Mawsynram with the measurement and analysis of the linear properties of the channel network and areal properties of the drainage basins. The data for the study has been worked out from the one inch topographic sheets No-78 0/7, 78 0/8, 78 0/11, 78 0/12. The six small drainage basins under analysis are (1) the Ummanrat, (2) the Phydymper, (3) the Umjngut, (4) the Umsaitkha, (5) the Umkatang, and (6) the Umnokria (Fig. 14). The areal and linear properties of these stream basins are measured with the planimeter and the rotameter. The geological as well as the climatological background of the drainage basins are supplemented to the present analysis (for detail see chapter I and II). The 'pearson's product moment correlation co-efficient' has been adopted

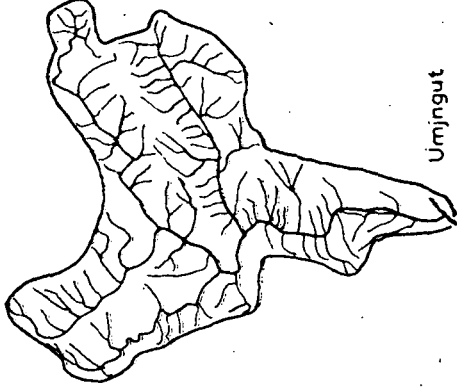
MAWSYNRAM
DRAINAGE BASINS
mile 0 1 mile



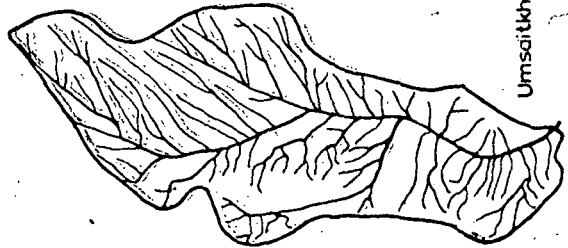
Ummannat



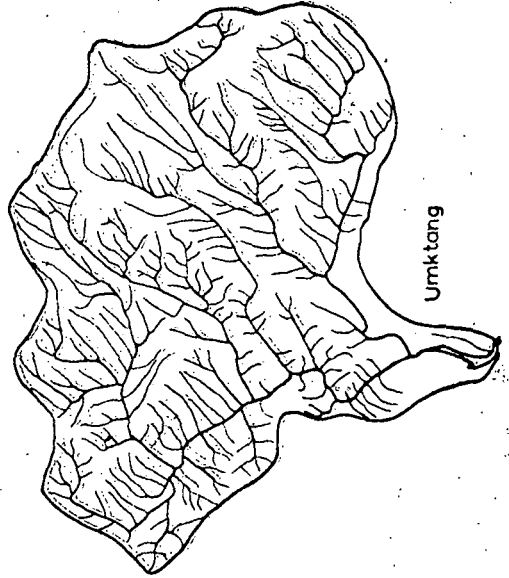
Rhudsymper



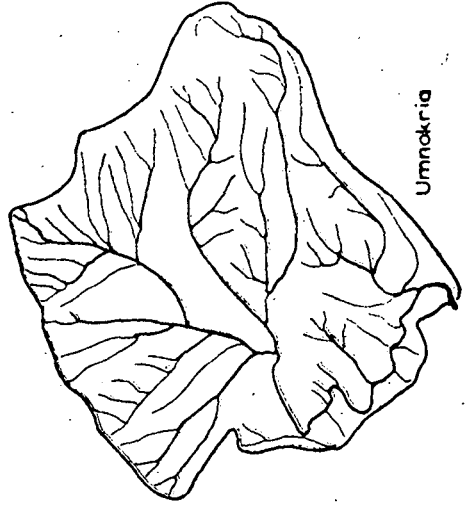
Umjngut



Umsaitkha



Umktang



Umnokria

fig.14

to establish the degree of association of the morphometric variables and the significance of the observed relationships had been evaluated with 't' test. The magnitude of change in the dependent variable with an independent variable has been treated by the regression analysis. Linear and non-linear equations have been used to reveal the best fit of this data. Lastly the geometrical similarity of the drainage basins are studied with the dimensional properties and non-dimensional ratios.

DRAINAGE BASINS

The drainage basins of the six small streams under study extend over the Mawsynram region of the southern Meghalaya Plateau (Fig. 14). Their basin areas range from 33.5 sq. miles of the Umkatang to 11.00 sq. miles of the phudsymper. The Umkatang, the Ummanrat, the Umnokria are all 5th order streams whereas the rest are of the 4th order streams. All the details of the stream basins i.e. their highest order, total number of streams total length of streams and basin area are enumerated below in the Table IV(i).

TABLE IV(1)
MATOR CHARACTERISTICS OF THE DRAINAGE CHANNELS

Sl No.	River basins	Order of the trunk stream	Total No. of streams	Total stream length (in miles)	Basin area in (sq.miles)
1.	Ummanrat	5	340	157.00	26.50
2.	Phudsymper	4	89	55.50	11.00
3.	Umjangnt	4	138	78.50	14.50
4.	Umsaitkha	4	133	89.00	15.50
5.	Umkatang	5	309	195.00	33.50
6.	Umnokria	5	105	99.00	25.50

Geologically most part of the drainage basins are formed of very ancient Archaean and Upper-Cretaceous rocks, although there are Jurassic and Oligo-Miocene sediments at the southern part of the study area, particularly in the Umkatang, the Umnokria and the Umsaitkha basins, where sandstone, shale and fossiliferous limestone are the dominant rock types(Fig.2). The Umkatang originates over the sandstone and fossiliferous southern slope surface of the Mawsynram Plateau. In northern part of the study area, the Ummanrat, the Phudsymper and the Umjngut stream basins extends over

the highly resistant rocks of Archaean and Upper-Cretaceous rocks, which predominantly composed of granitegneiss, Migmatite, Biotite-gneiss and Arkose etc. A detailed account of the stream basins, with their physiographic areas, average height and their geological formations are given in the Table IV(ii).

TABLE IV(ii)

GEOLOGICAL CHARACTERISTICS OF THE STREAM BASINS

Stream Basin	Trunk river	Coverage of the Drainage Basin	Average height above sea level	Geological Formations	Major Rock types.
1	2	3	4	5	6
Umman-rat	Umnagi	Sobphoh and Makham village area.	5400	Archaean, Upper-Cretaceous	Biotite-gneiss, migmatite, mica-schist etc. Arkose (Glaucinite)
Phudsym-per	-do-	Mawhiang & Kmawan Village (symer peak area 5827 ft)	5200	Upper-Cretaceous.	Arkose (Glaucinite)
Umjngut	Umiew or Bagra	Painsanngut & Nonglewai village area.	5000	Upper-Cretaceous	Arkose (Glaucinite)
Umsa-itkha	Umiew or Bagra	Nongshyluit & Sinei village area.	4100	Upper-Cretaceous, Oligo-Miocene, Jurassic.	Arkose (Glaucinite); sand, Siltstone, clay clay marl; Basalt, alkali-basalt rhyolite, acid tuff.

Table IV(ii) (contd...)

1	2	3	4	5	6
Umka- tang	Umiew of Bagra	Mawlyngbna & Hat Mawdon village area	2000	Jurassic, Eocene, Oligo-Mio- cene, Mio- pliocene, Recent	Basalt, Alka- li-basalt, rhyolite acid tuff; Sand stone limestone, silt-stone, sand, clay, marl, pebble- conglomora- te, Shale; sand, Silt & clays.
Umno- kria	Umpar- sumai	Nongkl & Maiaisohmat village area.	1500	Archaean, Jurassic	Biotite- gneiss and granite, mica-schist. Basalt, alkali-bas- lt, rhyolite acid tuff.

In terms of climate, all the drainage basins can be broadly put under tropical Monsoon climate, But, however there is considerable variation in rainfall and temperature over the different basins according to their extension, altitude, passage of the S.E. Monsoon and depressions, which the researcher has already discussed in detail in chapter-II.

LINEAR CHARACTERISTIC OF THE CHANNEL SYSTEM

The linear properties of drainage basins portray the branching system of drainage lines regardless of their

width . It includes the study of the channel patterns of the drainage network in terms of open links where in the topological properties of the stream segments are analysed. 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-relationship are analysed.

STREAM ORDER AND BIFURCATION RATIO

The streams of all the six small drainage basins are ordered based on the most popular ordering system of strahler (1952)², where the smallest finger tip tributaries are designated as order one (U1) and the joining of two streams of first order form a stream segment of 2nd order and so on, so that the trunk stream gets the highest order. Total number of stream segments are counted and the bifurcation ratio is calculated by the division of the number of stream segments of the given order to the number of segments of the next higher order (Appendix-I) i.e.,

$$R b = \frac{NU}{N(U+1)}$$

Where

NU = Number of stream segments of order 'U'
Rb = Bifurcation Ratio.

2. Strahler, A.N., (1952): op.cit., Vol.63 pp.923-38, also 1964 quantitative Geomorphology of drainage Basins and Channel Networks, in chaw, V.T.(ed.) Hand book of Applied Hydrology, MC Graw Hill Sec.411.

It has been established that in a region of uniform climate and rock type, the bifurcation ratios tend to remain constant in different drainage basins. It varies between 3.0 to 5.0 for river basins where the geological structure do not distort the drainage pattern. Abnormally high bifurcation ratios are expected in regions of steeply dipping rock strata where narrow strike valleys are confined to hogback ridges and the minor variations are due to chance variations in the watershed geometry (Strahler, 1971). In the present analysis, the bifurcation ratios of all the stream networks of the drainage basins range between 3.0 to 5.0 (Table IV(iii)). The Rb values indicate how many times the number of streams increase from any given order to the next lower order. The average Rb is calculated by determining the regression coefficient of the stream numbers on order.

TABLE IV(iii)*

MORPHOMETRO PROPERTY OF THE DRAINAGE BASINS

Name of the stream	Average Bifurcation Ratio(Rb)	Average length Ratio(R _l)	Average Area Ratio (Ra)	Elonga- tion Ratio (Re)	Drai- nage Dens- ity Ratio mile/ Sq.mile	Stream Frequ- ency (Sp. mile)
Ummanrat	3.82	1.50	4.93	0.320	5.92	12.83
Phudsymper	4.24	1.95	3.86	0.454	5.04	8.09
Umjngut	4.84	3.26	3.83	0.482	5.41	9.51
Umsaitkha	4.70	2.01	3.29	0.580	5.74	8.58
Umkatang	4.27	1.95	3.02	0.238	5.82	9.22
Umnokria	3.08	2.40	5.27	0.294	3.88	4.11

*Average Rb, Ri and Ra are the regression coefficients of stream order Versus stream number, stream length and stream area respectively for all the six drainage basins.

The little higher bifurcation ratio for the umjngut and the umsaitkha streams can be attributed to its elongated course for a long distance being confined to the deep gorges over paisangut to Nonglewai and Nongshyluit to sinei village areas respectively, till it meets the Umiew or Bagra river in the east. The bifurcation ratios decreasing towards the lower reaches in the drainage basins such as the phudsymper, the Umjngut, the Umkatang and the Umnokria (Appendix-i) seem to have a close association with lack of conspicuous relief and smooth topographic surface in opposition to high available relief promoting severe dissection of the landscape and favouring the development of headward eroding streams. The increasing Rb value towards the lower reaches in the Ummanrat and the Umsaitkha stream basins indicated development under structural control.

It is interesting to note the decreasing bifurcation ratios in the lower reaches of the Umnokria (Appendix-I) as a result of the arrested development of small streams. This is because of the north ward extension of the Bangladesh plain where lack of conspicuous relief

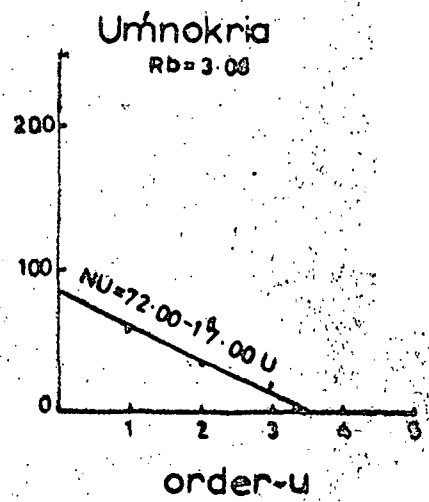
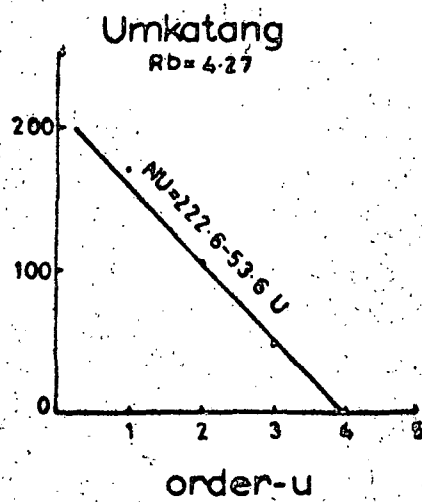
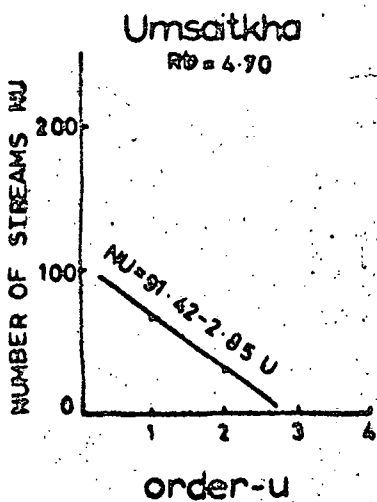
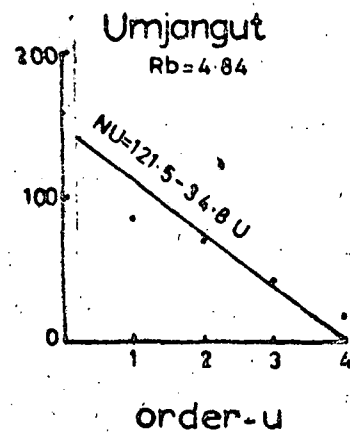
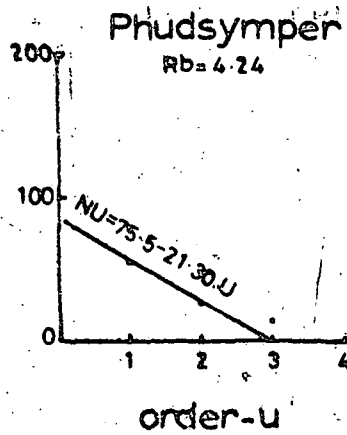
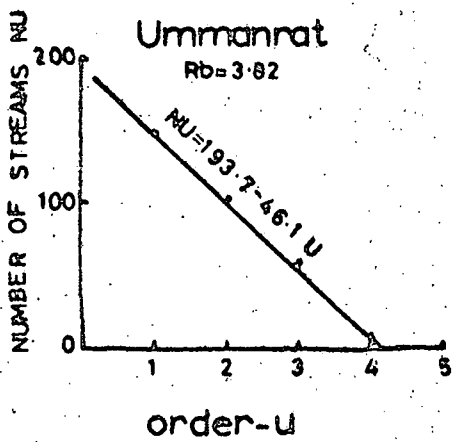
has acted as a retarding factor in the evolution of the drainage network. In this connection the umkatang crossing the southern scarp face of Mawsynram structural platform and limiting the development of the tributaries in the lower reaches bear an evidence to the previous statement.

STREAM ORDER AND STREAM NUMBER

The plotting of the number of streams against order for the six drainage basins on a arithmetic graph shows a linear relationship with small deviations from the straight line (Fig.15). The correlation-coefficients between stream order and stream number varies between - 0.795 (Table IV(iv)). The regression of stream number on stream order for the stream basins confirms to the mathematical model of negative exponential function i.e.,

$$NU = a+bu$$

Thus the number of streams of successively lower orders tend to approximate a geometric series beginning with a single segment or the highest order and increasing according to a constant ratio: Rb i.e. the Regression Coefficient.



REGRESSION OF NUMBER OF STREAM SEGMENTS
ON ORDER FOR SIX DRAINAGE BASINS

fig-15

TABLE IV(iv)

PAIR-WISE RELATIONSHIPS AMONG MORPHOMETRIC VARIABLES IN
STREAM BASINS

Drainage Basin	Correlation Coefficients among different pairs of morphometric variables.					
	Order vs Numbers	Order vs stream length	Order vs mean stream area	Mean areas vs. mean stream length	Total area vs. cumulative stream length	Total area vs Mean stream length
Ummanrat	-0.835*	0.917*	0.913*	0.787	-0.987*	-0.859*
Phudsymper	-0.893*	0.898*	0.946*	0.860	-0.890	-0.764
Umjngut	-0.866	0.937	0.964*	0.988*	-0.876	-0.780
Umsaitkha	-0.961*	0.894*	0.879*	0.998*	-0.996*	-0.658
Umkatang	-0.795	0.831	0.866*	0.993	-0.948*	-0.563
Umnokria	-0.825*	0.728	0.789	0.985*	-0.703*	0.161

(*Indicates the significant correlation coefficients(at 95% probability and the rest are insignificant).

STREAM ORDER AND LENGTH RATIO

It is the ratio of mean length of streams of order 'U' to the mean length of the streams of the next lower order i.e.

$$R_i = \frac{\bar{L}_U}{\bar{L}_{(U-1)}}$$

Where RI = Length Ratio

\bar{L}_U = Mean length of stream of order 'U'

It indicates how many times the mean length of streams of any order increases with respect to the mean length of the immediate lower order. The mean length ratio (R_L) for the drainage basins are obtained from the regression coefficient of order against mean stream length which varies between 3.26 for the Umjangut to 1.50 for the Ummanrat (Table IV(iii)). The length ratios computed for the successive orders (Appendix-I) remain within a short range upto 4th order for the Ummanrat, the Umkatang and the Umnokria and upto 3rd order for the Phudsymper, the Umjngut and the Umsaitkha. The high length ratios for the higher order streams in the Umnokria, the Umkatang, the Umsaitkha and the phudsymper reflect the long course of the trunk stream under structural control as well as their meandering nature towards the lower reaches on the eastern, western and southern low-land section of the study region. The deviation from the general principle of length ratio at their lower reaches in case of the Ummanrat is because this stream springs into the narrow undulating plateau surface around village Sohphoh in northern Mawsynram leaving its more mountainous path in north, where the

trunk stream join with the Ummagi at an altitude of 4687 feet after flowing for a short distance. The hard granite surface of the northern Mawsynram region does not allow large amount of percolation and hence the Ummanrat carry enormous quantity of water in the rainy season which has not supported the development of meanders to contribute significantly to the total stream length of the Ummanrat.

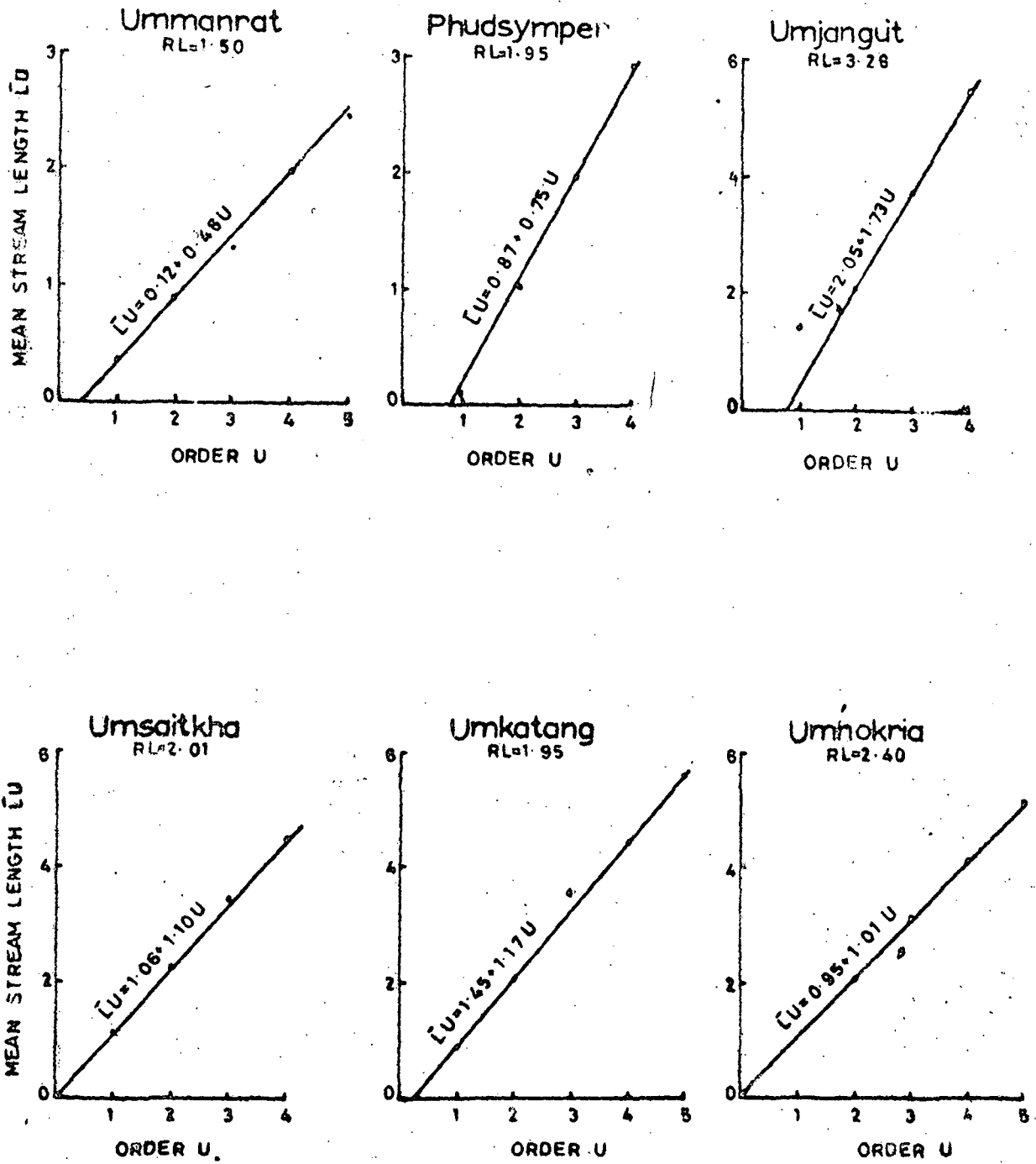
STREAM ORDER AND MEAN STREAM LENGTH

The mean length of the channels of the order 'U' is obtained for all the six drainage basins by measuring with a rotameter and dividing the total length of streams of the given order by the number of the given order by the number of stream segments of that order i.e.

$$\bar{L}_U = \frac{\sum_{n=1}^U L_n^n}{NU}$$

When \bar{L}_U is the mean length of the stream of order 'U'. NU is the total number of streams of order 'U'

Graphs have been drawn with the plotting of mean stream lengthⁿ against the stream order (Fig-16) which yields a straight line relation confirming to the



REGRESSION OF MEAN STREAM SEGMENT LENGTH ON ORDER FOR SIX DRAINAGE BASINS

fig.16

mathematical model of positive exponential function
i.e.

$$\overline{LU} = a + bu$$

Thus it can be stated that the average length of streams of the successively higher orders tend to approximate a direct geometric series increasing according to the constant length ratio (of the regression - Coefficient).

AREAL CHARACTERISTICS OF THE DRAINAGE BASINS

Areal properties of the sample basins are associated with the surface area and shape of basins. Basin area is one of the most important Morphometric parameters affecting the spatial distribution of a number of morphometric attributes such as drainage density, texture, stream frequency, slopes, dissection index etc.

STREAM ORDER AND MEAN STREAM AREA

The area of a stream of order 'U' (AU) is defined as the total area projected upon a horizontal plane contributing overland flow to the channel segments of the given order and all tributaries of lower order and the inter-basin areas contributing directly to a channel of order higher than the first (Schumm, 1956)³. The plotting

3. Schumm, S.A.: (1956) op.cit., pp. 597-646.

of mean stream area against stream order yields a set of points along a straight line (Fig.17) showing very high positive correlation. The regression of mean stream length versus stream order yields a positive exponential function i.e.

$$\overline{AU} = a + bu$$

When \overline{AU} is the mean area of the streams of order 'U'

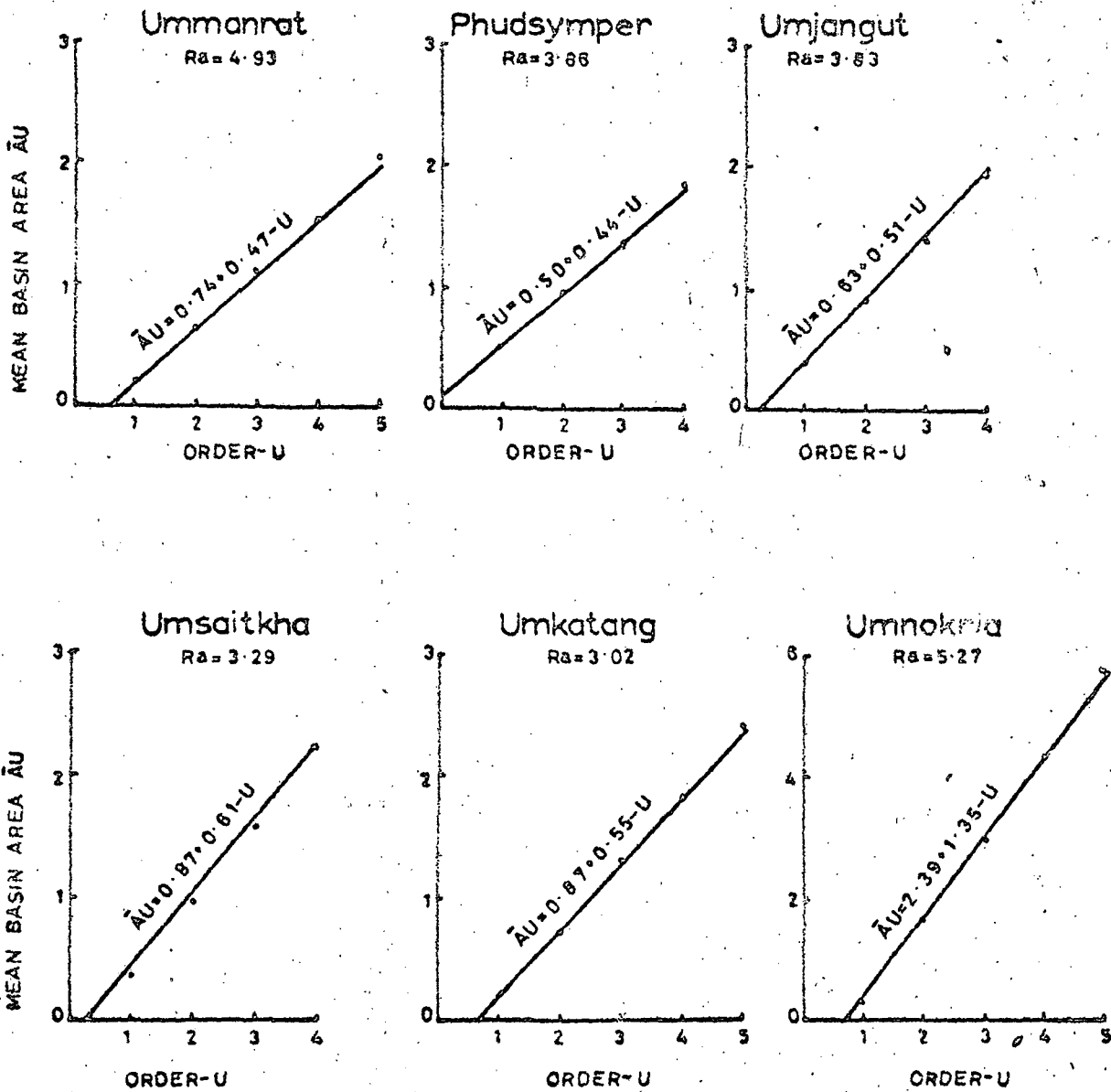
This reveals that like stream number and mean stream length the mean stream area of progressively higher orders increase in a geometric sequence according to a constant area ratio (of the regression-Coefficient).

The mean area ratio for the six drainage basins vary from 3.02 from the umkatang to 5.27 in case of the Umnokria (Table IV(iii)). The area ratios for the successive stream orders has been calculated by the formula i.e.

$$Ra = \frac{\overline{AU}}{A}^{(U-1)}$$

When Ra = Area Ratio

The variation in the area ratios of the successive orders in the drainage basins reflect the difference in geological set up and relief features which seems to be responsible for the varied development of the stream network in the down stream directions.



REGRESSION OF MEAN BASIN AREA ON ORDER
FOR SIX DRAINAGE BASINS

fig-17

RELATION OF STREAM AREA AND STREAM LENGTH

The relationship of stream length to basin area is one of the most sensitive morphometric parameter which determines the texture of landscape dissection and spacing of streams (Chorley, 1969)⁴. Assuming the validity of exponential increase in mean stream length and mean stream area with order, the parameters i.e. length and area should be related to each other. The plotting of mean stream length and cumulative stream length versus total stream area of the six small stream basins show a linear relationship i.e. (Fig.18)

$$Y = a + bx$$

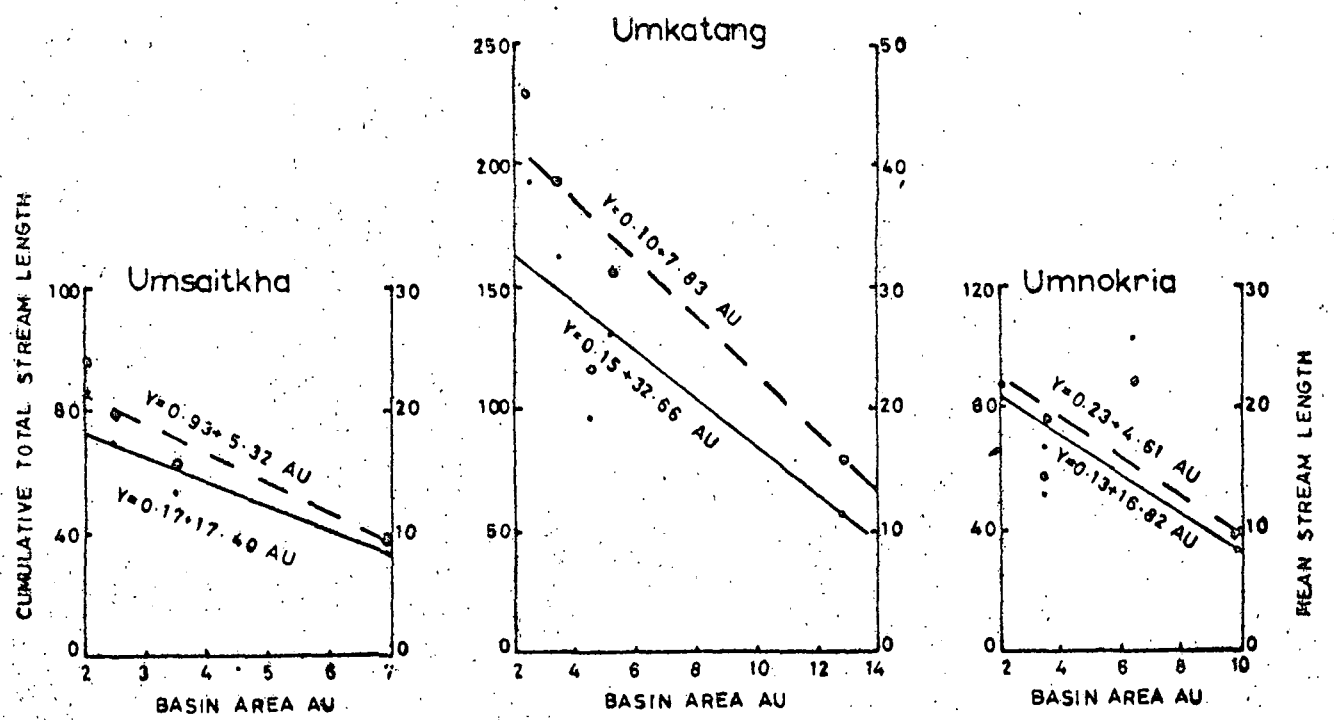
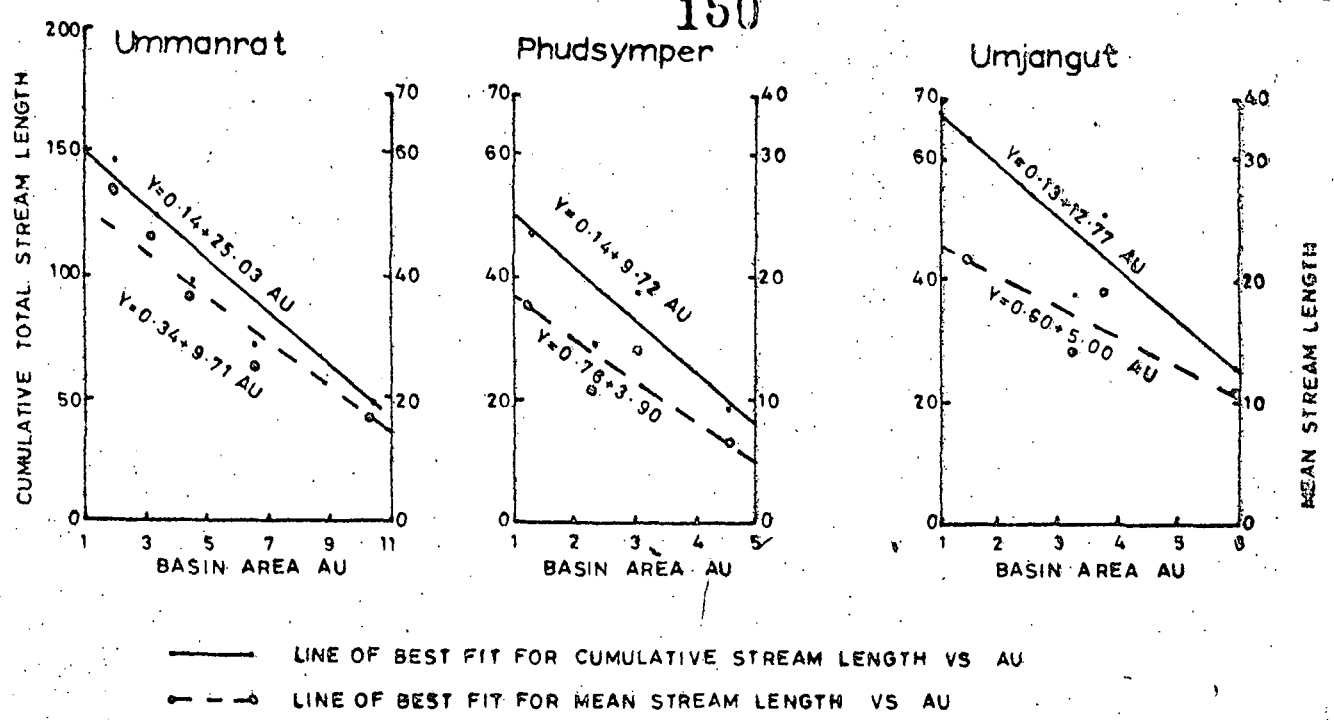
When x & y are the two variables.

BASIN SHAPE

It is an important Morphometric parameter in the geometry of the channel network. The Elongation Ratio as a measure of shape (Schumm, 1956)⁵ was found out for the drainage basins under study (Table IV(iii)). It is a non-dimensional property defined as the ratio of the diameter of a circle of the same area as the basin to the

4. Chorley, R.J: The drainage Basins as the Fundamental Geomorphic units' in "Water; Earth and Man-A Synthesis of Hydrology, Geomorphology and Socio-economic Geography"(ed), Methuen & Co. Ltd. 1969.

5. Schumm, S.A., : (1956) op.cit. pp. 597-646.



RELATION OF STREAM LENGTH TO BASIN AREA FOR SIX DRAINAGE BASINS
 fig.18

maximum basin length. The ratios vary between 0.6 to 1.0 over a wide range of climatic and geological types. Values near to 1.0 are typical of regions of the low-relief where as the value below 0.8 are associated with strong relief and steep ground slope.

The elongation ratios for all the six stream basins under review present a value ranging between 0.2 to 0.6 (Table IV(iii)) indicating very high relief and steep slope in the basins where the reduction of divides are still in progress with headward extension of the actively eroding channels at the upper reaches.

DRAINAGE DENSITY AND TEXTURE

It is an indication of the nature of landform dissection and closeness in the spacing of stream channels. It is defined as the ratio of the total stream length cumulated for all orders within a basin to total basin area projected over a planimetric surface.

The high drainage density values for all the six basins ranging from 3.00 to 6.00 mile/sq. mile (Table IV(iii)) indicates fine texture. The lowest drainage density value is shown by the Umnokria basin

of south-western Mawsynram region, while, the highest drainage density is shown by the Ummanrat basin. The low drainage density of the Umnokria (3.88) is due to the fact that this basin is located in regions of highly permeable Cretaceous-Tertiary sediments with low relief features. While, the high drainage densities shown by other five stream basins can be attributed to the hard resistant 'Archaean complex and the Shillong Group of rocks spreading over the undulating northern and highly dissected eastern, western and central Mawsynram region, which becomes a controlling factor to the development of streams of lower order.

An examination of isopleth map of drainage densities for all six selected stream basins (Fig.19) would reveal that more than half of the basins area is covered by the category of moderate to High i.e. 1.5-3.0 and 3.0-4.5 mile/sq.mile, (Table IV(v) drainage densities. This isopleth map also showing the spatial variation of drainage density over the surface at different parts of the each six stream basins, all these figures with categories of drainage density and the area covered by each categories for individual stream basins has been enumerated in following table:

MAWSYNRAM
STREAM DENSITY

0 1 mile

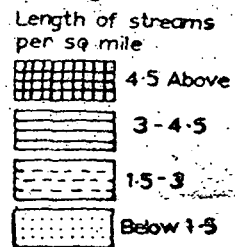
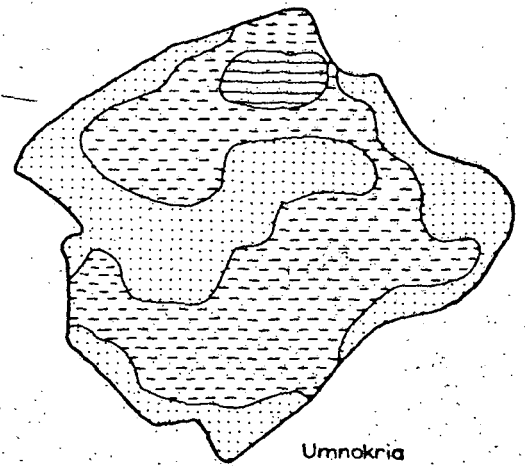
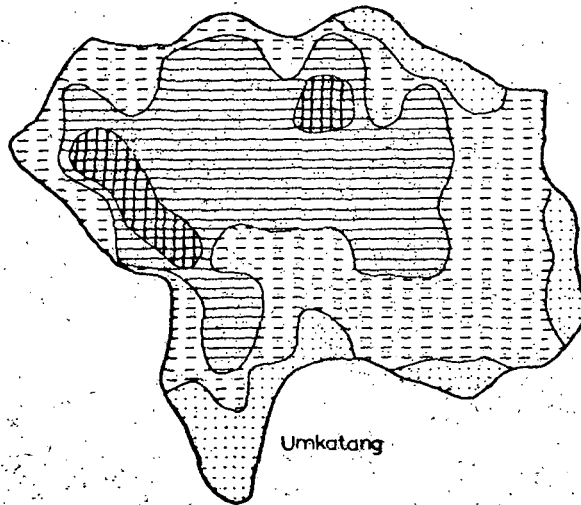
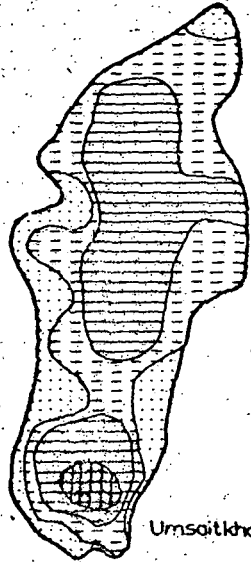
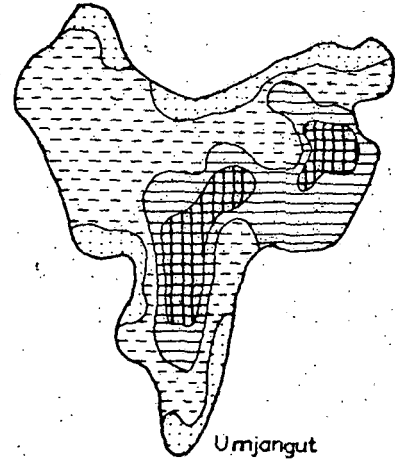
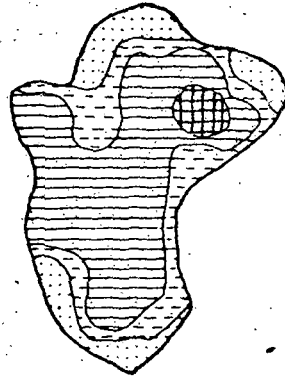
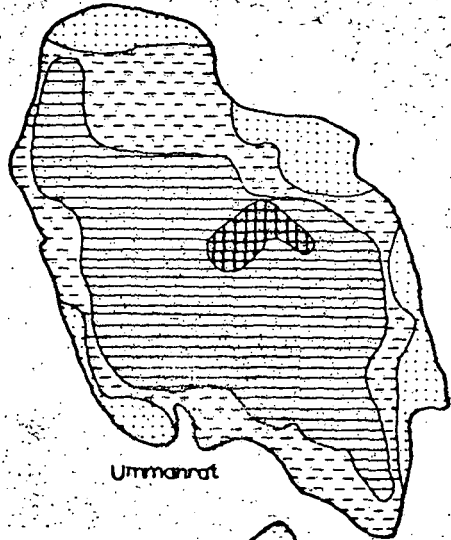


TABLE IV(v)

DRAINAGE DENSITY CATEGORIES AND AREA COVERED BY SIX SMALL STREAM
BASINS

Basins	Total Area in sq. mile.	0-1.5(mile/sq.mile) Low	1.5-3.0mile/sq.mile) Moderate	3.0-4.5(mile sq.mile) High	4.5 above mile/sq. mile) Very high
Ummanrat	26.50	4.66 (17.58%)	8.34 (31.47%)	12.75 (48.12%)	0.75 (2.83%)
Phudsymper	11.00	2.50 (22.72%)	2.75 (25.00%)	5.25 (47.72%)	0.50 (4.54%)
Umjngut	14.50	2.75 (18.96%)	7.25 (50.00%)	2.50 (17.24%)	2.00 (13.79%)
Umsaitkha	15.50	2.75 (17.74%)	4.75 (30.64%)	7.50 (48.38%)	0.50 (3.22%)
Umkatang	33.50	4.75 (14.17%)	14.35 (42.83%)	12.15 (36.26%)	2.25 (6.71%)
Umnokria	25.50	10.75 (42.15%)	14.30 (56.07%)	0.45 (1.76%)	0.00 (0%)

STREAM FREQUENCY

By stream frequency is meant the number of streams per unit of area (Horton, 1945)⁶. It generally varies with the drainage area. In the present six selected drainage basins it increases with the steeper slope gradients; The high frequency values for all the basins ranging from 4.00 to 13.00 streams per sq. mile (Table IV(iii)) indicates fine texture which can be attributed to the heavy rainfall and lithological and structural characteristics of the Archaean complex and Uppercretaceous sediments which has covered vast areas of all the six basins under study. (Table IV(ii)). It is interesting to note that the highest and lowest drainage density basins i.e. the Ummanrat and the Umnokria are also the highest and lowest stream frequency basins, with 12.83 and 4.11 number of stream per sq. mile respectively.

The stream frequency map (Fig.20) for selected six small stream basins show clearly the regional variation of frequency of streams per sq. mile on its surface. It is also noticed that the areas of moderate to high stream frequency i.e. 4 to 8 and 8 to 12 number of streams per sq. mile, coincides with the areas of moderate to high stream density i.e. 1.5 to 3.0 and 3.0 to 4.5 miles to stream length per sq. mile of six stream basins indicating fine texture of dissection. A detailed analysis of the different stream frequency categories

6. Horton, R.E. (1945) op.cit. pp.275-370.

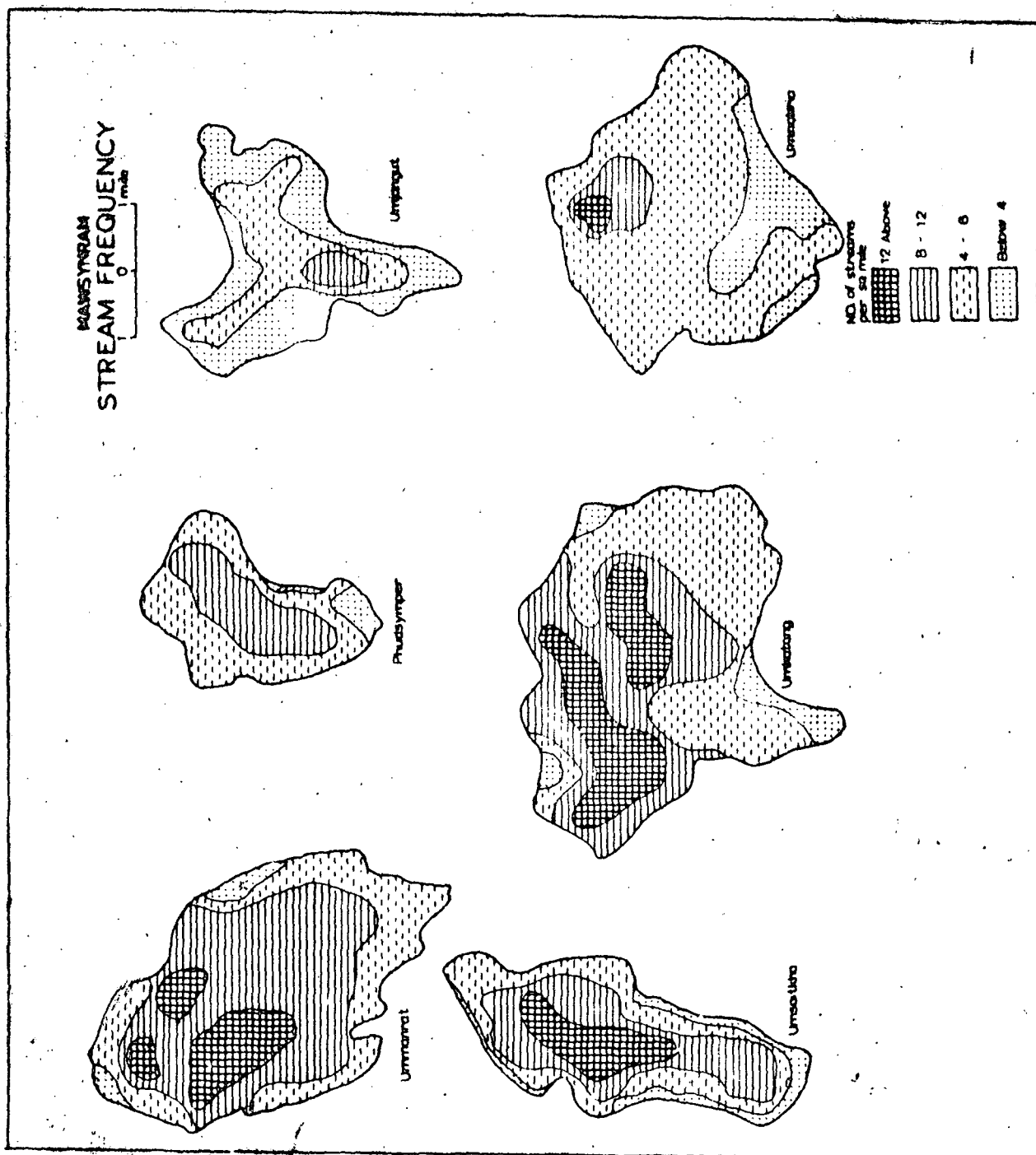


Fig. 20

and the area occupied by these categories for each stream basins and their per-centage to the total area has been given in the following table:

TABLE IV(vi)

STREAM FREQUENCY CATEGORIES AND THE AREA COVERED BY SIX
SMALL DRAINAGE BASINS: (Area in sq.mile)

Basins	Total area in sq.mile	0-4 per sq.mile LOW	4-8 per sq.mile Moderate	8-12 per sq.mile High	12 above very high
Umma-nrat	26.50	1.15 (4.34%)	6.25 (23.58%)	15.35 (57.92%)	3.75 (14.16%)
Phudsy-mper	11.00	0.75 (6.82%)	3.75 (34.10%)	6.50 (59.10%)	0.00 (0%)
Umjngut	14.50	9.00 (62.06%)	4.55 (31.38%)	0.95 (6.55%)	0.00 (0%)
Umsai-tkha	15.50	2.25 (14.51%)	5.25 (33.87%)	5.75 (37.10%)	2.25 (14.51%)
Umkat-ang	33.50	2.75 (8.20%)	14.25 (42.53%)	9.75 (29.11%)	6.75 (20.15%)
Umno-kria	25.50	5.75 (22.55%)	17.50 (68.62%)	1.75 (6.86%)	0.50 (1.96%)

GEOMETRICAL SIMILARITY OF THE DRAINAGE BASINS

From a number of studies, it has been established that the geometrical similarity is preserved in the drainage basins when all corresponding landform elements having the dimension of length are in the ratio $\sqrt[n]{n}$ all corresponding measures

having the dimension inverse of length are in ratio $1/L^1$, and all those having the dimensions of length squared are in the ratio $1/L^2$ and further more all dimensionless properties should have identical value in corresponding parts of both the systems (Strahler, 1954)⁷. The analysis of the dimensionless property of the drainage basins i.e. R_b , R_l and R_a of successive orders (Appendix - I) within the main basins show wide variations although these property of the drainage basins (mean stream area, mean stream length, stream number) bear an exponential relationship with the magnitude of order of the streams. This reveals that although the areal extent of the six drainage basins are small in size, but because of the geological complexity of its structure and climatic variations with the altitudes resulting differential rates of erosion and deposition leading to varied development of stream network which tend to distort the basin morphometry. It is also marked that geometrical dissimilarity is minimum at the lower orders. Wide fluctuations in the dimensionless numbers i.e. R_b , R_a and R_l (Appendix - I) in their magnitude for the successive orders for the Ummanrat, the Phudsymper, the Umjngut, the Umsaitkha, the Umkatang and the Umnokria reflect the dominance of structural control in the development of drainage network.

7. Strahler, A.N.: Statistical Analysis in Geomorphic Research, J. Geol, Vol 62, 1954, pp. 1-25.

In comparing the dimensionless numbers of all the six drainage basins, rather a clear conclusion emerges that in considering the drainage basins of the trunk streams, the geometrical similarity is retained more or less in all the six stream basins, where the R_b , R_a and R_l values (Table IV(iii)) are having good correspondence although the basins are too small to compare their geometrical similarity.

With an attempt towards testing the concept of geometrical similarity in landforms of all the six drainage basins produced under fluvial processes, the linear scale ratio (λ) are computed based upon mean length dimension i.e. ratios for mean length of streams of 1st and 2nd order, mean basin area for the 1st and 2nd order, mean basin area for the 1st and 2nd order and drainage density. The analysis of the scale ratios for the all stream basins, it is interesting to note that in considering the length dimensions the Ummanrat basin has approximate geometrical similarity with the Umnokria, the Phudsymper with the Umkatang and the Umjngut with the Umsaitkha. The remarkably similar scale ratios for the geometrically similar drainage basins are given below in Table IV(vii).

TABLE IV(vii)LINEAR SCALE RATIOS FOR GEOMETRICALLY SIMILAR DRAINAGE BASINS

Scale Ratios	Symbol	Ummannrat vs Umjokria	Phudsymper vs Umkatang	Umjngut vs Umsaitkha
Mean length of the 1st order stre- ams.	L1	0.67	1.01	0.78
Mean length of the 2nd ord- er Streams	L2	0.42	0.87	0.67
Mean areath of the 1st order basin	A1	0.08	1.20	0.71
Mean area of the 2nd order basin.	A2	0.63	1.20	1.16
Drainage Density	D	1.52	0.86	0.94

The morphometric analysis of the drainage basins reveals the following salient points on the morphological evolution and geometrical similarity of the drainage basins. The dimensionless ratios i.e. Ra, Rb, R1, (Appendix-I) between the successive orders of the streams i.e. their trend and fluctuations are the indicators in the varied

development of the stream networks under the impact of geological structure, relief configuration, rock type and rainfall variation.

It is noticeable to remark the abrupt drop in the mean length and area of the 4th order streams in the Umnokria because of lack of development of the tributaries beyond this order. It seems to be probable that the rise of the northern part of Mawsynram during the late Tertiary period has limited the development of large tributaries in the down stream directions. The abrupt change in altitude between the upper and lower reaches, as well as the antecedent character of the Umnokria stream bears an evidence to it. A considerable portion of the Ummanrat, the Phudsymper, the Umjngut and the Umsaitkha in its middle reaches flows across the highly dissected surface of Archaean, Upper-Cretaceous and Jurassic & oligo-miocene sediments, with conspicuous relief has acted as the main factors in the development of the tributaries resulting in highly unequal mean stream length for the 3rd and 4th order streams (Appendix - I).

The direction of the Umjngut is guided by the undulating granite surface of Mawphalang area. The hard resistant rocks along its valley seems to have exerted considerable influence in guiding the direction of valley

carving which has resulted in high bifurcation ratio (4.84), length ratio (3.26) and area ratios (3.83) (Table-IV(iii)). Because of the strong structural control in the direction of flow the Phudsymper, the Umjngut, the Umsaitkha and the Umkatang has resulted in the high Rb and Rl values for the trunk streams. It is significant to mark the sharp rise in the Ra, Rb and Rl values (Appendix I) between the 2nd and 3rd order streams because of high available relief and heavy rainfall favouring the development of the stream network.

As regards the geometry of the drainage basins, the geometrical similarity is maintained among the streams of lower orders of the different streams which is exhibited by the similar dimensionless ratios i.e. Ra, Rb and Rl (Appendix-I). Gradually with increasing orders, the drainage basins tend to deviate from each other in their geometrical property. In comparing the geometry of the drainage basins as a whole with the dimensionless ratios and scale ratios (Table- IV(vii)). It has been observed that the Ummanrat is more similar with the Umnokria; the Phudsymper with the Umkatang and the Umjngut with the Umsaitkha. From this it becomes clear that the geometrical property of the drainage basins

is a function of geological structure, rock type, relief configuration, rainfall variation and other associated phenomena. In considering the geometrical similarity of the tributary basins of the successive orders within the basin of the trunk stream, the variations mainly because, the tributary basins had come from different environments and altitudes, which have a wide range of differing characteristics, they have been cut into a variety of rock types including varying amounts of summit planation surface and relief configuration. Although climatic data is scarce, it is also probable that the tributary basins are also climatically different in terms of amount of rainfall and temperature.

Thus keeping in view the limitations of the scale of analysis a remarkable degree of correspondence is found in the dimensionless ratios to reveal the geometrical similarities because absolute correspondence will not be same except by purest chance. Hence, it can be concluded that under similar conditions of geology, climate and relief the landforms will exhibit similar geometry.

CHAPTER - V

ANALYSIS OF SLOPE

"The hills are shadows, and they flow
From form to form, and nothing stands;
They melt like mist, the solid lands,
Like clouds they shape themselves and go".

LORD TENNYSON
In Memoriam.

Introduction:

Slopes which make up a large part of any land surface, are important landforms for Geomorphologists, Pedologists, and engineers. Slopes are formed by erosion, deposition, or a combination of both processes. When a stream cuts into a landsurface, a valley is created and slopes form that descend to the valley bottom and ascend to the upland. Slopes form by constructional processes, such as Glacier deposits, wind deposits and mainly by water deposits sediment. Sooner after a slope is formed, it is subject to alteration by weathering, erosion, sedimentation and mass movement. By their inherent nature, slopes are unstable geomorphic features and so it is not surprising that the study of slopes has become one of the foremost branches of geomorphology.

Since the second world war, the study of slopes has to be recognized as an integral part of other branches of geomorphology. In the field of applied geomorphology, studies of landslides and of accelerated erosion are concerned with slopes, and involve links with the techniques of soil mechanics, hydrology and soil science. The direct influence of landforms on soil is primarily through the effects of slope; steep slopes tend to carry lithosols, and concave slopes are liable to gleying. There are also indirect effects of slope, as it affects micro-climate, which in turn influences vegetation. There is no doubt, however, that slope angle is the main property of landforms that affects man, in agriculture, transport or urban activities. The study of slopes was developed for the intellectual challenge that it offered. It originated, like geomorphology in general, from curiosity about the natural world. It has come to have some part to play in one of the greatest challenges of our time: planning of the use and conservation of the earth's resources for its present and future population.

The morphological character of the study region is depicted by the appearance, dimension and magnitude of slope. The study of slope provides not only the variety

of topographical features, but makes available also the evidence needed for the interpretation of the complex form of landscape. The area under study is believed to be a part of Ancient Gondawana landmass which has registered the engravings of unhindered erosion, weathering and earthmovements. The northern and central Mawsynram region is a true plateau capped by Mesozoic-Tertiary rocks and underlain by Mesozoic flood basalts (The Sylhet Traps) and polycyclic Precambrian gneisses, meta-sedimentaries (The Shillong group) and plutons, whose surface expresses subdued topography with gentle slope forms. The eastern and western parts of the plateau are highly dissected and the southern Margin is reflected with a sharp fracture zone of very steep slope forms. The slope of the area seems to have been influenced by the factors like endo-genetic forces, weathering under heavy rainfall and process of erosion and drainage pattern.

The palaeogeography of this region shows that the Mawsynram plateau, which is also a part of Shillong plateau, have been subjected to a variety of diastrophic movements since the Pre-cambrian period. The different

movements recorded during these periods must have created new slopes along the line of uplifts-fracture zones and also evolved because of plateau volcanism. Newer slope forms developed gradually over these surfaces. It is seen that scarps separating different topographic levels coincide with traces of fracture faults, some of which are very young¹. The rapidity of denudation and its apparent influence can be observed along the steep banks of the Umanrat, Phudsymper, Umkatang, Umnokria, and Umsaitkha streams of the study area. The deep gorges of these antecedant streams is the result of massive headward erosion along joints and control exercised by the well-jointed Cretaceous-Tertiary sandstone cover². The development of drainage system has produced the present surface in Mawsynram with their characteristic slope forms.

(ii) Factors Affecting slope Evolution:

The broad parameters which control the evolution of the hill slopes are structure, process and time. According to Peci(1970)³ "the existing types of slopes are

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1. Mazumdar, S.K., 'States of fracture Analysis in Meghalaya', Geological survey of India, Shillong.
 2. Murthy, M.V.N. 'An outline of Geomorphological evolution of the Assam region, Geological survey of India, Shillong.
 3. Peci, M. (1970) Factors affecting slope evolution and formation of slope elements in Hungary, Augments geographical Bond, 12, PP-193.

the results of the joint dynamism of the Tectonic, Structural-Morphological and lithological conditions of the relief and of the climatomorphologic processes acting perennially on a given region of the surface."

Like in the other parts of Shillong plateau, convex-concave form of slope is found in Mawsynram region. The upper convexity is due to soil creep (Gilbert 1902)⁴ and the lower concavity is mainly due to concentrated rill action (Fennemen, 1908)⁵. The researcher has observed during the field trips that in the wet-season the middle part of the slope of this region is coming under the influence of concentrated rill action while during the dry season, it is affected by creep. Creep which means the slow movement of rock and soil down slope solely under the influence of gravity is the dominant process of slope formation, though slow, in the upper convex segment,. Penck (1953)⁶ has stated that creep might occur in all climates" so long as the mean slope is estimated to be 5°. As the average slope gradients of the study region are very high, ranging from 7° to 40°.

4. Gilbert, G.K., (1902). The convexity of hill tops, Journ. of Geology, Vol.17 pp.344-350.

5. Fenneman, N.M., (1908) some features of erosion by un-concentrated wash Journ. Geol. Vol.6, pp.746-754.

6. Penck, W., 'Die Geomorphologische, Analyse-Stuttgrat: J. Engelhorn's Nachf, 1929, English translation by H. Czech and K.C. Bose, London: Macmillan, 1953, p.119.

the creep taken place predominantly over its surface. On the steeper slopes where the vegetation cover has been stripped of mainly due to shifting cultivation, the mud flows occur during the period of precipitation of high intensity e.g. during the month of May to August. Debris avalanches are also not uncommon.

Although thick debris cover is observed on the slopes of south Mawsynram, yet, in the northern and central scarp region and in Mawphlang, over the granite surface the amount of debris to be carried away by the streams is not considerable. In the absence of large scale landsliding, which is considered to be an important factor in the erosion of slope (W. penck, 1924; Blackwelder, 1942) running water is the most active agent of slope erosion and waste transportation. As in this region most of the streams have yet to attain graded profiles, it is quite likely that their influence is maximum in the convex hill-tops and on the free face. It has been observed that due to surface cover with green grasses and shrubs the impact of weathering and erosion is less perceptible.

(iii) Evolution of Hill Slopes:

Evolution concerns the change of slope form with time. Among studies of the different aspects of the geomorphology of slopes evolution occupies a central position. Application of divergent views on slope evolution on a particular region is very difficult. It is difficult to say with accuracy whether the typical convexo-concave profiles of the slope are the products of progressive flattening (Davis, 1902) or 'Central rectilinear recession' (Bakker and Letteux, 1946, 1947, 1950 and 1952) or by the retreat of slopes in parallel planes (Penck, 1924 and King, 1963) or by the parallel rectilinear recession (Dijk and Letteux, 1952). Whether the evolution of different hill slopes should be a geometrical treatment (Wood, 1942, Fisher, 1966, Lechmann, 1933 and Lawson, 1915) which is more precise or should be analysed by the inductive process as envisaged by Gilbert (1909); Davis (1902, 1938); Sharpe (1938) and which constantly keeps the slope in the forefront even though it may not explain them fully. Although the Davisian concept of progressive flattening in hill slope development cannot be totally ignored in this present study region; the following study of the selected six slope profiles of

Mawsynram, would help us to switch our opinion in favour of any one of the above mentioned views.

(iv) Slope Profile:

The shape of the landsurface can be considered a profile form, Profile form refers to the two-dimensional shape of valley slopes and scarps along a plane that follows the direction of maximum slope. Slope profiles reveal many salient geomorphic problems related to the processes operating over the landscape. It also provides the basis for making assumptions regarding the development of slope of any region under study.

The modern hill slope study in the analysis of hill slope form was made by Wood (1941)⁷, who suggests an idealized model of a fully developed normal slope. This reveals four distinct sections of slope form: (i) Waxing (ii) Free face (iii) Debris or talus (iv) Pediment. This slope form does not differ from the views of King (1953)⁸, Schumm(1966)⁹ and Savigiar (1967)¹⁰. Woods view is related

7. Wood, A. (1942). The Development of Hill side Scarps. Proc. Geol. Ass, Vol-53, pp.128-140.

8. King, L.C., (1953): Conons of Landscape evolution, Bull Geol. Soc. Ame, Vol-64, pp.721-752.

9. Schumm (1966): The Development and Evolution of Hill Slopes, Jour. Geol. Edu. Vol-14(3), pp.98-104.

10. Savigiar, R.A.G. (1967): The analysis and classification of slope profile Forms, in: P. Macar (ed), L. Evolution des versants, Univ. of Liegs, pp.271-290.

to a cyclic development of slope, while four units of both kind Schumm's are related to slope progress in which changes take place in each unit through time and environmental influences respectively.

In this chapter an attempt has been made to study the characteristics of hill slope profile forms and weathered materials of the Mawsynram region, preceded by an account of the measurement and description of slope angle.

Procedure of work:

The researcher has conducted an extensive field work and has tried to analyse the trend of development of slope elements in Mawsynram region. At first he has selected a few typical hills of the northern Mawsynram and a few of central Mawsynram to prepare slope profiles from top of the hills to their bottoms. For preparation of profiles the instruments used were one minute Theodolite (Carlzeise) and with the help of spot height of Bench mark of the area, various readings of the profiles were taken. Four profile: two of the northern and two of the central Mawsynram have been prepared. The measured four slope profile angles and height is given in Appendix - 2.

The observations regarding the nature of soil and weathered material at different heights were also taken during field trips. The type of vegetation was studied at different heights during the preparation of profiles. The details of horizontal and vertical scales of profiles would be visualized from the profiles itself.

The slope in Mawsynram Hills:

The four profiles (Fig.21) of Mawsynram hills clearly indicate that all the four elements of slope identified by Wood (1942) (i) Crest (ii) Scarp (iii) Debris and (iv) pediment, may be clearly seen here.

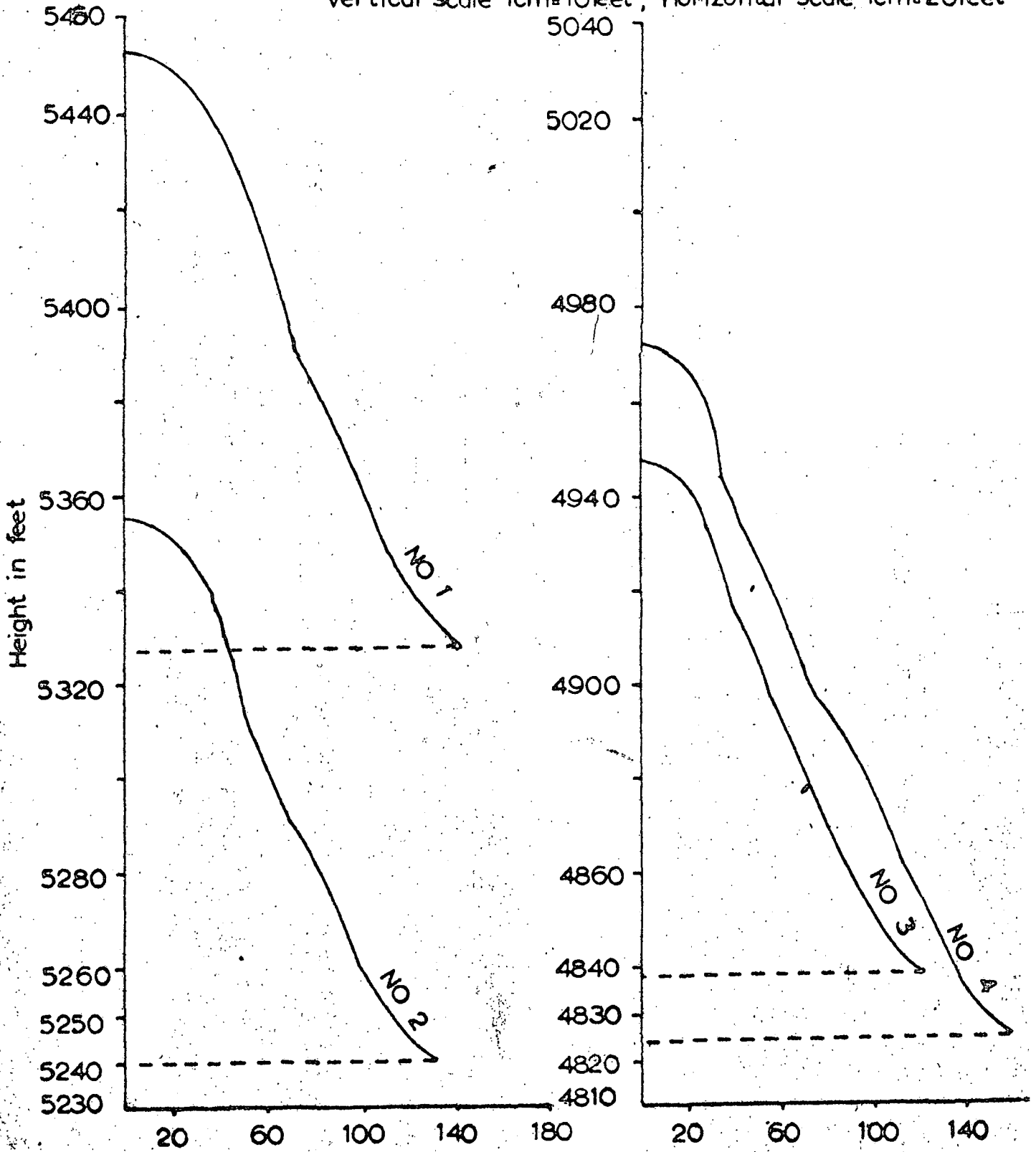
(i) Crest (Waxing slope).

This part of the slope is the summit area of hill or slope; the profile is usually Convex. Weathering and soil creep are the main processes forming this convexity.

The profiles that have been discussed here show the hills are characterised by a less extensive convex crest. The surface is covered with loamy soft soil with high organic matter and nitrogen contain. The thickness of this soil varies in different hills.

HILLSLOPE PROFILES

Vertical scale 1cm=10feet, Horizontal scale 1cm=20feet



Length in feet
fig-21

In profile No.1 and No.2 the thickness of the surface soil is less than two feet, while in profile No.3 and No.4, it is more than two feet. During the rainy season, from May to August, because of heavy downpour the surface soil is washed downwards in the form of rill or gully erosion. The rills descending down the slope are flooded with the weathered material in the form of solution and suspension. The bedded gneiss and sandstone are resistant to weathering, therefore the bare rock surface is a common feature (Plate-13) The weathered material accumulating in the hollows and depressions are conducive to the growth of vegetation. The crest surface of profile No.3 and No.4 is covered with sprinkled bushes of *Rhododendron formosum* and other species such as *Rhododendron arboreum*, *pyrus pashia* etc., while in profile No.1 and No.2 hills the vegetation is totally destroyed and the slope is under cultivation of Jhum. In some places the crest surface is covered with shrubs of *Engilhardtia spicata*, *Drimycarpurrecemosus* and *Elacocarpur Spp*, Species. Thus, the presence of vegetation and thick grass cover reduces the erosion by running water.

(ii) Scarp (Free face):

Below the crest comes the zone of scarp. Here the bedrock outcrop on the steepest part of the slope.

It is the most active element in backwearing of the slope as a whole. This backwearing is caused by rillwash and landslides.

In the profile No.1 and No.2 the scarp face may be noticed at the height of 5410 to 5390 feet and 5340 to 5310 feet. While in profile No.3 and No.4 the scarp is at the height of 4910 to 4940 feet and 4960 feet respectively. Along scarp face the angle of slope is maximum from 65° to 83° . The scarp surface is composed of bare massive Cretaceous-Tertiary sandstone, which are affected mostly by basement controlled faults. Since the zone has a steep slope, the soil does not accumulate and the surface is completely devoid of vegetation(Plate.14) only few shrubs and long grass are noticed along the joints and cracks of the rocks. There are no possibilities of any kind of soil accumulation, as it is a zone of bare surface with very steep slopes. The soil produced on the crest is completely washed down-ward under the force of gravity and running water. This zone is very much prone to rillwash and landslides.

(iii) Debris slope (constant slope):

This slope has been formed by detribus fallen from the scarp above and resting at its angle of repose against

the lower part of the scarp face. Weathering reduces the coarse detritus to finer particles which are then removed by wash, flowing as rills or turbulent sheet flow.

In our present study the height of debris slope zone varies in different hill profiles. In the profile No.1 and No.2 the height of debris is from 5350 to 5380 feet and 5260 to 5290 feet, while in profile No.3 and No.4 from 4855 to 4895 feet and 4840 to 4890 feet. The slope angle along debris varies from 44° to 65° . The thickness of soil decreases from low angle to high angle. In the all four profiles the thickness of soil on the debris varies from 4 to 6 feet with coarse loams and clay.

The profile No.3 shows thick growth of vegetation with the species of *pyrus pashia*, *Gentiana quadrifaria*, and *cleridandron* SPP. In other hills the vegetation has been cleared for cultivation. It is noticed that even up to slope of 65° , parallel narrow soil strips have been prepared along the hill slope. The important crops growth in this zone are potato, maize and some paddy. Due to Jhum farming and loose soil, the erosion is vigorous, particularly during the rainy season.

(iv) Pediment(Waning slope):

The pediment is the broad concavity extending from the base of the other elements to the stream or alluvial plain. Although frequently veneered with detritus, it is essentially a rock cut feature. It is produced by surface wash, and its profile may approximate to an hydraulic curve.¹¹

In our present study of profiles, below the zone of debris or constant slope, there is a less extensive concave surface developed by the hill side recession which has been designated as a pediment or wanning surface. The profile No.1 and No.2 clearly indicate the zone of the pediment at the height of 5330 to 5345 feet and 5240 to 5250 feet. The angle of slope varies from 10 to 20 degree. The pediment slope of profile No.1 is slightly more steep and less extensive then the profile No.2. We can also notice the pediment zone in profile No.3 and No.4 at a height of 4840 to 4850 feet and 4830 to 4835 feet respectively. The zone of pediment in profile No.4 is also less extensive and little bit steeper then profile No.3.

11. Young.A., 'Slopes' Geomorphology Text-3, Published in the united states of America by Longman Inc.New York, Edited by K.M.Clayton, (1972) pp.37.

It has been also marked during the field study that there is a thick light grey loam soil deposit in the form of fine to coarse materials. The soil deposit, which is found at the pediment zone of profile No.1, No.2 and No.3 has developed from the Cretaceous-Tertiary sediments, whereas in profile No.4 Archaean gneissic complex is dominating parent material. The thickness of soil also varies from 5 to 10 feet, in this zone.

However it is very much clear from the study of these profiles that, the pediment zone in these slopes has not been so well developed. The value of slope angle indicates that the pediment zone of these profiles have high degree of slope angle than it is usually to be noticed on pediment surface. It appears that the topography is very much dissected into steep slopes and deep narrow galleys. Thus the process of recession of slope is not so well marked, which is very much important for the development of an extensive pediment zone.

It is also noticed that the pediment zone of profile No.1 and No.2 is dominated by the vegetation species of the scred grove (*castanopsis kurzii*, *quercus griffithii* etc),

where as in profile No.3 and No.4 this zone has been almost devoid of vegetation, and usually used as grazing land. At places some land is under cultivation of maize, potatoes and paddy.

The analysis of slope forms and profiles of the area reveals that the hill slopes reflect more the procedure of retreat, as pointed out by Penck,(1953), then the old classical view given by Geomorphologist (Davis, 1902)¹² of progressive flattening of slopes. According to Penck(1953)¹³ there is little reason to believe that uplift and planation are taking place alternately; rather, uplift and planation are concurrent phenomena and should be treated as such. So there is little justification in speaking of a 'cycle' as classical Geomorphologist. There is no true beginning nor any end to such a cycle ; slope development is a differential process in which at best, several typical quasistationary stages, as discussed in our present slope profile study of Mawsynram, can be discerned.

12. Davis, W.M., (1902), Base-level, grade and Peneplain, Journ. Geol., Vol. 10, pp. 77-111.

13. Penck, W. (1953) op. cit. Macmillan (1953), p. 119.

(v) Profiles and Slope:

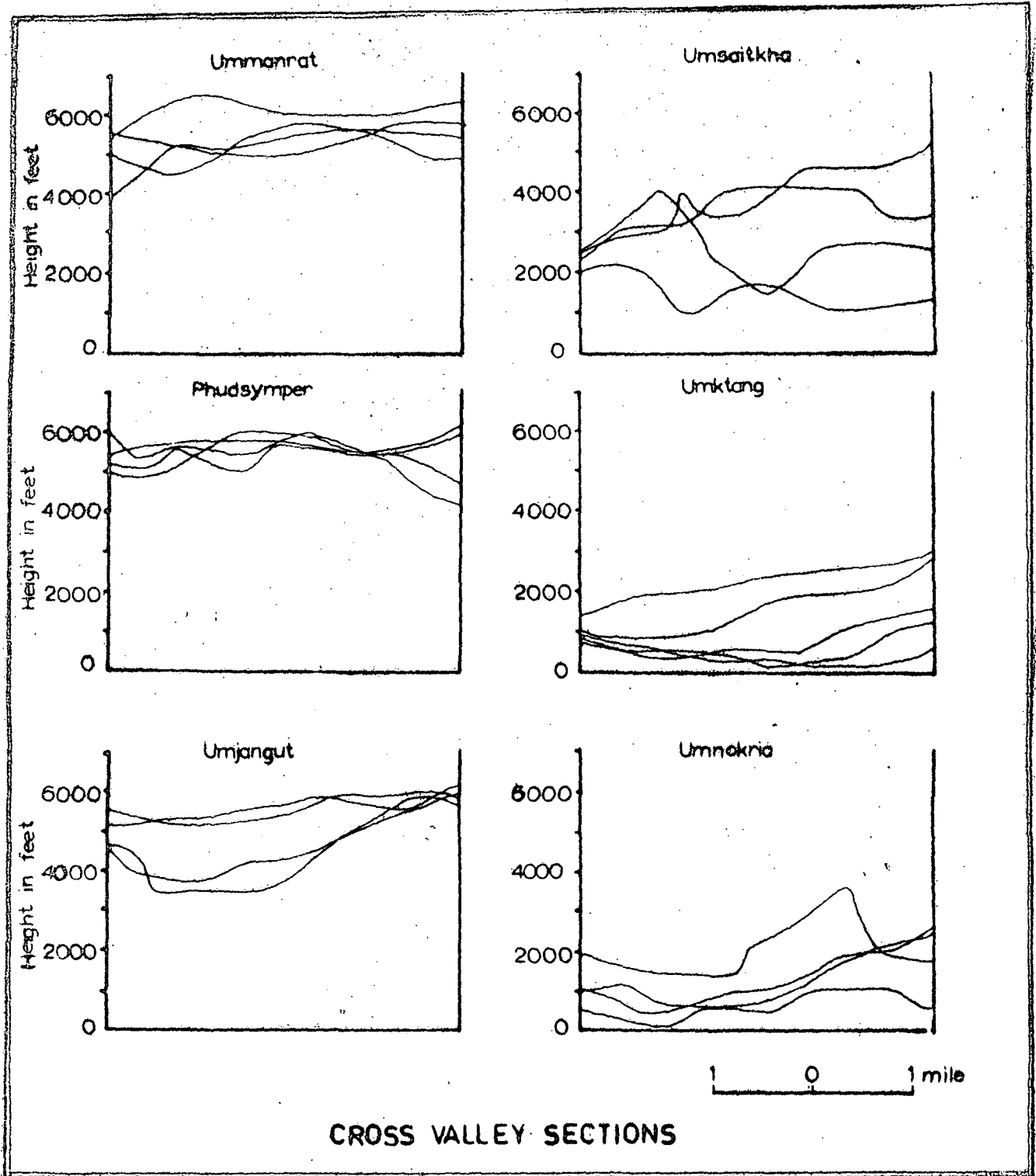
The long profiles of the Umnagi, Umeiw of Bagra and the six other tributaries give a general impression of slope of surface at various levels with break-in-slope. The break-in-slope of the Umnagi (Fig.8) depicts not only the site of one water fall, but it outlines also the deep gorge, before reaching the Bangladesh plain. The one important break-in-slope of the Umnagi demarcate 6000 to 4550 feet surface. During the field study the researcher has also marked wall like, steep slope bank of Umnagi river near Nongpung.

The long profile of the Umeiw river (Fig.8) also convey the nature of slope of gentle undulating surface in its upper reaches and changes in its gradient, where it has carved out deep gorge through the Cretaceous sandstone and lime-stone surface in the lower part. The two important break-in-slope along its long profile, demarcate two gentle 6000 to 5000 feet and 3050 surface. Thus the long profiles of Umnagi and Umeiw show that both rivers seem to be in old stage of cycle of erosion, with their gentle slope profile, in their upper-reaches but youthful in lower stages, where the slope gradient is high.

The long profile of the, Umjangut, Umsaitkha, Umktang and Umnokria except Ummanrat and phudsymer (Fig.9) reveals different gentle rolling surface in their upper reaches and breaks-in-slope in their lower stages. The change in gradient in their lower stage, all along the southern margin of study area is the result of the greater upliftment of the northern part than the south, during the Tertiary period.

The valley side slope angles of all above six small streams have been measured from the Cross-profiles (Fig.22) of the study region. From the valley side slope angles of the Ummanrat and phudsymper basins it is quite clear that the valley side slope does not decrease progressively from the source region to the mouth as in case of Umjangut, umsaitkha, Umktang and Umnokria drainage basins. Thus the valley side slope angles of these four basins have decreased abruptly in their lower stages, because of the presence of deep gorges and abrupt change in altitude of Mawsynram structural platform towards the Bangladesh plain.

The slope of the country around Mawsynram can be analysed from Super imposed profiles drawn from one inch topographical maps. These profiles not only classify



CROSS VALLEY SECTIONS

fig-22

gently sloping lands of various levels and topographic expression of the area under analysis, but their categories are also arranged for landscape analysis from genetic point of view.

An interpretation of the superimposed profiles (Fig.23) gives a summary of the slope pattern of Mawsynram area as noted below:

The longitudinal, superimposed profiles (Fig.23A) show that the northern Archaean gneisses complex rocks capped on high plateau have an undulating surface, with more or less gentle slope profiles, which seems to represent a true peneplain surface. Towards south the undulating surfaces abruptly descend and slope categories change to express steep gradient. Only in extreme southern margin of study area, close to Bangladesh plain, the slope gradient seems to be very gentle.

The superimposed profiles prepared in west-east direction (Fig.23B) of the study area also reveal that the slope gradient has increased progressively from north to south direction.

Thus the long profiles and cross valley profiles of river basins and superimposed profiles of the region

SUPERIMPOSED PROFILES

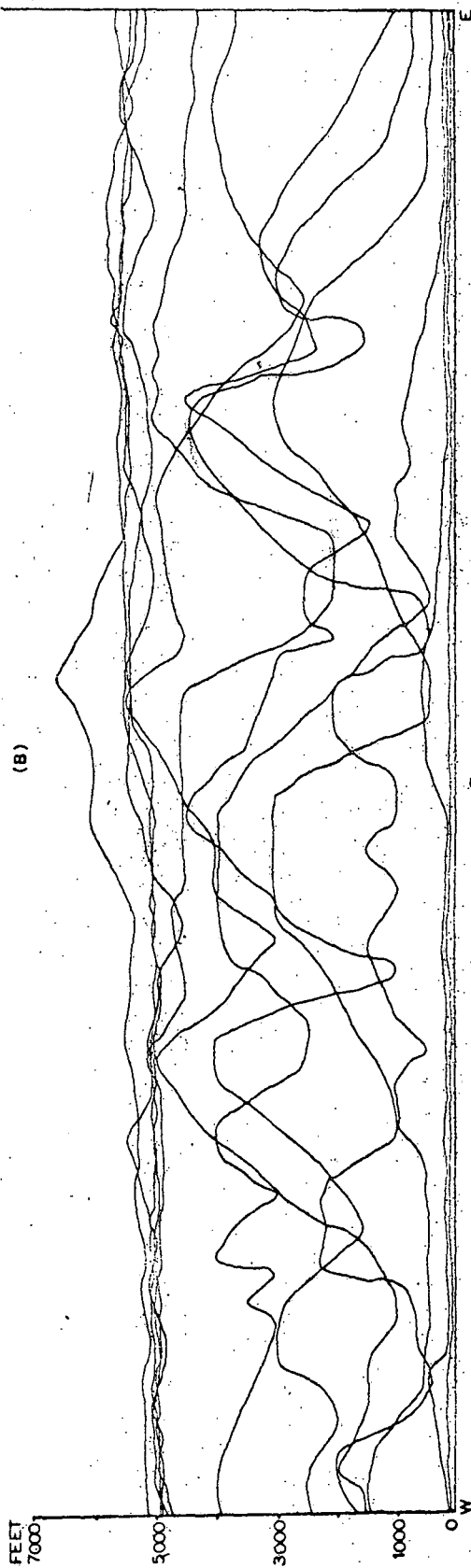
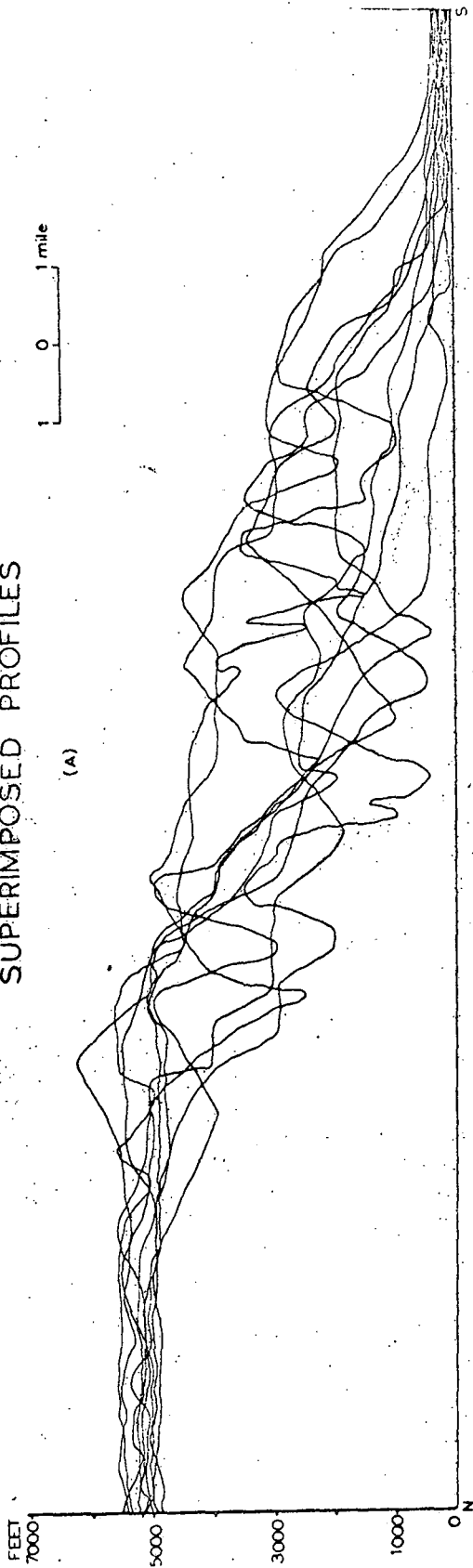


fig-23

under study has expressed very clearly the nature of terrain and slope of the area concerned.

(vi) Slope and Relief:

The first-hand impression about the ground slope of any region can be obtained by the study of contours (Fig.2). The relative spacing of contours reflect the nature of slope. A measurement of the number of contours per unit area gives an idea of general slope. A detailed study of the slope and its relation to the relief of the region under study has been made below with the help of various methods of relief and slope study.

(a) Intensity of Relief:

The trend and distribution of the area in different categories of average relief has been depicted by the intensity of relief map. The relief intensity has been determined by finding out the average relief per unit area of Mawsynram region. The isopleth map (Fig.24) shows distinctly eleven categories of intensity of relief in different parts of the area. The map also outlines areas of different intensity of relief under different categories and their percentage from the total area is summarized below:

MAWSYNRAM
INTENSITY OF RELIEF

0 1
mile

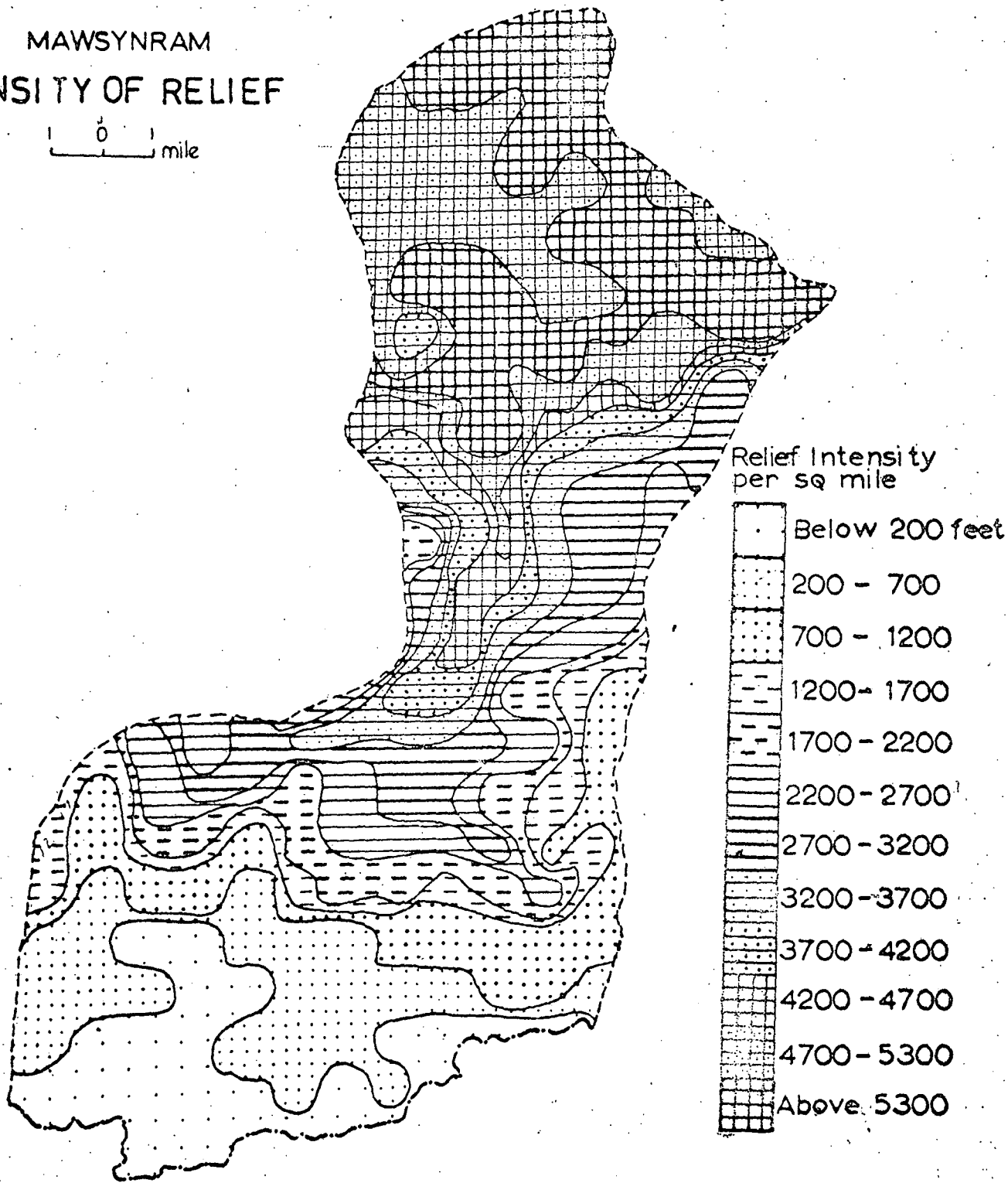


fig-24°

TABLE V(1)

Intensity of relief in feet	Total area in sq mile	Percentage frequency	Cumulative frequency.	Major categories of intensity of relief.
5300 Above	27.5960	15.7242	15.7242	High 35.41%
4700-5300	20.6344	11.7574	27.4816	
4200-4700	7.1392	4.0679	31.5459	
3700-4200	6.7872	3.8673	35.4167	Moderate 27.98%
3200-3700	10.4408	5.9491	41.3658	
2700-3200	16.9352	9.0798	50.4456	
2200-2700	12.1504	6.9233	57.3689	
1700-2200	10.5720	6.0239	63.3928	
1200-1700	10.6580	6.0729	69.4657	Low 36.61%
700-1200	16.6028	9.4033	78.8690	
200-700	19.4760	11.0974	89.9664	
Below 200	17.6080	10.0330	100.000	
	175.50	100.00		

The isopleth map shows the area of high intensity of relief occupies 35.41% of the region under study and extends over the Northern, North-Eastern and Western part, where the dissected terrains and high undulating hills

appear. Area of moderate intensity of relief marks the surface of the central Mawsynram structural platform, with maximum span around eastern part of the region, It forms a belt running from north-east to south west along the central undulating plateau. About 27.98% of the area falls under this category. Area at low intensity of relief covers about 36.61% of the total area. It has an extension over the Southern, South-Western, and South-Eastern part of the study region. The area under this category coincides with low dissected surface of the south, close to Bangladesh Plain.

By summing up, it can safely be said that major area lies in the category of High to moderate category of intensity of relief. Thus, intensity of relief map gives a very clear conception of the nature and distribution of slope of the area under study. It also shows that higher the intensity of relief, the steeper is the slope.

(b) Area-height diagram:

The area height curve (or diagram) represents the absolute or relative areas of land between adjacent contours.¹⁴ In this diagram areas calculated in terms

14. Strahler A.N., 1952, Hypsometric (area-altitude) Analysis of erosional topography, B VII. Geol. Soc. Vol. 63, pp. 241.

of percentage have been plotted against the height which are in absolute values. The area height curve (Fig.25) of Mawsynram shows a 'trimodal' distribution of lands: first mode at 200 feet above sea level, second at 2700 feet to 4200 feet and third one is between 4200 feet to 5400 feet above sea level.

The percentage of land above 5400 feet shows a sharp diminishing trend, although it is a fact that 5800 feet surface is one of the most important erosion surfaces of this region with moderate slope gradients. The land between 2700 feet and 5400 feet above sea level has been subjected to deep dissection and severe erosion, which is interestingly coincide with the region of steep slope.

(c) Hypsometric Curve:

Hypsometric is the measurement of the interrelationships of area and altitude¹⁵. Which has an intimate relationship with the distribution of slopes. It is an Ogive or Cumulative frequency curve or may be said as the cumulative version of the area height curve discussed earlier in this chapter.

15. King, C.A.M., Techniques in Geomorphology, Edward Arnold, London, 1966, pp.

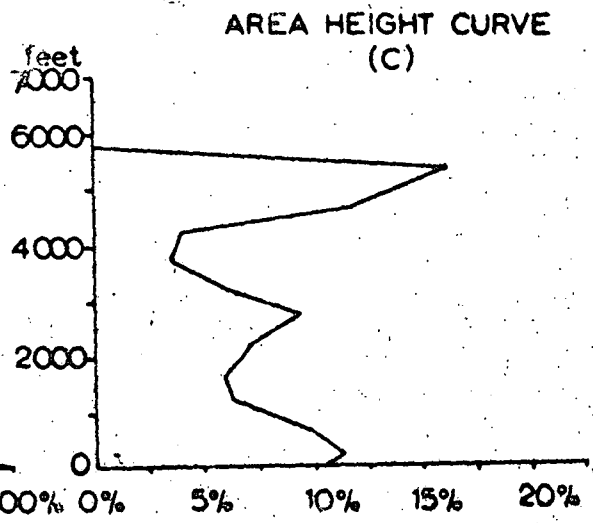
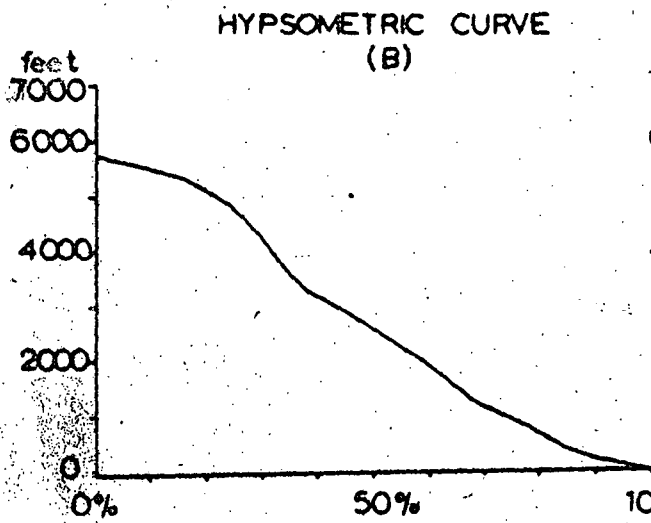
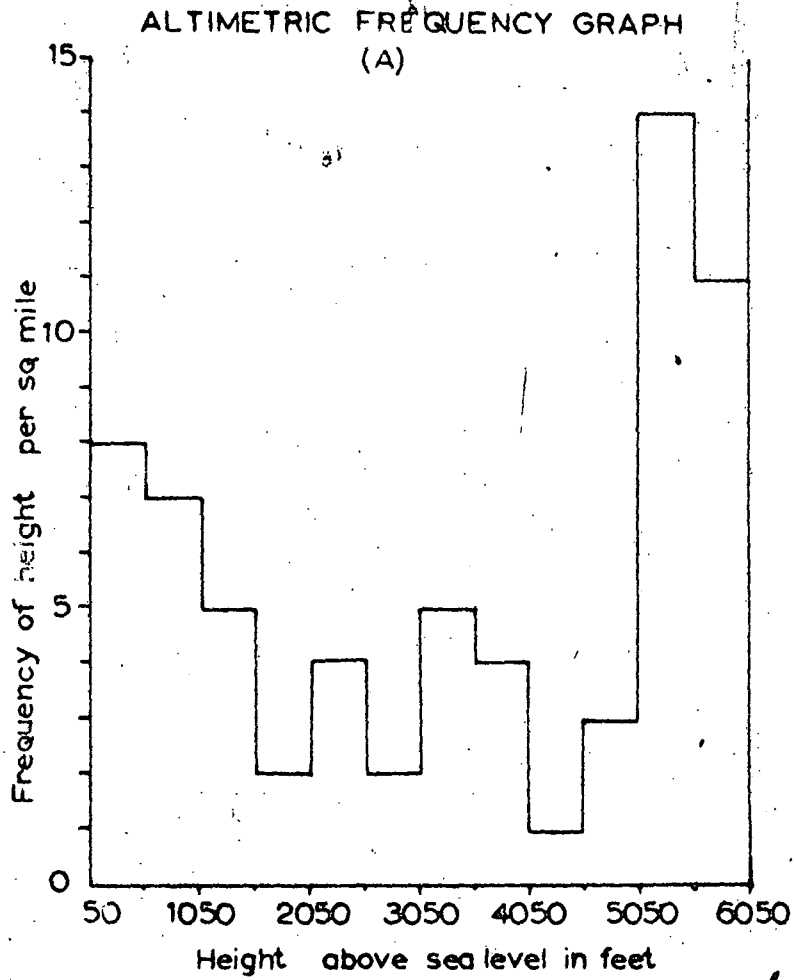


fig-25

The hypsometric curve of Mawsynram (Fig. 25) shows the starting of profile at 5800 feet above the sea level and ending at about 50 feet above the sea level, near the Bangladesh Plain. The longitudinal superimposed profiles of this region (Fig. 23A) discussed earlier seems to be similar to the hypsometric curve. Hence the area is perfectly marked out as a geomorphic unit with distinct homogeneity.

The surface above 4200 feet is extensive and occupy around 32% of the total area, of the study region. It roughly coincides with the undulating moderate slope gradient surface of northern and central Mawsynram structural Platform area. The land between 800 feet and 4200 feet seems to represent the steep scarp and deep dissected Valleys of Southern Mawsynram region, which is also a zone of very high slope gradient and has occupied 40% of the total land surface.

The surface between 50 feet to 800 feet has minimum percentage of the total land, e.g. 28%, which roughly coincides with the older and newer alluvium surface in southern foot hills region of Mawsynram, close to Bangladesh plain. On these surface monadnocks, with gentle slope gradients stand out attaining height up to 800 feet. Thus, the form of the hypsometric curve

of the region under study, shows an intimate interrelationships between area, altitude and nature of slopes.

(d) Altimetric Frequency Graph:

The altimetric frequency histogram deals with the frequency of occurrence of different elevation groups in a region. It is especially valuable when the geomorphologist is seeking to recognize and correlate the different groups of relief with the nature and character of slopes. The altimetric frequency graph of Mawsynram region have been prepared after finding out the highest point in a grid of one inch from one inch topographical maps to show their frequency distribution.

The frequency graph (Fig.25) gives a clear picture, that the land surface of 4950 feet to 5950 feet is dominant in Mawsynram. But the surface is restricted mainly to the northern and central part e.g. around Nongpung, Welloi and Mawsynram village region, which also roughly coincides with the zone of moderate slope area.

The second important surface is between 50 feet to 950 feet, which covers almost all the plain areas of study region e.g. the extreme southern foot hills,

gentle slope area situated very close to Bangladesh Plain. The third one is between 2950 feet to 3950 feet surface above the sea level. This part represents highlands and scarp lands surface, which coincides with the zone of very steep slopes.

The diagrams (Fig.25) therefore, has helped a great deal in identifying the high level erosion surfaces and in roughly correlating these surface with slope form in different parts of the study region. In spite of the fact that the diagram cannot give any clear information of general slope form and origin of any surfaces, although it is an important tool for understanding certain details of the geomorphology of Mawsynram region.

(e) Average Slope:

The calculation of average slope is useful in making quantitative generalization for the study of slope. There are different methods suggested by geomorphologists for the study of average slope of the region. Some methods are much laborious and complicated calculation and results obtained are also not satisfactory. But the method devised by C.K.Wentworth (1930)¹⁶ is a

16. Wentworth, C.K. (1930): A simple method of determining the average slope of land surface, Ame. Jour. of Sc., Vol. 22, pp. 184-194.

general and random' method of determining average slope over an area from a map. This procedure has been used by geomorphologists very often as it is simple and the results obtained are also encouraging to get the general picture of the region under study. So in the present study the method suggested by Wentworth to determine the average slope of the Mawsynram region has been used.

The formula*devised by Wentworth is as follows:

$$\text{Average Slope} = \tan \theta = \frac{N \times 1}{3361}$$

$$\text{Angle} = \theta = \tan^{-1} \theta = \frac{N \times 1}{3361}$$

Where, N= average number of contour crossing in an area per mile.

1= contour interval in feet

3361 = a constant figure.

Following the Wentworth's method (1930), the average slope has been calculated for the preparation of an average slope map of Mawsynram region. First of all, the researcher has traced the contour map from the one inch to one mile topographical sheets of the study region and then grids of one inch north-south and east-west line have been drawn. After that, the total number counter crossings have been counted for each grid and that has

*The constant figure 3361 (is derived from a formula by Wentworth; it is 5280×0.6366 , which figure is the mean of all possible values of $\sin \theta$, θ is the angle between the grid-lines and contours.

been divided by 4 to get the average number of counter crossing per mile. By applying the formula:

$$\text{Average slope} = \text{Tan } \theta = \frac{N \times 1}{3361}$$

(1=50 feet);

The researcher obtained the value of Tan for each grid. Using the natural tangent we obtained the 0° (degree) value of each grid and then slope (degree) has been grouped into five classes (Table V(ii)) and isolines have been drawn for each classes of slope.

TABLE V (ii)

S.No.	Average slope in degree	Area in sq.mile	Per-centage of total area.	Categories of slope.
1	0 - 8 ^o	6.1590	3.50	Gentle
2	8 ^o - 16 ^o	36.3300	20.7090	moderate
3	16 ^o - 24 ^o	52.4500	29.8940	moderately steep
4.	24 ^o - 32 ^o	55.3300	31.52	Steep
5	above 32	25.250	14.39	Very steep
		175.50	100.00	

The average slope map (Fig.26) shows the distribution of average slope and concentration of major slope categories in certain section of area. Isopleth lines express the intensity of slope change and demarcate the

MAWSYNRAM
AVERAGE SLOPE

0 1 mile

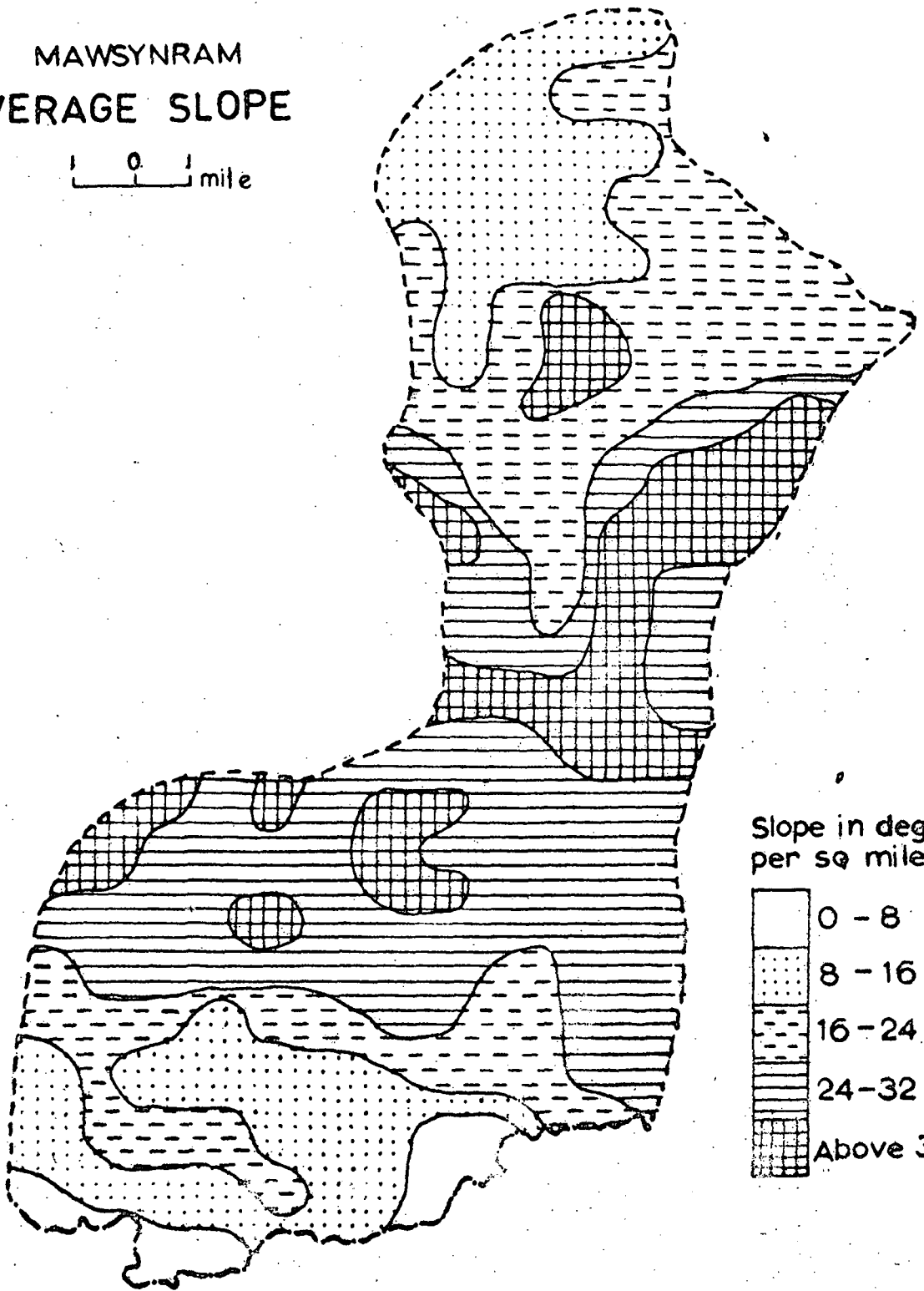


fig 5

five; Gentle, Moderate, Moderately Steep, Steep and very Steep average slope zones. The areal distribution of these five average slope zones in Mawsynram region has been discussed below:

(i) Gentle Slope:

Gentle Slope category with 6° to 8° of average slope, covers an area of 6,1600 sq.mile, which is 3.50 per cent of the total surface and lies in the Southern extreme part of the Mawsynram region, close to Bangladesh Plain, in two conspicuous pockets. One just South-Western corner around the village Dhalaigaon and Kathalbari, the second one located near mouth of the streams, Umparsumai and Umktang, around the Katrang and Hatmawdon village, in South-eastern corner of the study region.

Area covered by this slope category almost coincides with the sections of low-relief (500 feet average), coarse to moderate texture, low-stream frequency (below 7), minimum stream confluences (below 7), and low density of drainage (below 4 and 4 to 8). The soil in this area is mostly alluvial (Newer and Older) type, which is very much suitable for agricultural practices.

(ii) Moderate Slope:

Moderate Slope category with 8° to 16° slope is mainly associated with the interfluvial tracts of South and undulating northern plateau areas of the study region. Both the tracts have covered an area of 36.33 sq.mile, represents 20.70 per cent of the total area. The interfluvial sections of the south, with moderate average slope covers the lower middle section of the Umparsumai and Umktang, Stream basins. Similarly the northern undulating plateau with moderate slope, covers the whole basin of Ummanrat and mainly around the village Sohphoh.

It has been observed that this slope category zone is covered with shifting as well as sedentary cultivation. The slope zone follows the trend of the country and gradually merges into the areas of moderately steep to steep slope categories.

(iii) & (iv) Moderately Steep to Steep Slope:

The areal extent of this category of slope is 107.78 sq.miles (52.45 sq.miles is of 16° to 24° of slopes and 55.33 sq.mile of 24° to 32° of slopes) which is 61.41 percent of total area of the region under study.

It spans over the entire central Mawsynram structural platform region and Southern hilly terrain except a narrow track of very steep (above 32 degree) zone in between, which divides the moderately steep category of slope into two distinct north-central and south central zone of slopes. The north-central zone of this category of slope acts as a major East-west drainage divide between the tributaries of Munagi and the Umei or Bagra rivers. It covers the villages such as Welloi, Nongpung, Painsangut, Laitmawsiang, Sonpian, Lawkhla, Mawling and Twahlongwar etc. The second prominent, south-central zone of moderately steep to steep slope category extends over the southern hilly terrain and dissected parts region of the upper Umparsumai, Umktang and Umnokaria basins.

This slope zone area of Mawsynram region is very often witnessed by land slides and debris flow. One could find while travelling towards Mawsynram village minor to major land slides are frequent. In this area, mixed type of cultivation is practised viz. Maize, Potato etc. Interestingly this zone of slope category almost coincides with the sections of fine texture with high (21 to 28) stream confluence category and high density of drainage.

(v) Very Steep Slope:

Very Steep Slope category (Above 32 degree) covers an area of 25.25 sq.mile with 14.39 per cent of total area of the region under study.

This is the highest category of slope zone in this region and is generally associated with the high relief areas and dissected scarp region. Areas of very steep slope are scattered in small pockets in North, North-Eastern, North-Western and South-Western part of the region under study. In north and North-Western part there are two small pockets of very steep slope category, one is around Sympet peak(5827 feet) and the second one is located north-west corner of this. The most important track of this slope category stretching in between the moderately steep to steep category of north-central and south-central part, all along the Southern and North-Eastern scarp face of Mawsynram structural platform. In South-Western part of the study region three conspicuous pockets of this slope category are located in upper reaches of Umparsumai and Umktang stream.

A study of average slope map of Mawsynram reveals various zones of different magnitudes of slopes. It also

shows that the undulating and low-relief region are the areas of gentle to moderate slope. The elevated Mawsynram structural platform represents, on the other hand, a moderately steep to steep slope zone. The displaced surface have evolved scarps of very steep slope. Although this slope map depict some abstract surfaces and keep the eyes from the actual slopes on the landscape, yet the results are interesting and not far off from the truth.

To sum up the entire analysis of slope, it can be said that mean range of slope varies greatly from one region to the other, but within a selected area of uniform conditions of climate, vegetation, bed rock and the stages of development; slope tends to cluster closely round a mean value (Strahler-1950)¹⁷. Thus, an analysis of Mawsynram region shows close correlations among relief, drainage texture, dissection and slope.

17. Strahler, A.N.(1950): Davis's concept of slope development viewed in the light of recent quantitative investigation, Ann.As.Ame.Geog., Vol.XL,No.3,p.212.

CHAPTER - VI

CLASSIFICATION OF LANDFORM REGIONS

"I believe it is within nature itself that we should seek the principles for geographical division"

GALLOIS, 1908

Introduction:

The basic concepts of landform classification are obtained from regional science, the one that most concerns the Geomorphologist. The most useful type of classification, as pointed out by J.S. Mill (1891), relate to those classes which permit the widest range of generalisations¹. For this reason, classification of natural phenomena should be genetic and the select criteria used in defining the units should be chosen from the fundamental and permanent characteristics of the landscape. In general, therefore, the best type of landform regions classification is that which separates the landscape into natural units, based on origin, process, and form.

Landform is the expression of the geological character, and the surface geometry of the earth's crust, and its general nature can be most easily understood by

1. Mill, J.S. (1891) A system of Logic, 8th edn. Harper New York as quoted in "Terrain Evaluation 'An Introductory Handbook to the history principles and methods of practical terrain assessment" by Mitchell W. Colin, longman group Limited, 1973, pp.27-30.

considering the maps which reveal these two aspects. For the classification of the present study area into different landform regions, various maps such as, Geological map, relative relief map, Drainage density map, Drainage frequency map and average slope map are superimposed and a map has been prepared to faithfully portray the different landform regions. In terms of surface geometry and geology these regions are more or less internally homogeneous and distinct from each other.

Landform Region:








Landform regions (Fig.27) have been outlined after correlating the results of various morphological methodologies and then the geological background of the area supplement to the present Analysis. The map is therefore based up on the informations collected about solid geometry of land and surface material to prepare a composite account of each carved out landform (Choromorphographic units) as noted below in Table VI(1).

TABLE VI(1)

Primary units (area in per cent)	Secondary units with Morphometric and Geolo- gic character.	Area covered in sq. mile	Area in percentage
1	2	3	4
A. Mountains: (26.79)	(1) High hills (GUC-A;RML-Vh;Dm-h; Fm; Svs).	11.50	6.56

MAWSYNRAM
LANDFORM REGIONS

1 0 1 mile

-  High hills
-  Low rolling dissected hills
-  Extensive undulating high tableland
-  Dissected tableland
-  Dissected scarps
-  Deeply dissected high uplands
-  Low rolling uplands with sandhills and swamps

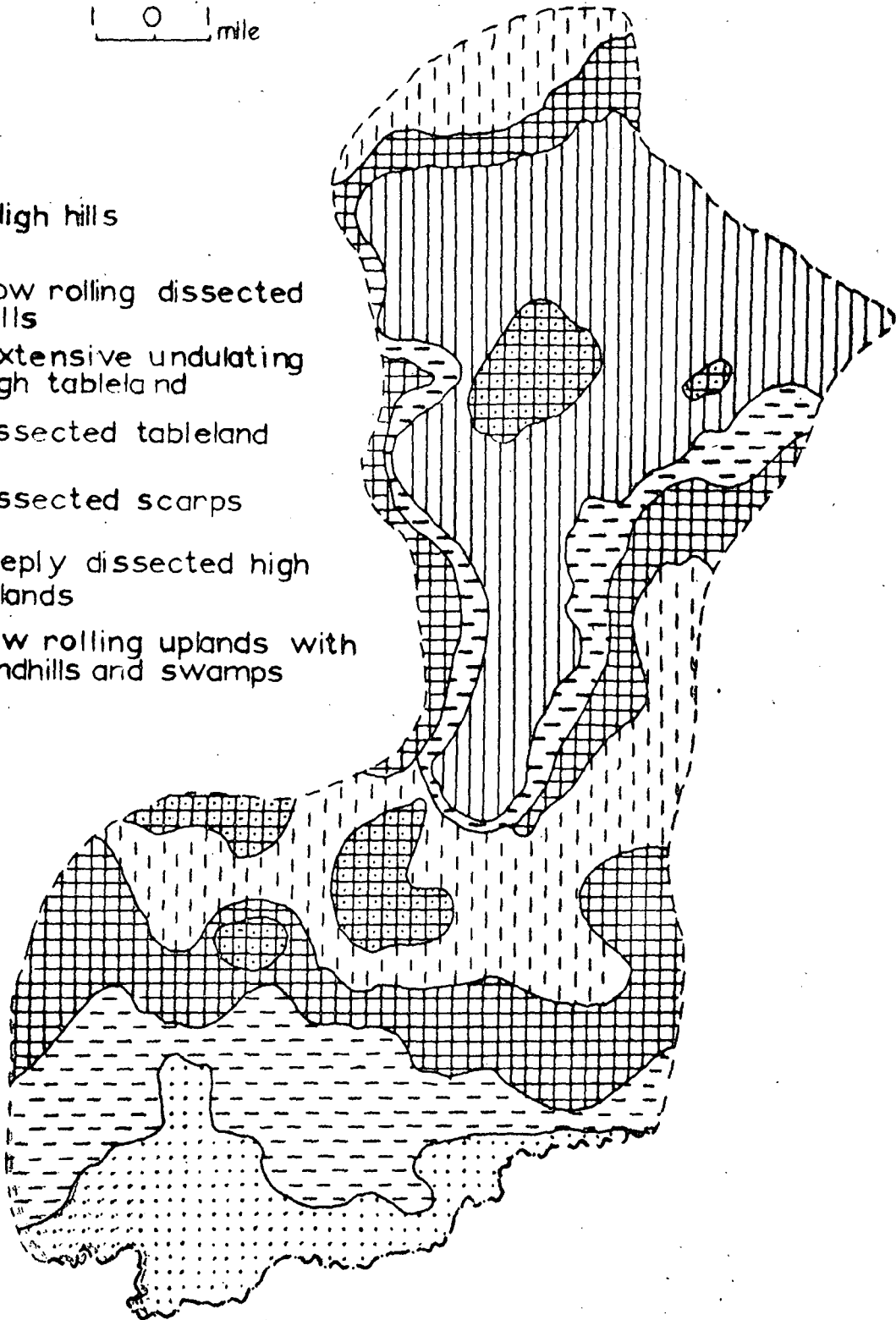


fig-27

1	2	3	4
	(ii) Low rolling hills (GA-VC-E-J; Rml-h; Dm-h; Fm; Ss).	35.50	20.23
B. Plateau: (40.44)	(iii) Extensive undulating high tableland (GUC-PC-A; Rh-vh; Dm; Fm; Sms-vs).	41.50	23.64
	(iv) Lower dissected table land (GE-UC-A, Rml-h, Dm-h, Fml-m, Svs)	29.50	16.80
C. Scarps: (7.26)	(v) Highly dissected scarps (GE-UC-OM-A; Rh; Dm- h; Fm-h; Svs)	12.75	7.26
D. Uplands: (25.5)	(vi) Deeply dissected high uplands (GMP-OM-E-J; Rml; RM-h; Sms).	24.50	13.97
	(vii) Low rolling uplands with many sand hills and swamps (GR-MP-OM-J; Rl; D1-M; F1-M1; Sg-m).	20.50	11.54

Legends:

- Geological formations(G) Recent (R), Mio-pliocene(MP), Oligo-miocene (OM), Eococene(E), Upper-Cretaceous(UC), Jurassic(J), Pre-Cambrian(PC), Archaean(A).
- Relative Relief(infeet)
(R) Low(l) below 700; Moderately low (ml) 700-2700; high(h) 2700-4700; very high (vh) above 5300.
- Drainage density (D)
(Length in/mile per sq.mile) Low(l) below 8; moderate(m) 8-12; high (h) above 16.

- | | |
|--|---|
| 4. Drainage frequency (F)
(Number per sq. mile) | Low(l) below 7; moderately low
(m-l) 7-14; moderate(m) 14-21;
high (h) 21-28; very high(vh)
above 28. |
| 5. Average slope (S)
(in degree per sq. mile) | Gengle (g) below 8, moderate(m)
8-16; moderately steep (ms)
16-24; steep(s) 24-32; very steep
(vs) above 32. |

The primary four landform units of the area clearly indicate that the plateau or table land-form a major landform unit occupying almost 40.44 per cent of the area under study. It is a region of less dissection and represents different uplifted plantation surfaces and their undulating extension.

Mountainous tracts, scattered all over the area, form a separate broad landform unit. They cover about 26.79 per cent of the area and are regions of high dissection. Their origin is related to upper-Tertiary Uplift and their inland extension from scarps. The area is also a region of differential dissection and structural difference. Considering these differences, this major land-form unit is further sub-divided into two secondary units².

The third very important primary landform units of the study area is the scarps. This tracts occupy very limited area (7.26 percent) and are distributed in the central,

2. Singh, R. L. (1957) Morphometric Analysis of Terrain, Nat. Geog. Soc. India, Bull. No. 22, pp. 1.24.

eastern and western part of the region. The presence of scarp is a conspicuous feature in the landscape. The central scarps are slightly less steep than eastern and western scarps. They are clearly associated in their characteristics with structure of their respective regions.

The next most important primary landform units is the uplands occupying almost 25.51 per cent of the study region. It is a region of deep dissection and represents various reliefs. It has been further subdivided into two secondary units according to their nature of dissection, relief and slope. The description of each of the seven secondary units would provide a fundamental differentiation of various morphological aspects of the region.

(i) High Hills:

This landscape unit occupies an area of 11.50 sq.miles, which is 6.56 per cent of the total area under study. It is an area of high relief characteristics and intensity of slope are high relative relief is above 5300 feet and intensity of slope is more than 32° . Drainage density is moderate to high (8-16) and above per sq.mile) depending upon relief, while the area is characterised by moderate stream frequency

(14-21 per sq.mile) ratio. The areas of high hills are scattered in five small pockets, north, central and South-Western part of the study region. In north the most important part mainly lie around the Phudsymper (5827 feet). The other conspicuous pockets of high hills region are located in upper reaches of the Umparsumai and the Umkatang stream basin.

(ii) Low Rolling Hills:

Low rolling hills dominate the landscape in the north, central and south-central part of the Mawsynram block. In north and central part it spans around the scarp face south it runs as a narrow track in an east-west direction between the dissected tableland in the north and deeply dissected high uplands towards the south. This landform unit covers 35.50 sq.mile, which is 20.23 per cent of the total area under study. The relative relief is moderately low to high and varies accordingly with intensity of slope in north and central regions where it is 8 to 12 and above 16 per sq.mile respectively. It is an area of moderate stream frequency with 14 to 21 streams per sq.mile and steep slope region which varies from 24° to 32° per sq. mile.

In the north it covers the part of Archaean gneissic complex rocks surface of the Ummaurat basin but in the central

part the Upper-Cretaceous, Archean, Eocene and Jurassic rocks surface form low rolling hills unit, which extends over the upper-reaches of the Umparsumai, the Umkatang and the Ummokaria stream basins.

(iii) Extensive undulating high tableland:

This extensive tableland is the south-west extension of the vast Shillong plateau, which remains separated from the south by well defined scarps region in the central part of the study region. It is extensive and prominent tableland with a relative relief of 2700 to above 5300 feet and covered an area of 41.50 sq.mile (23.64 per cent). This is an area of moderate drainage density (8-12 per sq.mile), moderate stream frequency (14-21 per sq.mble) and moderately steep (16° - 24°) to very steep (above 32°) of slope intensity and correspond to the para and ortho gneisses, migmatites, meta-sedimentary bands, Arkose, Quartzite etc. of Archaean, Upper-Cretaceous and pre-cambrian period.

(iv) Lower dissected tableland:

The lower dissected tableland seems to run in a south-west to North-East direction in the central part of the study region. This is an area of moderately low to high relative relief (700 to 4700 feet) where intensity of slope is also very high(above 32°). Drainage density is moderate

to high (8 to above 16 per sq.mile) and stream frequency with the moderately low (1-14 per sq.mile) to moderate (14-21 per sq. mile). This is a region with deeply dissected Upper-Cretaceous and Archaean sediments surface which occupies an area of 29.5 sq.mile (16.80 per cent).

(v) Highly dissected scarps:

In contrast to other categories this scarp terrain occupies only 12.75 sq.mile, which is 7.26 per cent of the total area under study, and is unevenly located. The extensive undulating high table land is clearly defined and delimited by highly dissected scarp which runs almost in continuous narrow tracks all along the high table land's eastern, southern and western face.

These scarps outline break in-slope where the streams such as the Umjangut, the Umparsumai and the Umkatang and have cut back their deep valleys since those have been elevated in early and middle Tertiary periods. It is an area of high relief between 2700 to 4700 feet of relative relief. The area exhibits moderate to high (8 to above 16 per sq.mile) drainage density; moderate to high stream frequency (14 to 28 per sq.mile) and very steep slope intensity (above 32°). This scarps region also cover the Eocene, Upper-Cretaceous, Oligo-Miocene and Archaean periods sediments surface.

(vi) Deeply dissected high upland:

This region covers 13.97 (24.5 sq.mile) percent of the area forming moderately low relief (700 to 2700 feet) and slope intensity varies between 16° to 24° per sq. mile. This is an area of low to moderate drainage density (below 8 to 12 per sq.mile) and moderate to high (14 to 28 per sq.mile) stream frequency.

This deeply dissected high upland lies in a east-west direction between the low rolling dissected hills region in the north and low rolling uplands with many sand hills and Swamps in the south. This dissected high upland has been formed by shale, sandstone marl, limestone, calcareous-shale, Arkose, mottled clays, conglomerate, Basalt, acid tuff rocks of Eocene, Upper-Cretaceous, miopliocene, Oligo-miocene and Jurassic period and occupies the middle part of the Umkatang, the Umparsumai and the Umnokia stream basins.

(vii) Low rolling upland with many sand hills and swamps:

This landform unit lies in the southern extreme part of the study area, close to Bangladesh plain, over the micaceous sand, silt stone, felspathic sandstone, clay, marl, calcareous shale, limestone, Arkose, fine silty sand, light to dark greyish clay of Mio-pliocene, Oligomiocene, Eocene, Upper-Cretaceous, quaternary and Recent periods sediments,

covering 11.54 per cent (20.25 sq.mile) of total area under study. This is both gentle to moderate in slope intensity (less than 8° to 16°) and relative relief (less than 700 feet). Similarly drainage density is low to moderate (less than 8 to 12 per sq.mile) and stream frequency is low to moderately low (less than 7 to 14 per sq. mile).

This area covers the villages such as Dhalaigaon, Kathalbari, Katrang, Balat and Hatmawdon etc. and also lower parts of the Umparsumai and the Umkatang basins. Many scattered low sand hill, and swamps located in between two sand hills is common features of this region. This zone is well forested and contain long leaf plants and shrubs.

The study of the landform regions of Mawsynram area not only defines their micro-morphometric units but also denotes the morphological character of each of them. For further recognition of lower order region each unit provides valuable informations. Thus such classification of landform regions is the first stage of the data acquisition for agricultural, engineering, military or planning purposes and caters to the interests of all land users by providing them with background information, and preventing costly duplication of field effort. It also facilitates the task of delimiting areas with different types of priorities of effort. In the area

under study, it is often more important to know the existence, location, and size of such areas and how they are related to one another geographically and the concentrations of population, Agriculture, settlements and transport systems. Thus land is the stage where its varying uses are depicted and the application of such geomorphological tools in different fields will yield substantial results.

SUMMARY AND CONCLUSION

The Mawsynram area forms the south-western part of East Khasi hills district of Meghalaya. The evolutionary story of its Geological landscape is one of recurring uplift and down-sinking during the past 100 million years, which led to the formation of the present spectacular landscape geometry. The variety of sediments from Archaean to the recent periods forming the region is discernible from its protruding surfaces. The following findings and observations pertaining to the Geology, tectonic, and structure of the study area are of paramount importance in so far as they throw light on its landscape evolution:

- (i) It is noteworthy that landscape evolution of this region is more in common with that of the peninsular region, rather than with that of the near by Himalayan ranges of the North-eastern part of India. The ancient rocks of north and Cretaceous deposits on southern part of the study area bear testimony to it.
- (ii) The region has experienced tectonic disturbances from the pre-Cambrian up to Tertiary period. The former movements were violent leading to complete folding and fracturing of the ancient rocks. The

Tectonics of the Jurassic and Tertiary are responsible for plateau volcanism, upliftment and downsinking of different parts resulting in the present unique physiographic configuration.

(iii) The area to the north and central part of study area during the post pre-cambrian period experienced peneplanation resulting in the formation of a flat levelled surface (structural platform-1305 m). The marks of different cycle of denudation noticeable on its surface and the presence of Ancient hard rocks on hill tops provide corroborative evidences to this fact. The plateau is also standing as a watershed between the Umnagi valley on the west and the Umiew or Bagra river valley on the east as a result of major upliftment of this block at the end of the Mio-cene period.

(iv) The general structural trends of the rocks of this region is N.E.,S.W but in south and western part the trend is becoming E-W. The rocks are folded and lineated. In the southern fringe of the study area, the Dauki fault-II,(Balat to Khasmara), from west to east it could be traced

as a high angle reverse to vertical fault. Here the amount of topographic and stratigraphic displacement is very conspicuous.

Though, it is an area with 175.5 sq.miles, the characteristics of the weathering products and processes occurring over its surface are marked to be distinctive. The study on 'Weathering and soil formation' of this region reveals the following facts:

- (i) From the study of the climatic, Biotic, Geomorphic and geological factors it is evident that in southern part of Mawsynram these factors operate to favour deep chemical decay of rocks, while the effect of physical and thermal weathering is more marked in the northern part. As a region of moderate temperature and world's wettest spot it promotes the weathering process and being a stable landsurface since late Tertiary favouring deep penetration of weathering and decomposition of rocks.
- (ii) The Analysis of rainfall and temperature data of this region shows that the rainfall is heaviest (80%) and temperature is maximum (average $24^{\circ}.00C^{\circ}$) during the month of May to August. As the rainfall

and temperature plays a vital role in weathering, it could be safely therefore pointed-out that the intensity of weathering must be very high during these months. The areas affected by processes of weathering are limestone area (25° - $19'$ N to 90° - $35'$ E), Mawphlong Myllem granite rock surface and foot hills area around Balat.

- (iii) The study of the limestone topography (25° - $19'$ N to 90° - $35'$ E) of Mawsynram reveals that Karst features are present but do not dominate the landscape. This may be a result of the topographic youthfulness of the karst features, as this region has been uplifted during the Upper-Tertiary period and also possibly due to the absence of one or more conditions essential to ideal karst development.
- (iv) Investigation of the Mawsyjymbuin cave situated above the water table (vadose zone) near Mawsynram village, reveals that the formation of this cave can theoretically be explained by the 'vadose theory' profounded by Matson.
- (v) The study of soils of this region also reveals that specific soils of the soil envelope fit specific weathered zones. Broadly speaking there are

two types of soils found here i.e. hill soils and plain alluvium. They are also characterised by high organic matter and nitrogen contents. It is also noticed that the soil of higher altitude belonging to Ancient sediments because of heavy rainfall are dominantly acidic. About 90 per cent soils of this region is acidic in nature. The study of soil landscape near Mawphlong of study region confirms that loamy silt with high organic matter and nitrogen content; clay and loams; light grey loams; are on hill summits, hillslopes, and low lying closed depressions. These soils are from the same parent material (Archean gneisses complex) but vary with altitude. The whole area under study is susceptible to large scale soil erosion, consequent upon climatic and human rather than by Geological and Geomorphological factors.

The investigation about the 'Drainage and its Evolution' of the study region have been very much useful in understanding the geomorphological character. The Ummagi, the Umiew or Bagra, the Umparsumai, the Umkatang, and number of other small stream basins bear witness to the denudational history

for they continue to preserve many dissectional forms of varying ages in their beds. The following are the findings of our investigation:

- (i) The present form of drainage pattern was attained through different geological events since mesozoic to present day as indicated by the polycyclic erosional surface of various levels; In southern part of study region the consequent streams are mostly controlled by the structures (monoclines and faults) in the Cretaceous - Tertiary sediments. Many deep gorges scooped out by the streams are the result of massive headward erosion by mainly extensive shifting cultivation on hill slopes, antecedent streams along these joints. The drainage system of this area is to a great extent determined by the central structural platform zone in various direction. The analysis of long profiles confirms that the main river, "the Umnagi" and 'the Umiew' are in old stage of cycle of erosion in their upper reaches but youthful in the lower stages.
- (ii) The drainage pattern study of this region reveals four types of drainage pattern i.e. Rectilinear,

Radial, Semi-dendritic and parallel pattern.

The radial pattern of drainage over granite surface of Sympet peak (5827 feet) in central part stands as a contrast to the semi-dendritic drainage pattern of eastern region. The southern part is dominated by rectilinear pattern, which has developed with joints and the whole pattern has possibly been developed due to Tertiary upliftment of this block. These patterns have focussed light on the rock type, geological structure and stages in drainage evolutions in different parts of the study area.

(iii) The stream frequency study of this region has confirmed that the central and north-eastern part has a higher frequency (14-28 above) than that of the north-western and south-western part (below 7 to 14). This higher frequency may be attributed to the high rainfall (more than 12,000 mm. in a year), non-permeability of the mantle rock (Archaea rock surface) and relief (average 53 00 feet), on the other hand the low stream frequency is mainly due to lack of relief (average 250 feet) and the presence of highly permeable rocks of the Cretaceous-Tertiary sediments.

The analysis of the stream confluence and drainage density does also indicate that, high of these two are related to the rainfall, relief and permeability of rocks and interestingly coincides with the areas of stream frequency.

- (iv) The denudation chronology discloses a clear picture of the antiquity of the present river systems and complex landscape evolution of the study region in different geological periods. On the basis of this study one can conclude that the present river system of this region has probably been stable from late Tertiary or a little earlier to it.

The morphometric analysis of the six stream basins reveals the following salient points on the landform evolution and geometrical similarity of the different drainage basins:

- (i) The abrupt drop in the mean length and area of the 4th order streams of the Umnokria is due to the lack of development of large tributaries beyond this order. During late Tertiary period the rise of the northern part of Mawsynram has probably limited the large tributaries in the down stream directions. The antecedent character and abrupt change in altitude between upper and lower reaches of the Umnokria bear evidence to it.

- (ii) The Ummonrat, the Phudsymper, the Umjangest and the Umsaitkha in its middle reaches flowing across the dissected Archaean and Upper Cretaceous sediments, with conspicuous relief and excessive rainfall have determined the development of many tributaries resulting in highly unequal mainstream length for its 3rd and 4th order stream(Appx.1).
- (iii) The strong structural control guides the direction of the flow of the Phudsymper, the Umjangut, the Umsaitkha and the Umkatang, resulting in high R_b and R_l values for these trunk streams. The sharp rise in the values of R_a , R_b and R_l (Appendix-I) between the 2nd and 3rd order streams of the above streams is due to the influence of high available relief and heavy rainfall favouring the development of the stream network.
- (iv) The geometry of the six drainage basins reveals that the geometrical similarity is maintained among the stream of lower orders as exhibited by similar dimensionless ratios i.e. R_a , R_b , and R_l (Appendix-I). With increasing orders; the drainage basins tend to deviate from each other in their geometrical property.

(v) By comparing the geometry of the drainage basins consisting of six streams with the dimensionless ratios and scale ratios it has been observed that the Ummanrat is similar with the Umnokria, the Phudsymper with the Umkatang and the UmJngut with the Umsaitkha. This similarity points forth the fact that between these stream basins their must have been more or less similar type of geological structure, rock type, relief configuration, rainfall distributions and other associated phenomena. But there is not much geometrical similarity among the tributary basins of the successive orders within main basin. This variation is perhaps, due to the fact that the tributary basins had come from different environments, altitudes and climatic background.

The Morphological character of the area is exhibited by the appearance, dimension and magnitude of slope. The slope of the region is the outcome of the factors like endogenetic forces, intensive weathering process of erosion and transportation. Tectonic movement associated with high degree of denudational activity has produced regional variation in slope. The study of slope which has ultimately influenced the classification of the landform regions of the area under study reveals the following interesting factors

- (i) The plateau region of the northern and central Mawsynram surface expresses subdued topography with gentle slope forms. The eastern and western parts of the plateau are highly dissected and the southern part is reflected with a sharp fracture zone (Dauki fault - II) of very steep slope forms.
- (ii) The general dominating type of slope is convexo-concave form of slope. The upper convexity is due to soil creep mainly during the dry season, and lower concavity is due to the concentrated rill action in the wet season. The soil creeping and rill action can be attributed to the high average slope gradient, ranging from 8° to 32° and possibly due to extensive shifting cultivation on the steeper slopes.
- (iii) The study of the hill slope profiles clearly confirmed that all the four elements of slope identified by Wood(1942), i.e. Waxing, freeface, debris and pediment have clearly been marked here. The analysis of different slope profiles reveal that the pediment zone has not been so well developed. The value of slope angles also indicates that this zone of these profiles have

high degree of slope angle. Thus the process of recession of slope is not so well marked, which is very important for the development of an extensive pediment zone.

- (iv) The study of the long-profiles and cross profiles of the region under study has thrown light on the nature of terrain and slope. The long profiles of all streams show that these rivers seem to be in old stage of cycle of erosion with their gentle slope profile in their upper reaches but youthful in lower stages, where the slope gradient is high. The different other profiles also go to corroborate this facts. This abrupt change in slope profiles gradient towards the southern part is the result of the greater upliftment of the northern block and that of the south, during the Upper-Tertiary period.
- (v) The study of average slope of Mawsynram indicate the five zones of slopes of different magnitudes ranging from 8° to 32° . It also shows that the undulating and low-relief region are the areas of gentle to moderate slope. The elevated structural platform (1305 m) represents a moderate to steep slope zone.

Finally the genetic classification of landform regions of study area defines four primary and seven secondary micro-morphometric units and also denotes the morphological character of each of them. This classification is based on the fundamental and permanent characteristics of the landscape; i.e. Origin, Process and form; which would not only help in acquiring initial data for various planning purposes but also brings together the interests of all land users by providing them with background information and help them to save costly duplication of field effort.

Geomorphology, therefore, is the expression of the geological character, processes operative, the soil and the solid surface geometry of the earth's crust. The systematic study of the discipline goes a long way in facilitating the research in the unchartered areas of agriculture, engineering, military terrain analysis and may provide a sound basis for opening new vistas for other related disciplines. We humbly hope that the Geomorphic study of Mawsynram have its relative importance for the planners and investigators.

APPENDIX - I

Name of the Drainage Basins	Stream Order	Number of streams (NJ)	Length of the Streams in mile (LU)	Area of the Streams in sq. mile (AU)	Meanstream Length in mile (LU)	Cumulative Stream length in mile	Mean stream Area in sq. mile (AU)	Bifurcation Ratio (RB)	Length Ratio (RL)	Area Ratio (RA)
1	2	3	4	5	6	7	8	9	10	11
Ummarat	1	207	102.00	10.25	0.49	102.00	0.01	3.90	1.20	12.00
	2	53	31.00	6.50	0.59	133.00	0.12	4.41	1.83	3.08
	3	12	13.00	4.50	1.08	146.00	0.37	3.00	2.08	2.18
	4	4	9.00	3.25	2.25	155.00	0.81	4.00	0.89	2.46
	5	1	2.00	2.00	2.00	156.00	2.00	-	-	-
Phud Sympar	1	67	36.00	4.50	0.54	36.00	0.06	3.72	1.24	2.00
	2	18	12.00	2.25	0.67	48.00	0.12	6.00	1.98	8.33
	3	3	4.00	3.00	1.33	52.00	1.00	3.00	2.63	1.25
	4	1	3.50	1.25	3.50	55.50	1.25	-	-	-
Umjngut	1	111	52.00	6.00	0.47	52.00	0.05	5.04	0.96	2.80
	2	22	10.00	3.25	0.45	62.00	0.14	5.50	6.11	6.64
	3	4	11.00	3.75	2.75	73.00	0.93	4.00	2.00	1.61
	4	1	5.50	1.50	5.50	78.50	1.50	-	-	-
Umsaitkha	1	100	60.00	7.00	0.60	60.00	0.07	3.70	1.12	1.71
	2	27	18.00	3.50	0.67	78.00	0.12	5.40	2.24	4.16
	3	5	7.00	2.50	1.50	85.00	0.50	5.00	2.67	4.00
	4	1	4.00	2.00	4.00	89.00	2.00	-	-	-
Umkatang	1	250	133.00	12.75	0.53	133.00	0.05	5.81	1.45	2.00
	2	43	33.00	4.50	0.77	166.00	0.10	4.30	1.94	5.20
	3	10	15.00	5.25	1.50	181.00	0.52	2.00	0.67	1.34
	4	5	8.00	3.50	1.60	189.00	0.70	5.00	3.75	3.54
	5	1	6.00	2.50	6.00	195.00	2.50	-	-	-
Umnokria	1	78	57.00	10.00	0.73	57.00	0.12	4.33	1.90	1.58
	2	18	25.00	3.50	1.39	82.00	0.19	3.00	0.95	3.05
	3	6	8.00	3.50	1.33	90.00	0.58	3.00	0.75	1.72
	4	2	2.00	2.00	1.00	92.00	1.00	2.00	6.00	6.50
	5	1	6.00	6.50	6.00	98.00	6.50	-	-	-

APPENDIX - IIPROFILE No.1PROFILE No.2

<u>Height above the sea level (in feet)</u>	<u>Angle of slope (in degree)</u>	<u>Height above the sea level (in feet)</u>	<u>Angle of slope (in degree)</u>
5450	46	5350	37
5440	59	5340	50
5430	78	5330	52
5420	83	5320	55
5410	80	5310	63
5400	70	5300	72
5390	62	5290	75
5380	60	5280	67
5370	57	5270	53
5360	55	5260	48
5350	51	5250	20
5340	39	5240	10
5330	20		

APPENDIX - II (Contd...)PROFILE No.3

Height above
the sea level
(in feet)

Angle of
slope
(in degree)

4940

49

4930

61

4920

78

4910

83

4900

81

4890

63

4880

59

4870

57

4860

53

4850

49

4840

44

4830

15

PROFILE No.4

Height above
the sea level
(in feet)

Angle of
slope
(in degree)

4970

41

4960

49

4950

62

4940

64

4930

60

4920

56

4910

53

4900

50

4890

48

4880

47

4870

45

4860

36

4850

28

4840

38

4830

20

4820

18

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PLATE NO. 1



PLATE NO. 2

245



PLATE NO. 3



PLATE NO. 4

240



PLATE NO. 5

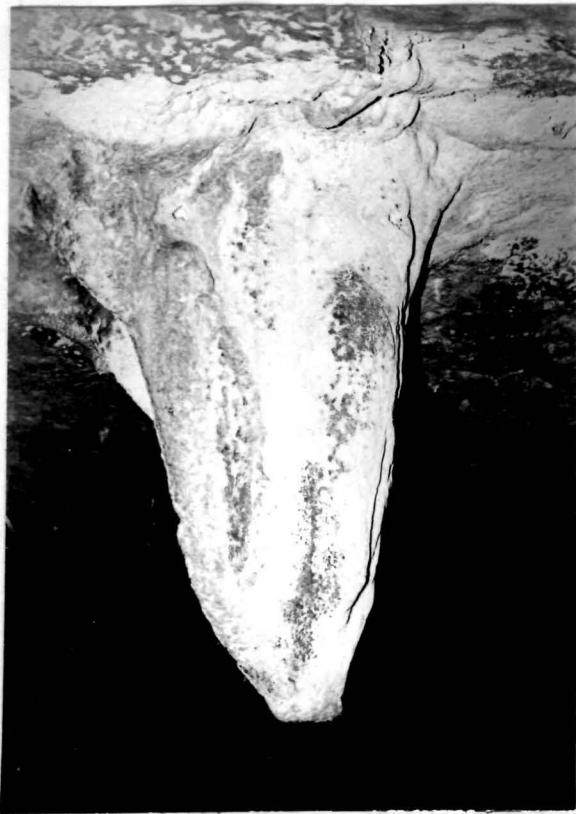


PLATE NO. 6

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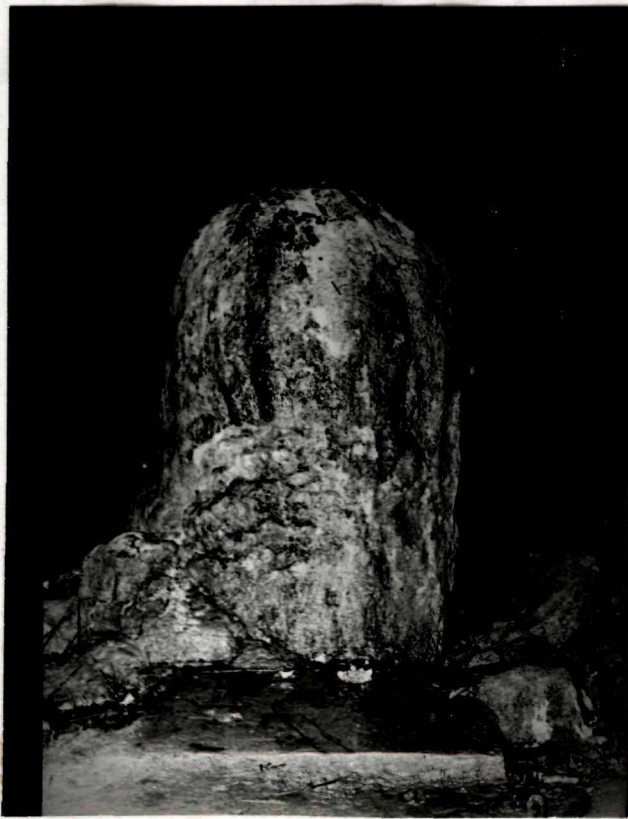


PLATE NO. 7



PLATE NO. 8

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PLATE NO. 9



PLATE NO. 10

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PLATE NO. 11



PLATE NO. 12



PLATE NO. 13

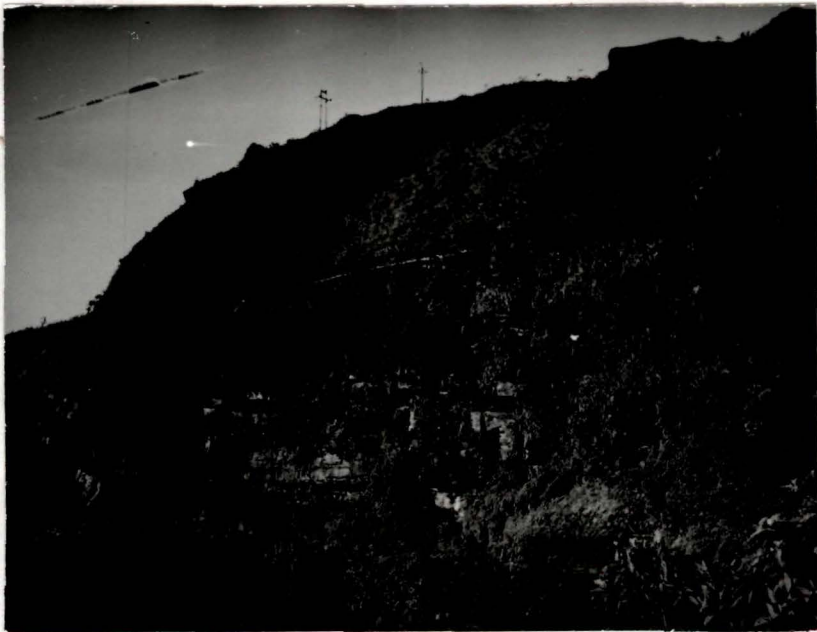


PLATE NO. 14

RECORD
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