GEOMORPHIC STUDIES AROUND CHERRAPUNJI EAST KHASI HILLS, MEGHALAYA

ABSTRACT

Miss SUMITA BISWAS
DEPARTMENT OF GEOGRAPHY
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Dissertation

SUBMITTED
IN
PARTIAL FULFILMENT OF THE REQUIREMENT
FOR THE DEGREE OF

MASTER OF PHILOSOPHY

NORTH-EASTERN HILL UNIVERSITY

SHILLONG (INDIA)

1990

GEOMORPHIC STUDIES AROUND CHERRAPUNJI, EAST KHASI HILLS, MEGHALAYA

Introduction

Geomorphology is the study of evolution of landforms. It is the science which is concerned with the study of landforms at the surface of the earth. Geomorphology plays a dominant role in developmental programmes and resource management.

Geomorphology tells about the shape and size of hills, mountains, the relief of an area, the degree of slope, the characteristics of soil, the subsurface geology and the nature of raw material exposed in all available sections. But the application of geomorphological principles could be increasing. The same parameters may be applicable in the soil science, economic geology, military geology, engineering geology, mining geology, hydrology, location for construction of dams, railways, highways, industries, townships and channel network etc.

Geomorphology is a very dominating factor in the human environment that its influence on the pattern of land use at any place is immense. Thus land use in mountains, plateaus and plains differ greatly. Similarly, the underlying strata of geological formations, surface configuration and climatic conditions control the geomorphic processes and their varied impacts upon the human activities.

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

The main idea is to identify individual landform or landform complexes as either favourable or unfavourable to a particular type of economic activity.

There has been a phenomenal development in the field of geomorphological studies in the 20th century. Each geomorphic process have distinctive features and develops characteristics assemblages of landforms. Thus the importance of geomorphology in any developmental activity cannot just be over ruled.

The present study "Geomorphic Studies Around Cherrapunji, East Khasi Hills, Meghalaya" has been taken up to understand the geomorphological traits of the study area.

Choice of the Area

The area selected for present study has certain very interesting geological and physical features and unique geomorphological characteristics. Besides that it can be said that no intensive geomorphic study of this region has so far been done. Another important aspect is the world's wettest spot with about 11000 mm or 1100 cm rainfall in a year, which results in the formation of strong fluvial dominated landforms.

The area of study falls in the survey of India toposheet No. $78\frac{O}{11}$ and $78\frac{O}{15}$. The area of study lies between 25°15' to 25°22' N latitudes and 91°39' to 91°51' E longitudes around Cherrapunji. The study area includes the Shella Bholaganj C.D. Block, Pynursla C.D. Block and Cherrapunji town.

Objective

The aim of the present study is,

(i) To study the geology of the study area in relation to lithology and structural characteristics of rocks.

(ii) To investigate the spatial nature of weathering variations on different rock types with an inventory of soil characteristics and its relationships with rock types and climate.

(iii) To examine the nature of relief and slopes and their association with structure, process and form.

(iv) To examine the type, evolution and characteristics features of drainage systems.

(v) To study the type and characteristic of limestone topography in the area.

(vi) Identification and classification of different landforms and geomorphic domains in the area. To study their characteristics and evolution.

Plan of Work

The work was carried out in three phases, viz.

1) Pre-field phase.
2) Field work phase.
3) Post field work.

To understand the geomorphology the following inter-related aspects were studied.

1) Geology

2) Relief and Slope.

3) Weathering, soil and mass wasting.

4) Drainage and its evolution.

5) Analysis of limestone topography.

6) Landforms Analysis.

Geology

Physiographically it forms part of the peninsular shield lying south of the northeastern Himalayas. It is a horst forming plateau region block uplifted since Pre-cambrian. The Kernel of the plateau comprises the oldest rocks in the State i.e., the geneissic complex along with Shillong group of rocks. The southern fringe of the massif has Cretaceous-Tertiary sedimentary pile.

Physiographically the formation of Cherrapunji plateau is linked with the structural evolution of the Shillong plateau. Shillong plateau comprises of the oldest rocks in the state, i.e, the Shillong group of rocks in the eastern part. The western part is composed of Creta-ceous-Tertiary sedimentary rocks. The area has quite exten-sive deposits of limestone formations and also has many interesting tectonic features including the famous Dawki fault.

As a part of Shillong plateau this region consists of the Pre-Cambrian rocks acutely folded and steeply dipping with an overturned fringe of Mesozoic and Tertiary sediments. The geological chronology seems to have similar sequence as that of the Chotnagpur plateau and the Rajmahal Highlands.

Relief

The different geomorphological features in any area have relief manifestation on different scales. The relief is based on differences in elevation. The important relief analysis includes altitudinal zones, absolute relief and relative relief.

The altitudinal distribution reveals erosion surfaces occurring at different levels. Generally, the maximum concentration of altitudinal zone lies towards southeastern part in Wah Tymshun catchment area and its tributaries.

The lowest elevation (600 m) of absolute relief lies in very small part of the study area. In general the absolute relief decreases towards south. The height group of above 1600 m occurs in patches towards the north-western part of the area.

The lowest relative relief less than 100 m is confined in the central west corner. The relative relief gives more regional character of the physical landscape.

Slope

Slopes are the basic features of landscape. The slope profile is not constant. It is subjected to alteration by weathering, erosion and mass movement. Slope analysis revealed nine categories of slope in the area.

The level to gentle slope less than 5° category is confined mainly in the southern part of the study area. The moderate slope (10° to 15°) is mainly found in the south central part. Rest of the categories are distributed throughout the area. Slope analysis reveals that no vegetation cover is found on steep slopes. The weathered rocks are slipping and rolling along the slopes as a result very few settlements are found in such area.

Weathering, Soil and Mass Wasting

These three phenomena occur in nature in a sequence. Weathering is the disentegration and decomposition of rocks and minerals at the earth surface as a result of physical and chemical action. The physical landscape of the study area is a cumulative function of the exogenetic and endogenetic forces active in the area. Lithology, structure and climate play a very significant role in shaping the landscape.

The limestone formation of the area shows a complete dissolution of rocks in water. It is observed that the cave deposits are mainly due to chemical processes. There are some unique development of stalactites and stalagmites as noticed inside the cave.

The soil formation has been described along with the type and properties of soils in succeeding sections. The most important soil is red loamy soil, lateritic soil, red and yellow soil and recent alluvium. Shifting cultivation in the hilly areas is generally hazardous and associated with continued slope degradation, consequent upon the low production, soil erosion is a common feature in the area.

Drainage Analysis

An understanding of both the drainage characteristics and fluvial processes is very important to understand the evolution of landscape in the area. The area by and large form part of Wah Tymshun basin.

The drainage frequency and drainage density maps have been prepared. It is seen that the northern half of the area has relatively lower drainage frequency and drainage density with comparison to the southern half. Some underground channels in limestone formation are clearly seen.

Limestone Topography

In the study area well developed caves and developing caves of limestone are found. The area is full of sedimentary, massive, crystalline rocks like sandstone, limestone, clay and they are well bedded and well jointed. In the study area the Lakadong limestone, Sylhet limestone, Prang limestone, and Therria limestone are found here. The lower part of the limestone beds contains good quality of limestone which is suitable for cement manufacturing. Small rounded limestone hills of the Eocene period are found scattered in the region. Limestone cave, Karst topography Caverns and cone are the common feature in this region.

Landforms

Landform is the expression of the geological character and the surface geometry of the earth's crust. Geomorphologically the area is divided into two domains.

1. Plateau or table land.
2. Hill

Each domain is characterized by distinct landforms.

The plateau depicts the following landforms.

1. Gently sloping plateau.

2. Plateau Relicts.

3. Cuesta.

The hill depicts the following landforms.

1. Moderately Sloping Hill.

2. Steeply Sloping Hill.

3. Scarp.

Recent terraces are confined by and large along the southern part of the study area, and along the valley of Wah Tymshun river. The terraces are mostly of sandstone and limestone.

Conclusion

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

1) Geological information indicate the Shillong group of rocks are highly dissected and slopy but the sedimentary rocks have less undulation and thin layer of soil.

2) The relief (absolute and as well as relative) rises south to north. The relative relief gives more regional character of the physical landscape.

Nine slope categories varying between below 5° to above 30° have been identified in the area. A general pattern of slope rise with rise in absolute relief is observed. The weathered rocks are slipping and rolling along the slopes as a result very few settlements are found in such area.

3) Weathering is the disentegration and decomposition of rocks and minerals at the earth surface as a result of physical and chemical action. Lithology, structure and climate play a very significant role in shaping the landscape.

4) The drainage characteristics and fluvial processes is very important to understand the evolution of landscape in the area. Some underground channels in limestone formation are clearly seen.

5) The limestone formation of the area shows a complete dissolution of rocks in water. It is observed that the cave deposits are mainly due to chemical processes. There are some unique development of stalactites and stalagmites as noticed inside the cave.

6) The area has two distinct geomorphic domains (Plateau or table land and Hill domain), each having its characteristics landforms.

Underground channels are developing because of less soil cover and weak planes joints and bedding planes in the limestone rocks.

ACKNOWLEDGEMENTS

I express my deep sense of gratitude to my Supervisor Professor R.K. Rai, Department of Geography, North-Eastern Hill University, Shillong, for his valuable guidance during this work.

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

Sumita Biswas

THE 12 DECEMBER 1990 SUMITA BISWAS

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Professor R.K. Rai
Department of Geography

CERTIFICATE

This is to certify that the dissertation entitled **"Geomorphic Studies Around Cherrapunji, East Khasi Hills, Meghalaya"**, submitted by **Miss Sumita Biswas** in partial fulfilment of the **Degree of Master of Philosophy** of the Department of Geography, School of Environmental Sciences, North-Eastern Hill University, Shillong, is a bonafide study of the author carried out under my supervision and guidance. The matter embodied in the dissertation has not been submitted by her for the award of any other Degree or Diploma.

R.K. Rai
(R. K. Rai)
Supervisor

SHILLONG
THE 12 DECEMBER 1990

12/12/90
Dr. A. C. Mohapatra
HEAD
Department of Geography
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NORTH EASTERN HILL UNIVERSITY
Date.........

CONTENTS

ACKNOWLEDGEMENTS

I express my deep sense of gratitude to my Supervisor, Dr. R.K. Rai, Professor of Geography, North-Eastern Hill University, Shillong. His protective guidance, care sustained interest and personal involvement to the problem has shaped the work to the present form.

I am also immensely grateful to Dr. A.C. Mohapatra, Head, Department of Geography, North-Eastern Hill University, Shillong, for providing the facilities for the present work.

I acknowledge with a deep sense of gratitude for the library facilities of the Geological Survey of India, Shillong, and ICAR Research Complex for North-Eastern Circle, Shillong.

I acknowledge with a deep sense of gratitude to my friends Dr. S.K. Shahi, Dr. R.C. Joshi, Mr. R.P. Sharma and Mrs. M. Agarwal of NEHU for their kind help on different occasions.

I also extend my sincerest thanks to Mr. Joseph F. Khongbuh, for ensuring the excellent and timely typing of the dissertation.

I gratefully acknowledge the assistance of the research fellowship of the Department of Environment and Forest, North-Eastern Hill University, Shillong, for the completion of this work.

I am thankful to all the staff of the Department for kindly extending their help and cooperation in this work.

Sumita Biswas

SHILLONG *(SUMITA BISWAS)*

THE 12 DECEMBER 1990

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CHAPTER I

INTRODUCTION

INTRODUCTION

Geomorphology is the study of origin and evolution of topographic features by physical and chemical processes operating at or near the earth's surface. The study of geomorphology has been described as the 'Earth shape science' (Brown 1970). The study of geomorphology is based on the principle that all landforms can be related to a particular geomorphic process or set of processes and that all landforms thus developed may evolve with time through a sequence of form dependent in part on the relative time, a particular process has been operating underlying all geological and geomorphical principles in the concept of uniformitarianism, which states that the natural, physical and chemical processes which operate today have operated in the past and will continue to do so in the future. Study of present phenomena which can be observed in operation allows exploration into the past to infer the origin of landforms which are the effects of past processes.

The first aspect geomorphology is derived from the Greek word 'geo' meaning 'earth', 'morpho' meaning 'form', and 'logas' meaning 'science', the science of landforms.

The second aspect is surficial geology, the study of the rocks and mainly unconsolidated materials that lie at or near the land surface. These unconsolidated materials overlying bedrock are surficial deposits or surficial sediments. They are the materials in which soils form, on which crops grow on and in which life exists and which man made structures are built together the landscapes surface rocks and surficial deposits comprise a major part of the scenery that is pleasing to the eye and is enjoyed places set aside for recreation.

Recent works emphasise the definition of F. Hijulstram, that geomorphology is the science of land forms and land forming processes. In a sense a landscape cannot be understood until the entire geologic history of the rocks is known. The concept was first succinctly stated in 1875 by James Hutton, who thought that the present phenomena which can be observed in operation allows extrapolation into the past to infer the origin of landforms which are the effects of past processes. Building upon the work of his predecessors William Morris~~an~~ Davis in 1909 synthesized many earlier geomorphic ideas and molded them into a unified system for the study of landforms. He recognized that the origin and evolution of topography was dependent on geologic structure, geomorphic process and stage of development. This concept provides the framework for interpretive geomorphology and thus its understanding is imperative to the geomorphology.

Geomorphology tells about the shapes and size of hills and mountains the morphometric analysis the degree of slopes, the drainage pattern and the nature of raw material exposed in all available sections. But the term geomorphology is not limited to this context only. Application of geomorphological principles could be increasing. In the field of soil geology, military geology, social sciences, economic geology, engineering geology, mining geology, hydrology ecology and agriculture could be mentioned, which could be well served and strengthened by the application of geomorphological knowledge.

Geomorphology is a very dominating factor in the human environment that its influence on the pattern of land use at any place is immense. Thus land use in mountains, plateaus and plains differ greatly. Similarly, the underlying strata of geological formations, surface configuration and climatic conditions control the geomorphic processes and their varied impacts upon the human activities.

How far regional description, historical reconstruction and the details of the chemical and physical response of rocks to water and air be unified into the science of geomorphology. There has been a phenomenal development in the field of geomorphological studies in the 20th Century. Since 1960 a phase of intensification and concentration has emerged during which attempts have been made to place the study of geomorphology in the correct perspective. Each geomorphic process imparts to the landscape distinctive features and develops characteristics assemblages of land forms. Since landforms bear the stamp of the process that developed them, it becomes possible not only to describe landforms but also to infer their origin. Interpretation of the origin and evolution of landforms is the principal objective in geomorphology. The growth of the geomorphology in India is rather recent. Among the geographers and geologists are D.N. Wadia, Krishnan, J.A. Dunn, W.D. West, S.P. Chatterjee, S.C. Bose, R.P. Singh and S.C. Chatterjee. Application of morphometric analysis in classification of landforms into various order has been done by R.L. Singh (1976). Recent researchs in regional geomorphology incorporate the study of the processes modifying the landscape.

In India geomorphological works have been done by the National Atlas Thematic mapping organisation and Oil and Natural Gas Commission and Geological Survey of India. During the past period many papers have been submitted by them in a number of seminars. A number of studies on regional geomorphology of India have also been done by some geomorphologists and geologists. A number of regional geomorphological studies such as some parts of Andhra Pradesh (R. Vaidyanathan, 1964), Chotnagpur Plateau (R.P. Singh, 1960), Rajasthan region (B. Ghosh and S. Singh, 1969) and Sonar Bearma basin of Madhya Pradesh (R.K. Rai, 1980).

Now-a-days Aerial photographs and Satellite imagery is becoming more and more popular in geomorphology. These are helped in the mapping of drainage, geology stream beds. More aerial photographs are used for soil erosion, gully and sheet erosion etc.

Choice of the Area

The area selected for present study has certain very interesting geological and physical features and possesses unique geomorphological characteristics. Besides that it can be said that no intensive geomorphic study of this region has so far been done. Again this region is the world's wettest spot with about 11,000 mm or 1100 cm rainfall in the year, which results in the formation of strong fluvial dominated landforms. Thus keeping in mind the above characteristics of the area Cherrapunji has been selected for the present study.

Area of Study

The State of Meghalaya is comprised of the Garo,

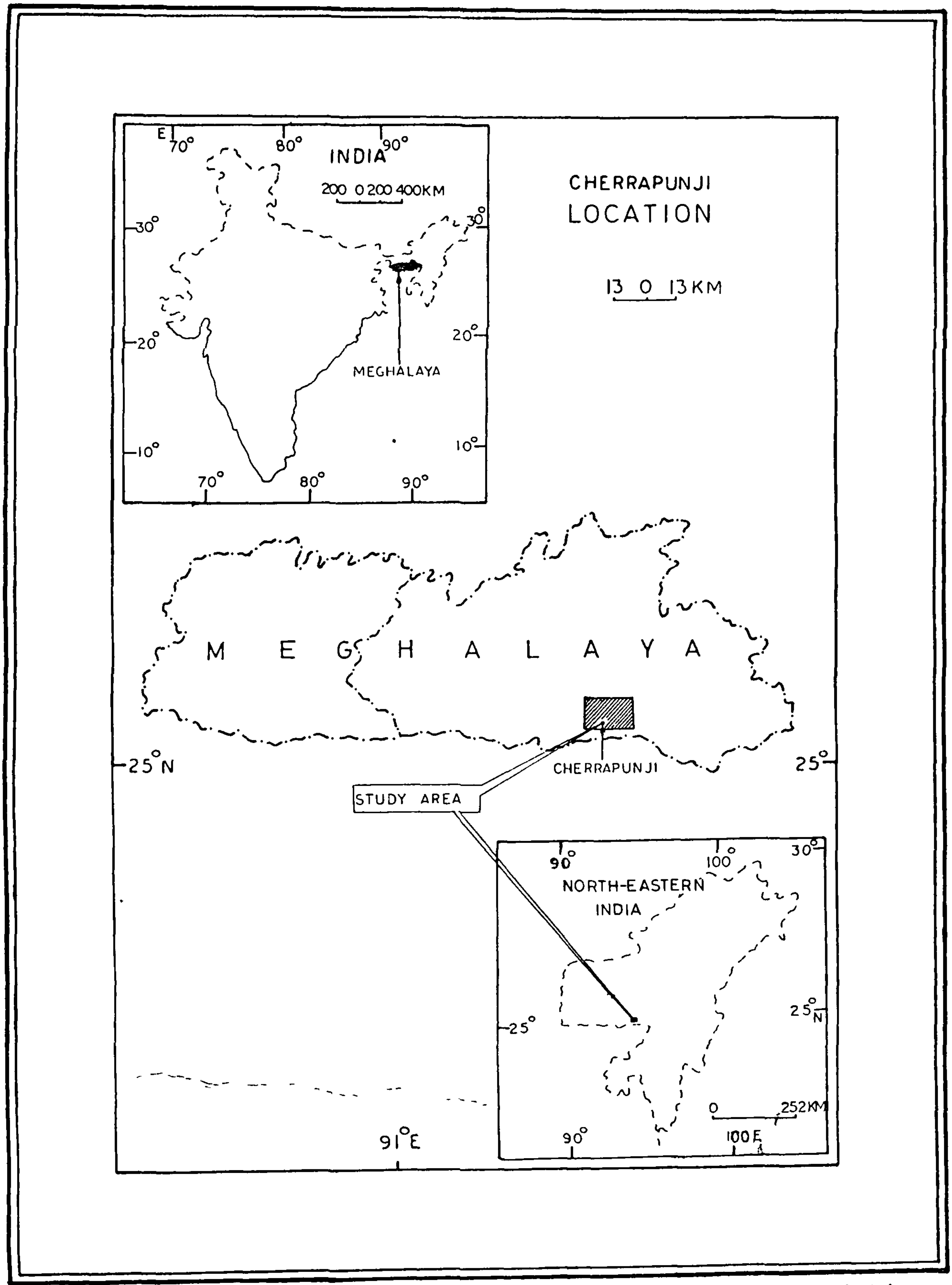
INDIA
200 0 200 400 KM
MEGHALAYA
CHERRAPUNJI
LOCATION
13 0 13 KM
M E G H A L A Y A
CHERRAPUNJI
25°N
25°
STUDY AREA
NORTH-EASTERN
INDIA
0 252 KM
91°E
100 E

FIG.1

Khasi and Jaintia Hills Districts which came into existence as a separate state in January 1972. The area of study falls in the Survey of India toposheet No. $78\frac{0}{11}$ and $78\frac{0}{15}$. The study area lies between 25°15' to 25°22' N latitudes and 91°39' to 91°51' E longitudes around Cherrapunji (Fig. 1). The total area of the study region is about 260 square kilometres. To the North of the study area lies Shillong Plateau and further South is Bangladesh plain. The diverse geology and geomorphic characteristics that is the occurrence of the extensive undulating high plateau with numerous hills to the North moderately high gently dipping table land in the Central part and lowlying dissected terrain in the South present a complex variety of landforms. The climate of the region also varies from Sub-Tropical to temperate type with highest rainfall in the world accounting more than 11,000 mm annually. Thus the fluvial geomorphic processes are dominating in shaping the landforms.

Physiography

The Cherrapunji plateau is a dissected terrain along the southern part of the Shillong Plateau. The plateau like character of the terrain is well developed within Cherrapunji town and to its North with an elevation between 1200 m to 1530 m whereas the gorges on the East and West sides go down about 450 m. Towards the South of Cherrapunji the plateau abruptly ends on a scarp face of thick cretaceous sandstones and then slope abruptly like a wall to the plains of Surma Valley along its Southern margin.

The Umstew, Umsohra, Wahrew, Umiew or Umlam or Bagra find their way down this wall originating over the plateau surface and given rise to waterfalls along the south of Cherrapunji. Towards the soutn the terrrain covering the Shella and Bholaganj shows a karst limestone topography with numerous sink holes over the thick limestone deposits covering the area.

Flora and Fauna

Over the plateau portion the flat topped hills area covered by coarse grass and pine groves whereas the gorges ravines support almost impenetrable jungles. Flora and fauna play an important role in this study area. The higher elevation over the plateau are clad and pine groves. Dense forest of mixed trees cover the area along the southern part of the terrain in which orange betel nut, jack fruit, pine apple, and varieties of fruits are the main agricultural products the hill slopes around Cherrapunji. Regarding fauna this part of the terrain along the southern part of the plateau is probably the least animal infested area except for a few variables of snakes, birds, wild cat, panther and rarely deer. This area is however well known for a variety of rare orchids and rare species of butter flies attracting visitors from outside.

Climate

The area experiences tropical monsoon climate. The plateau bears the burnt of the monsoon which begins from February to September. The moisture bearing winds obstructed first by this scarp face of the plateau, precipitate moisture over Cherrapunji areas with annual rainfall exceeding 1100 cm one of the rainest places of the world. The Cherrapunji area experiences cold temperate climate with foggy winter months while the southern part of the terrain along the Bangladesh border experiences hot summer and cool winter months similar to that of adjacent plains. The average monthly rainfall at Cherrapunji for last 12 years (1977-1988) is given in Table 1. Figure 2 reveals that for the period of last 12 years, the average annual rainfall in the area is 11,132.5 mm with highest rainfall of 16,673.5 mm in 1984 and minimum rainfall of 6,688.9 mm in 1979. The rainfall fluctuation and total annual rainfall from 1977 to 1988 is given in Figure 2. It is seen that the months of April to September have contributed maximum rainfall. During the last 12 years the month of January has contributed minimum rainfall of 1.4 mm and the month of July contributed the maximum rainfall of 5398.70 mm.

Table 1: Monthly rainfall (mm) at Cherrapunji (Meghalaya) from 1977-1988

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total Rainfall
1977	4.4	57.6	656.8	1471.2	1868.6	1469.6	2127.6	2741.2	430.5	543.1	62.3	15.1	11448.0
1978	0.0	11.4	109.4	325.2	1669.1	1346.8	3663.9	1179.5	1857.8	1478.4	35.4	58.0	11734.9
1979	0.0	19.2	72.7	210.9	649.1	2131.8	2146.0	623.1	570.0	222.4	43.7	0.0	6688.9
1980	1.4	82.6	142.4	1016.2	1141.4	1472.3	2088.0	2085.6	587.6	416.6	0.0	0.0	9034.1
1981	43.40	20.6	178.4	375.1	764.2	1381.3	3740.5	1406.5	1137.0	23.1	0.0	123.4	9242.4
1982	0.0	27.6	40.3	809.6	766.1	2261.7	3077.7	1825.2	1630.1	60.0	43.0	1.2	9467.2
1983	7.9	45.2	112.6	382.4	428.4	1315.6	3257.6	2014.7	1798.0	322.9	1.5	42.1	9752.9
1984	17.5	0.0	36.7	8711.1	3961.2	2169.8	5398.7	1069.8	2560.2	292.4	7.0	102.1	16673.5
1985	7.0	39.2	831.2	1041.0	1069.5	2708.2	3727.7	1633.6	264.2	32.4	2.3	21.7	11798.7
1986	11.1	0.0	53.8	1412.2	154.8	1429.3	1858.6	1350.9	1054.2	597.9	155.0	5.5	8132.5
1987	20.6	15.2	365.2	729.3	652.0	3047.1	4446.6	1542.9	1949.70	148.50	86.9	54.1	13113.2
1988	11.9	83.4	150.5	374.4	3532.4	2288.5	3820.8	4655.6	1735.5	875.7	291.5	112.0	15991.2

Source: Meteorological Department, Guwahati.

Table 2: Mean monthly temperature (°C) at Cherrapunji

Year	Min/ Max	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Average
1980	Min	10.9	8.4	12.7	15.9	15.6	18.6	20.7	20.3	20.8	15.0	16.4	8.3	15.3
	Max	15.1	16.2	19.7	23.8	22.3	23.1	22.6	22.3	23.4	21.8	20.9	17.3	20.7
1981	Min	7.9	9.3	12.3	14.1	16.0	21.0	18.4	18.5	18.1	15.6	12.7	9.1	14.4
	Max	16.0	16.7	19.4	20.2	18.9	23.7	21.8	22.8	22.9	23.4	16.9	16.4	19.9
1982	Min	7.7	8.4	11.2	13.6	16.7	18.2	18.4	18.7	17.9	15.4	11.4	7.8	13.8
	Max	17.9	17.0	20.7	21.5	24.1	22.8	22.5	23.4	22.8	22.8	19.1	15.7	20.9
1983	Min	7.1	8.0	12.1	14.1	16.1	18.1	18.7	18.6	18.0	17.1	12.6	7.5	14.0
	Max	16.8	17.1	18.9	21.6	22.1	16.0	23.2	22.3	22.6	22.0	22.8	21.1	20.5
1984	Min	6.7	8.9	12.7	15.1	16.2	18.2	17.5	18.2	15.9	15.4	10.8	7.1	13.6
	Max	14.2	17.7	20.9	22.2	20.6	22.6	21.2	23.3	21.3	22.7	20.3	16.7	20.3
1985	Min	6.5	9.5	12.6	14.3	15.8	17.4	16.9	18.0	16.7	15.1	10.3	8.3	13.5
	Max	15.6	18.4	19.6	21.6	22.6	22.5	21.0	23.2	22.5	23.4	20.1	17.3	20.7
1986	Min	6.9	8.3	12.1	13.5	15.2	17.7	17.5	17.4	17.0	14.4	11.0	8.1	13.3
	Max	15.9	18.0	21.5	21.2	22.6	23.4	22.1	23.8	22.4	21.7	20.1	17.8	20.9
1987	Min	7.6	10.1	12.5	14.9	16.3	18.9	19.6	18.6	18.4	15.5	13.3	9.9	14.4
	Max	17.2	19.0	20.0	21.9	23.0	23.3	21.4	23.4	22.5	23.0	21.3	18.0	21.1
1988	Min	8.1	10.5	12.8	15.9	16.5	18.2	18.6	17.0	17.1	16.2	13.5	9.6	14.5
	Max	16.7	18.9	19.9	23.1	22.7	23.0	22.3	22.8	23.1	23.7	22.4	18.3	21.4
Average	Min	7.7	9.04	12.33	14.6	16.04	18.5	18.5	18.4	17.8	15.5	10.7	8.4	14.1
	Max	16.2	17.7	20.1	21.9	22.1	23.1	21.9	22.95	22.5	22.8	20.2	17.1	20.7

Source: Meteorological Department, Guwahati.

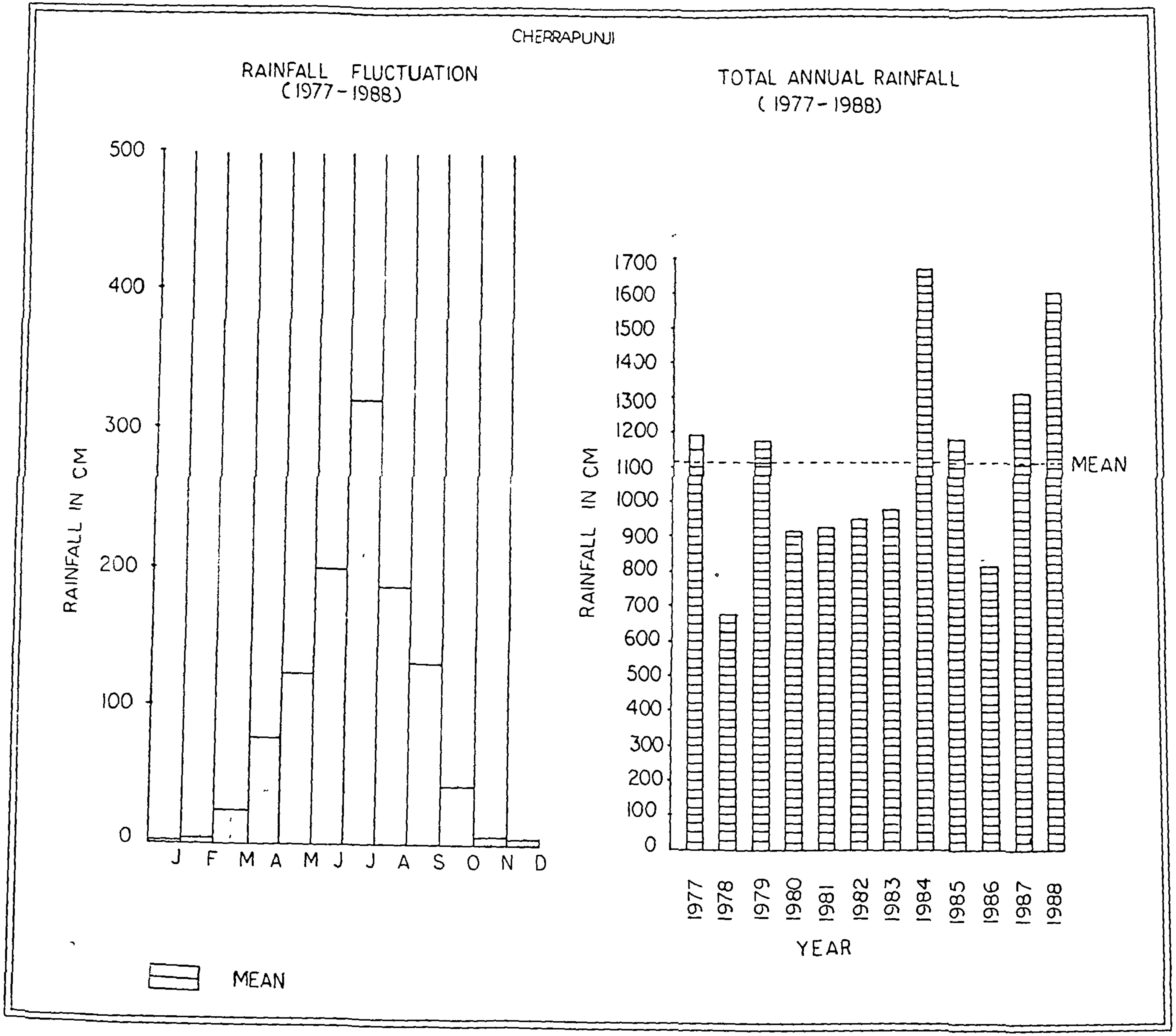
CHERRAPUNJI
RAINFALL FLUCTUATION
(1977 - 1988)
RAINFALL IN CM
500
400
300
200
100
0
J F M A M J J A S O N D
MEAN
TOTAL ANNUAL RAINFALL
(1977 - 1988)
RAINFALL IN CM
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
MEAN
1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988
YEAR

FIG. 2

The mean monthly minimum and maximum temperature at Cherrapunji for the last 9 years (1980 to 1988) is given in Table 2. The average minimum and maximum temperature for the period is 14.1°C and 20.7°C in August. However for this nine year period January 1985 had the minimum mean temperature of 6.5°C and May 1982 had the maximum mean temperature of 24.1°C.

People and Occupation

The area of the study comprises parts of Pynursla C-D Block, Shella Bholaganj C-D Block and Cherrapunji town. Religion wise the people are represented by Christians, Hindus Khasis etc. Language-wise the people can be differentiated as Khasi, Garo, Bengali, Nepali, Assamese and Hindi speaking. It is revealed from the Table 3 that the highest density of population 782 in Cherrapunji town against the state average of 60 and District average of 98. The decadal change in population is lowest in Shella-Bholaganj C-D Block.

Significantly the Shella-Bholaganj C-D Block together with Cherrapunji town represents with higher S.C. population ratio and lower S.T. population ratio. This is mainly due to large seggregations of 'other' denominations in the area.

The total population of the study area is 36,487, that is 2.74% of the total population of Meghalaya (1981).

Table 3: Blockwise Population Distribution

Administrative Unit Parameters		Meghalaya State	East Khasi Hills	Pynursla C-D Block	Shella-Bholaganj C-D Block	Cherrapunji town
Area		22,429 Sq.Km.	5,196 Sq.Km.	505 Sq.Km.	578 Sq.Km.	7.80 Sq.Km.
Population:						
Total:	Persons	1,335,819	511,414	34,001	36,549	6,097
	Male	683,710	262,952	16,679	18,648	3,066
	Female	652,109	248,462	17,322	17,901	3,031
Rural:	Persons	1,094,486	330,614	34,001	30,452	-
	Male	556,958	168,158	16,679	15,582	-
	Female	537,528	162,456	17,322	14,870	-
Urban:	Persons	241,333	180,800	-	-	6,097
	Male	126,752	94,794	-	-	3,066
	Female	114,581	86,006	-	-	3,031
Density per Sq. Km.		60	98	67	63	782
Decadal change in population (1971-81)		+32.04	+32.64	+24.19	+10.16	-
Sex Ratio per 1000 male						
	Total	954	945	1,043	959	988
	Rural	965	966	1,043	959	-
	Urban	904	907	-	-	988
Total No. of Literate Persons		455,191	233,618	11,646	15,125	3,277
Literacy %		34.07	43.73	34.25	41.38	53.74

Contd...

Table 3 (Contd.)

Administrative Unit Parameters		Meghalaya State	East Khasi Hills	Pynursla C-D Block	Shella-Bholaganj C-D Block	Cherrapunji town
No. of Households						
	Total	255,935	100,313	7,262	7,688	1,115
	Rural	209,618	65,228	7,262	7,688	1,115
	Urban	46,317	35,093	-	-	-
S.C.	Total	5,492	1,480	1	73	9
	Rural	2,950	408	1	64	-
	Urban	2,542	1,072	-	9	9
	%	41.00	28.00	.002	.19	.14
S.T.	Total	1,076,345	374,081	33,510	31,922	5,639
	Rural	942,734	282,009	33,510	26,283	-
	Urban	133,611	91,472	-	5,639	5,639
	%	80.57	73.14	98.55	87.34	92.48

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

The rural population is 30,383 (83.27%) and urban population is 6,104 (16.73%).

The working population is also lower in comparison to State and District averages. The rural working population is by and large engaged in Jhuming or shifting cultivation activities.

Previous Work

Very little work has been done on geomorphic study of this region. Siba Prasad Chatterjee (1941) for the first time work on the 'Meghalaya Plateau'. The name Meghalaya has come into existence from this 'Megha' means 'cloud' and 'alaya' means 'abode', i.e. abode of clouds. Oldham (1958) was first to visit Khasi Hills to document the geology of this part of the region. Subsequently, Medlicot (1869), Palmer (1923), Evans (1932), Das Gupta (1934), Khedkar (1936), Ghosh (1952), Gogoi (1975), Mazumdar (1976, 1986) have unravelled the geological history of Khasi Hills. Mazumdar (1986) has however given a very generalized regional physiography of Meghalaya.

Work Procedure

The present study comprises the following three component activities.

(a) Pre-field phase

(b) Field work phase

(c) Post field phase

(a) Pre-field Work

This stage has included the collection of data and study of all relevant literatures. The basic objective during this stage was collection of secondary data (Geological, Meteorological etc.) geological maps, toposheets, aerial photographs and synthesis of data. The data were extracted from 1:50,000 Survey of India toposheets No. $78\frac{0}{11}$ and $78\frac{0}{15}$ used for relief, slope and drainage maps. During this stage of work, general landform units were identified in the area with the help of aerial photographs and satellite imageries.

(b) Field Work Phase

During this stage micro-relief features and landslide zones were also identified and documented. All the sample sites were visited and on reaching a sample site identification of the landfacets were made on the basis of sufficiently uniform in form, relief and materials. Having identified the facets at different sample sites, information concerning weathering, soil characteristics, Karst features, slope characteristics etc. Field photographs were also taken to explain the significant aspects of geology, landform soil and vegetation.

(c) Post Field Phase

In this stage all collected data were classified, processed and tabulated wherever necessary. The final maps were prepared depicting distribution of geological units and geomorphic characteristics. Finally, the data was synthesized for interpretation and presentation of results.

Objective

The main objective of the present study is given below:

i) To study the geomorphic characteristics in relation to geology, characteristics of rocks and the geomorphic processes working in the area.

ii) To examine the nature and processes of relief, slope and its relations with geomorphological features.

iii) To have weathering characterisation in the area.

iv) To study the evolution and drainage analysis.

v) To assess the impact of limestone topography and characteristics on the study area.

vi) Identification and classification of different landforms in the area. To study their characteristics and evaluation.

Plan of Work

Identification of different landforms the area of study has been divided into seven chapters. The first chapter defines the nature of work, location of the area, its physiographic characteristics in relation to the Meghalaya plateau.

In the second chapter detailed account of geology has been described. The evolutionary story of its geological landscapes and characteristics of rocks of the Meghalaya plateau is discussed subseouently the geology of the study area is described.

Chapter three deals with relief and slope analysis. The average slope categories and distribution of slope of the area is discussed. Altitudinal zone, Absolute relief and Relative relief of the area is described in relation to geology of the area.

In the chapter four weathering and soil characteristics are discussed. The lithogroup wise weathering and soil characteristics are described.

Chapter five deals with the evolution and characteristic features of drainage systems. It describes the drainage pattern, drainage frequency and drainage density. It describes the drainage analysis and enumerate the important morphometric parameters in relation to geology of the area.

The chapter six deals with the analysis of limestone topography. The characteristics and types of limestone are discussed. Important features of limestone are described.

The last chapter, i.e. chapter seven deals with geomorphic characters of the area. The evolution of different landforms is described in this chapter.

In the last the general summary and conclusion of the study is presented in a meaningful way.

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CHAPTER II

GEOLOGICAL SETTING

GEOLOGICAL SETTING

Introduction

The state of Meghalaya comprising Garo, Khasi and Jaintia Hills Districts, which previously formed a part of Assam came into existence on 19th June 1972. To the north of the study area lies Shillong and further south is Bangladesh plain. The diverse geology and geomorphic characteristics of the Shillong Plateau with numerous hills to the north, moderately high gently dipping table land in the central part and the low lying dissected terrain in south present a complex variety of landform.

The formation of Cherrapunji Plateau is linked with the structural evolution of the Shillong Plateau. A further resemblance is seen in the marine transgressiong which affected the southern part of the Plateau in Cretaceous-Tertiary periods. Similar deposits are also found along the peninsular area. Considering the geology of the Shillong Plateau we can derive the geological units of the study area.

The earliest geological reference on this region was first made by T. Oldham (1859). The systematic geological mapping of the region was subsequently carried out in detail by H.B. Medlicott (1869), Godwin Austin (1869), La

Touche (1869). Their account helped considerably in continuation of systematic mapping of the region by later workers. They are R.W. Palner (1923), C.S. Fox (1936-38), V.R. Khedkar (1938-39), P.N. Mukharji (1938-39). Their work helped in the classification of stratigraphic units of different rocks of the region.

In Meghalaya, the Archaean and Pre Cambrian rocks of the Plateau have been mapped systematically by K. Gogoi (1961-62, 62-63, 65, 67-68 and 72-73), M.M. Munshi (1964-65), M.K. Das and B. Dayal (1964-65), S.K. Mazumdar (1965-66, 66-67). Their work is based on rocks and the relationship of the major rock groups and brought interesting structural features.

Regional Geology of Meghalaya

Geologically, Meghalaya represents remnant of an ancient plateau of Pre-Cambrian Indian Peninsular shield block uplifted to its present position. Geographically, the state covers an area of 22,429 Km^2. Physiographically, it is part of peninsular shield lying south of the North Eastern segment of the Himalaya. It forms a prominent geomorphic unit stretching across the Garo, Khasi and Jaintia Hills in E-W direction. The generalized stratigraphic succession is given in Table 4 and Figure 3. The different stratigraphic groups are described as:

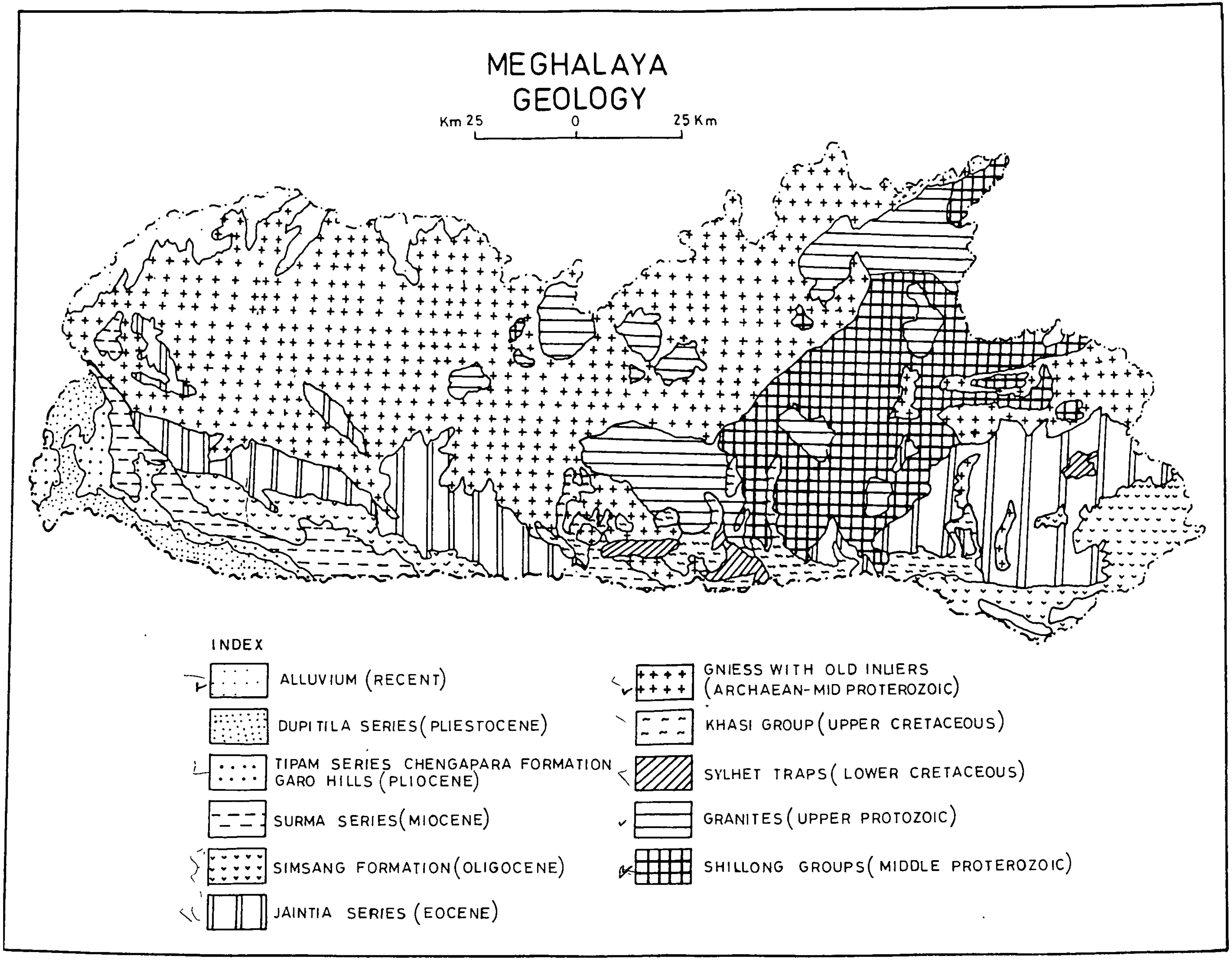
Table 4: Stratigraphic Sequence of the Rocks formed in Meghalaya

Geological Age	Group Name	Formation Name	Rock types
Recent	Newer Alluvium (Thickness not known	Unclassified	Sand, Clay silt and clays
----------------------------------		Unconformity----------------	
Pleistocene	Older Alluvium (Thickness not known)	Unclassified	Sand, clay, pebble,gravel and boulder deposits
----------------------------------		Unconformity---------------	
Mio-Pliocene	Dupitila group (1050 m)	Unclassified	Mittled clays feldsphathic sandstone and conglo-merate
----------------------------------		Unconformity---------------	
Oligo Miocene	Garo Group	Chengapara formation (700 m)	Sand, silt, clay, marl.
		Baghmara formation (530 cm)	Feldspathic sandstone, pebble, cong-lomerate, clay.
		Kopili formation (500 m)	Silt, clay sandstone
Eocene	Jaintia Group	Simsang formation (1150 m)	Silt stone, sandstone, alternations sand
		Shella Formation (600 m)	Alternation of sandstone limestone.

Table 4 (Contd.)

Geological Age	Group Name	Formation Name	Rock types
		Langpar formation (100 m)	Calcereous, Shale sandstone, limestone.
Upper Cretaceous	Khasi group	Mahadek formation (150 m)	Arkose (glauco nitic)
		Bottom Conglomerate (25 m)	Conglomerate arkose
		Jadukata formation (140 m)	Sandstone conglomerate alternations.
		Unconformity	
Jurrassic	Sylhet Trap (600 m)		Basalt, Alkali Basalt, Rhyolite Acid tuff.
		Unconformity	
Pre-Cambrian		Intrusive Acid and Basic)	Edpidorite, dolerite basalt.
		Shillong group	Quartzite, Phyllite conglomerate.
		Unconformity	
Archaean		Gneissic Complex	Biotite, gneiss, biotite-hornblende, gneiss granite, gneiss migmatite, mica schist, Biotite granulite amphibolite, pyroxene granulite.

Source: Geology and mineral resources of the states of India, Part IV, Miscellaneous Publications, No.30, GSI, 1974, pp. 69-79.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Km 25
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25 Km
INDEX
ALLUVIUM (RECENT)
DUPITILA SERIES (PLIESTOCENE)
TIPAM SERIES CHENGAPARA FORMATION GARO HILLS (PLIOCENE)
SURMA SERIES (MIOCENE)
SIMSANG FORMATION (OLIGOCENE)
JAINTIA SERIES (EOCENE)
GNIESS WITH OLD INLIERS (ARCHAEAN-MID PROTEROZOIC)
KHASI GROUP (UPPER CRETACEOUS)
SYLHET TRAPS (LOWER CRETACEOUS)
GRANITES (UPPER PROTOZOIC)
SHILLONG GROUPS (MIDDLE PROTEROZOIC)

FIG. 3

Archaean Gneissic Complex

Archaean gneissic complex is exposed in central and northern part of the Meghalaya Plateau. The rocks are believed to be the northeastern extension of the Indian Peninsular block, separated from it by the Garo Rajmahal fault.

The rocks are composed predominantly of para and ortho gneissic magnetites and sedimentary types. They comprise mainly bio-tite gneiss, bio-tite granulite, amphibolite etc. Possible presence of an unconformity is recently postulated between the two groups of rocks. At some places the rocks are feldspathic gneisses and garnatiferous, mica schists.

Shillong Group

The Shillong group of rocks comprising quartzite usually friable with subordinate phyllite quartz schist conglomerate etc. are exposed in the central and eastern parts of the Meghalaya Plateau. Rocks of this group generally strike in a N-E, S-W direction. The rocks are intruded by acidic sills and dykes. The basic and ultrabasic intrusives are represented by epidiorite, diorite, amphibolite, pyroxenite etc. The granite intrusive along the axial region of the Shillong group of rocks around Mylliem is termed Mylliem Granite. Several other granite such as south Khasi batholith, Pluton etc. are intrusive into the gneissic complex in different part of the plateau.

Sylhet Trap

The Sylhet Trap is of the nature of plateau (flood). Basalts exposed in a narrow E-W strip, 80 Kms long and 4 Km wide along the southern border of the Shillong Plateau.

The Sylhet Trap comprises predominantly basalts and alkali basalts and are 5 - 7 m in average thickness. The acid volcanoes occur as intrusions within the basalts and the close association of ryholites with the nature of the acid tuffs grading into ryholites shows that the ryholite are really occurring as dyke. The southern part of Shillong plateau is geologically quite interesting because of the Sylhet Trap and the overlying well developed thick succession of shelf sediment from Cretaceous to Eocene period.

As a part of Shillong Plateau this region consists of the Pre-Cambrian rocks acutely folded and steeply dipping with an overturned fringe of Mesozoic and Tertiary sediments. The Shillong Plateau is thus regarded as the north eastern tip of the Indian Peninsula. The geological chronology seems to have similar sequence as that of Chota Nagpur Plateau and Rajmahal Hills.

Cretaceous-Tertiary Sediments (Sedimentary Rocks)

The Cretaceous-Tertiary sediments occupying the south-east and south-west part of the Meghalaya. The sediments are generally sandstone, shale, limestone and mudstone etc. The sediments are divided into two groups: (1) Khasi Group, (2) Jaintia Group.

Khasi Group

Mahadek Formation

This formation consists of alternations of conglomerate and sandstone. These rocks overlie non-conformable the Sylhet Trap and their distribution is limited to the north of the Raibah fault which formed the shore line during their deposi-~~tion. This~~ is designated as the bottom conglomerate formation. The maximum exposed thickness of the Jadukata, bottom conglomerate and Mahadek formations are 140 m - 25 m and 150 m respectively.

Jaintia Group

(i) Langpar Formation - The Langpar formation of the Jaintia Group overlies the Mahadek formation. The rocks consist of calcereous shale, sandy limestone and sandstone.

(ii) The Shella Formation - The Shella formation consists of three sandstone and limestone members beginning with a sandstone over the Langpar formation. The Upper Sylhet limestone member has been traced north-east wards through Jaintia Hills into the North Cachar and Mikir Hills.

Garo Group

(i) **The Chengapara Formation** - This formation overlying the Baghmara formation consists of poorly cemented, fine grained, micaceous sand, brown sandstone and clays with a few thin bends at its base. It reappears in the extreme south-west near Balat, an erosional unconformity can be seen.

Recent Alluvium

Recent alluvium overlies the Tertiary rocks along the southern and western borders of Garo Hills in isolated areas and along the southern fringe of Khasi Hills. Such patches are also found along the northern fringe of Garo Hills. This deposit consists of beds of pebbles with coarse loose sand and brownish clay. The pebble beds at places occur in irregular repetition. These rocks usually form exceptionally flat topped low hillocks and mounds with red soil cover.

In the Garo Hills along the western border, older alluvium is found at various levels, invariably along the abundant river coarses representing a kind of river terraces. Along the southern border of Khasi Hills the older Alluvium mainly consists of assorted boulder deposits. Recent alluvium is found in the river valleys on the northern foothill region of Gâro and Khasi Hills.

The recent alluvium consists of fine silty and light to dark-greyish clay.

Local Geology of the Area

The area forms part of the Shillong plateau, by and large exposing the Shillong Group of rocks (Figure 4). The stratigraphic sequence of rocks formed is given in Table 5.

Shillong Group

The rocks of the Shillong group are covering a large part of the eastern portion of the study area. The rocks of the Shillong group are the oldest formation exposed in the Umstew gorge. The rocks are mainly composed of metamorphosed sediments and include quartzite frequently micaceous and auto clastic conglomerate. The Umstew gorge above the Nongpriang village exposes about 16 m of the formations. The auto clastic conglomerate composed of large angular to sub angular blocks of quartzites cemented by silicious material. The Pre-Cambrian rocks in the gorge to the east of Cherrapunji area overlain by the rocks of the Cretaceous age. But to the south Cretaceous rocks are overlain by the Sylhet Trap which did not extend further eastwards.

The rocks are intruded by altramafic and acidic dykes. The granite intrusive of the Shillong group of rocks around Mylliem village is termed Mylliem granite. Thus Mylliem granite name was given by first H.B. Medlicott.

Table 5: Stratigraphic sequence of rocks formed in the area

Geological Age	Group Name	Formation Name	Rock types
Recent	New Alluvium (Thickness not known)	Unclassified	Sand, silt and clay
----------------------------		Unconformity----------------------	
Oligo-Miocene	Garo Group	Chengapara formation (700 m)	Sand, silt stone clay.
		Kopili Formation (500 m).	Shella sandstone
Upper Eocene	Jaintia Group	Shella formation (600 m)	Alternating sandstone, limestone.
		Langpar formation (100 m)	Calcereous shale sandstone, limestone.
Lower Eocene		Sylhet formation (100 m)	Siliceous grey coloured limestone with sandstone.
Upper Cretaceous	Khasi Group	Mahadek formation (150 m)	Bedded fine grained buff coloured sandstone sandy and earthly limestone, clayey sandstony, clay.
----------------------------		Unconformity----------------------	
Jurassic	Sylhet Trap		Basalt clay ryholite acid tuff.
----------------------------		Unconformity----------------------	
Precambrian		Shillong Group	Hard Quartzite phyllite, conglomerate and auto clastic conglomerates exposed at the bottom of the gorges.

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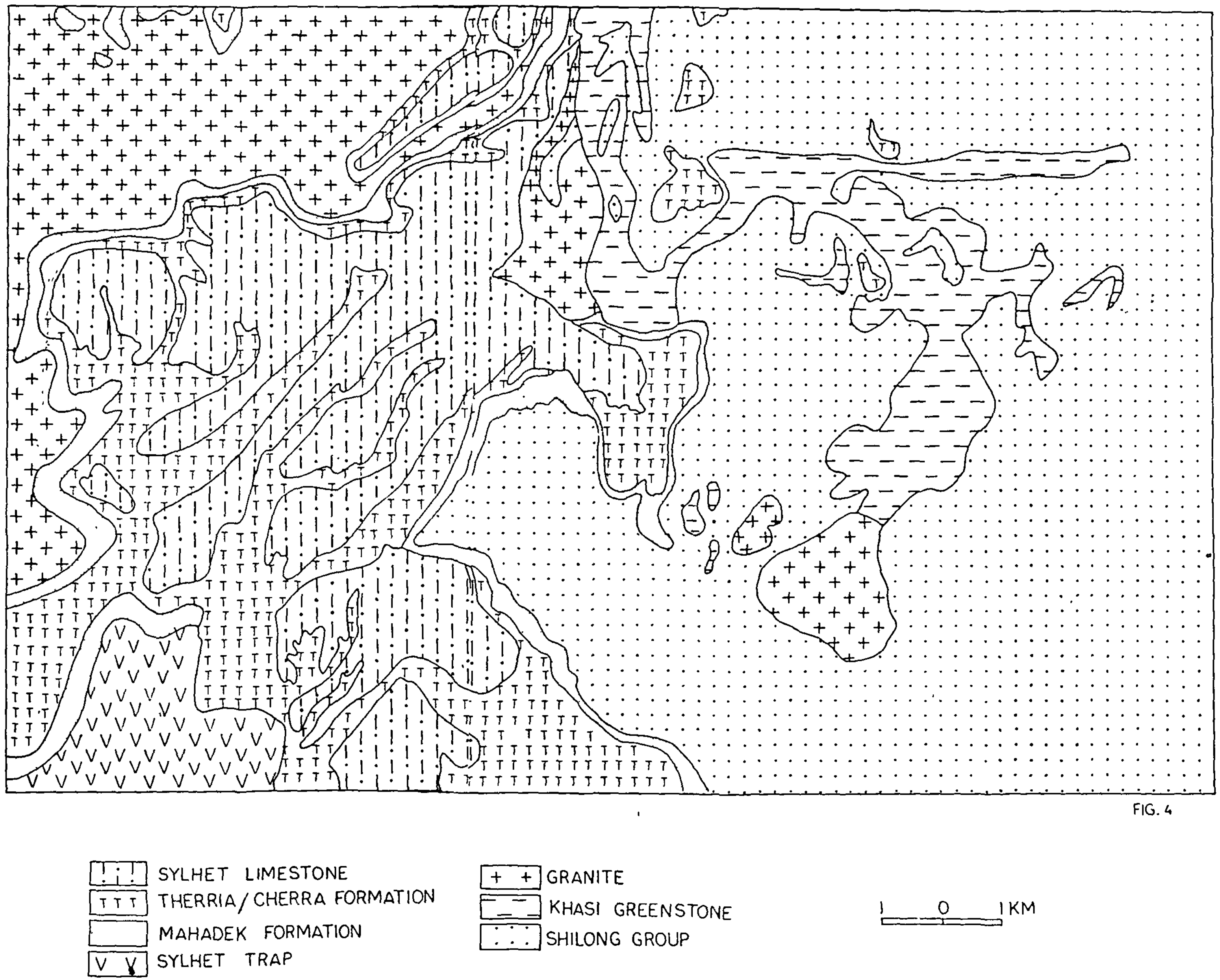

FIG. 4

Sylhet Trap

Along the south-western margin of the study area occurs the Trap rocks exposed in a S-W strip known as Sylhet Trap. It is a fine grained hard massive basaltic lava occasionally exhibiting porphyritic texture. Generally the trap has a vescicular nature towards the top becoming massive towards the bottom the base being unexposed. The rock gradually thins out towards the north and do not extend beyond Mawsmai falls. The traps form prominent cliffs facing the plains of Bangladesh.

Near the Sonali falls 12 Kms south of Cherrapunji the upper part of the basalt is well exposed and numerous vescicles observed along the road section. Vescicular filling of a different type was observed near Sohbar where green jaspar fills the vescicular flattered bedding. Near the road section the trap shows all stages of weathering exhibiting different colours like violet reddish etc. There is occurrences of copper in the Trap in Pyngad area. Boulders of laterite were found aroung Pyngad.

The Sylhet Traps comprise predominantly basalts, alkali basalts, rhyolites and acid tuffs. To the west in the Nonglyngkien Traps are in contact with the gneisses this trap is supposed to correspond with the Rajmahal trap which continuous below the Bengal alluvium and hence the trap is supposed to be of Jurassic age.

Cretaceous-Tertiary Sediments (Sedimentary Rock)

The Cretaceous-Tertiary sediments occupying the southern part of the study area are thick and extensive and are considered to be physical continuously with the Cretaceous Tertiary sediments of the Bengal basin. The sediments are affected mostly by basement controlled faults. The sediments are mainly sandstone, mud stone and limestone. The sediments are mainly divided into two types: Fig. (p. 1).

(a) Khasi Group

(b) Jaintia Group

The Khasi group is distinct erroneous facies consisting of the oldest Jadukata formation followed by the predominantly conglomerate. Mahadek formation which is the later formation occur only in the southern margin of the area.

Khasi Group

(i) Mahadek Formation - This formation consists of alternation of conglomerate and sandstone. These rocks overlie on the Sylhet trap and its distribution is limited to the north. The maximum exposed thickness of the Jadukata, bottom conglomerate and Mahadek formation are 140 m, 25 m and 150 m respectively.

The chief rock of a coarse to gritty feldspathic is very prominent in some section with green glauconite bearing bonds including fragment of decomposed felspar and quartz. The sandstone weathered to dirty brown, strong violent, grey and bluish colour observed mainly along the cliff. The Mahadek Formation contains of fossiliferous sandstone bond, and is well exposed in the road section down the Umstew gorge near Nongpriang village. The stage also includes their beds of clay as observed in the Umsohra river section south-west of Laitryngew. The deposition of Jadukata formation and progressive migration of the shore line towards the north is followed by the deposition of a thick horizon of conglomerate.

Jaintia Group

(i) Langpar Formation - The Langpar formation of the Jaintia group overlies the Mahadek formation. These rocks are seen on the north-east portion of the study area. The rocks consists of calcareous shale, sandy limestone and fine sandstone. The deposition of these sediments marks the beginning of a tableshelf condition which was firmly established later with the deposition of Shella formation.

(ii) Shella Formation - The Shella formation consists of sandstone and limestone lying over Langpar formation. These have been designated successively the Lower (Therria sandstone/Lakadong limestone/Umlatdeh limestone) Upper (Narpur sandstone/Prang limestone and Sylhet sandstone/limestone member has been traced north-east wards through Jaintia Hills into the North Cachar and Mikir Hills.

Garo Group

(i) **Kopili Formation** - The Kopili formation overlies the Shella formation and is about 500 m in thickness. The rocks are alternations of the sandstone and shale with rare thin fossiliferous bands of limestone.

(ii) **Chengapara Formation** - This formation overlying the Baghmara formation, consists of poorly cemented, fine grained, blue to brown silt stone and clays with base. It reappears in the extreme south-west near Balat, an erosional unconformity can be seen.

Recent Alluvium

Recent alluvium is found along the southern fringes of the study area along the Bangladesh plain. The deposits consist of beds of assorted pebbles with coarse loose sand and browish clay. These rocks usually forces exceptionally flat topped low hillocks and mounds with red soil cover. Along the southern border of Khasi Hills the recent alluvium mainly consists of assorted boulder deposits. The alluvium consists of fine silty sand and light to dark greyish clay with more pockets and layers of course sand. The apparent accordance of summit level in the south is produced by vertical dissolution of the once continues structural sediments. There is a marked contrast in landforms of the areas formed by the Pre-Cambrian metamorphics in the east and Tertiary sedimentaries in the south. So structure is the dominant factor in the evolution of landform in the area.

Tectonic and Structural Characteristics of Rocks

The Shillong-Cherrapunji area of the Meghalaya shows definite relationship between the structure and topography. The northern part of the study area is covered by the rocks of the Shillong series which includes quartzites with slates, schist and conglomerate. The southern portion is formed by Tertiary sediments including sandstone, limestone and shale. some of the rivers follow the structural weak zones and the landform in general show definite relationship with the structure. The Pre-Cambrian mass experienced peneplanation till Jurassic times resulting into the formation of a flat levelled surface preserved over the plateau till today. Since the end of Jurassic period the southern portion of Khasi Hills experienced with eruption of plateau basalts, the Sylhet traps. The rate of subsidence gradually showed down towards Eocene times when this area attended a stable shelf.

The southern portion of Meghalaya Plateau which forms an east-west nearly rectangular horst between the Brahmaputra Valley and the plains of Bangladesh is characterised by the Dawki lineament.

The Dawki lineament is exposed along the southern margin of the Meghalaya plateau for about 170 km from Jadukata river in the west to Haflong in the east. The lineament actually consist of four major east-west faults along Jadukata river and Therriaghat.

The tectonic history of Shillong plateau begins with the Plateau basalts, through fractures and faults in the basement. The trend of these faults is found to be E-W in the southern part of the area under study.

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CHAPTER III

RELIEF AND SLOPE ANALYSIS

RELIEF AND SLOPE ANALYSIS

Introduction

The morphological chapter of the study area is depicted by the appearance, dimension and magnitude of relief and slope. The study of relief and slope provide not only the variety of topographical features but also makes available the evidences needed for the interpretation of the complex form of landscape. The central part of the study area is a true plateau capped by Pre-Cambrian rocks. The eastern part of the plateau are highly dissected zone of very steep slope forms.

The palaeo-geography of this region reveals that the Plateau has been subjected to a variety of distrophic movements since the Pre-Cambrian period. The different movements recorded during these periods must have created new relief and slope forms along the line of uplift-fracture zone and also evolved because of plateau volcanism. Newer relief and slope forms developed gradually over these surfaces. The development of the drainage systems thus have played a vital role in shaping the present surface features of the study area, with their characteristics relief and slope forms.

The relief in its true meaning for the relative vertical inequality of the differences in elevation of any part of the earth surface, collectively or individually has been studied. Sometimes it has been misused for the altitude or absolute elevation from the sea level.

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

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

Altitude

The altitudinal range represented by heights. The range varies from area to area. The maximum elevation of 1740 m located on the north-west corner of the study area. The altitudinal range varies between 200 m to 1740 m, they are represented in five groups have an interval of 400 m (Figure 5). The heighest category of above 1600 m covers only 11% (28.17 Sq.Km.) of the total area. Table 6 reveals that the area has three major height categories viz. 1200 m-1600 m covering 31% (80.22 Sq. Km.), 800-1200 m covering

Table 6: Category-wise area distribution of altitudinal zone

Altitude height in m	Area in Sq. Km.	Cumulative area in Sq.Km.	Area in per cent	Cumulative area in percent
Below 400	17.47	17.47	7.0	7.0
400 - 800	60.67	78.14	23.0	30.0
800 - 1200	73.47	151.61	28.0	58.0
1200 - 1600	80.22	231.83	31.0	89.0
Above 1600	28.17	260.00	11.0	100.0
Total	260.00		100.00	

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ALTITUDE

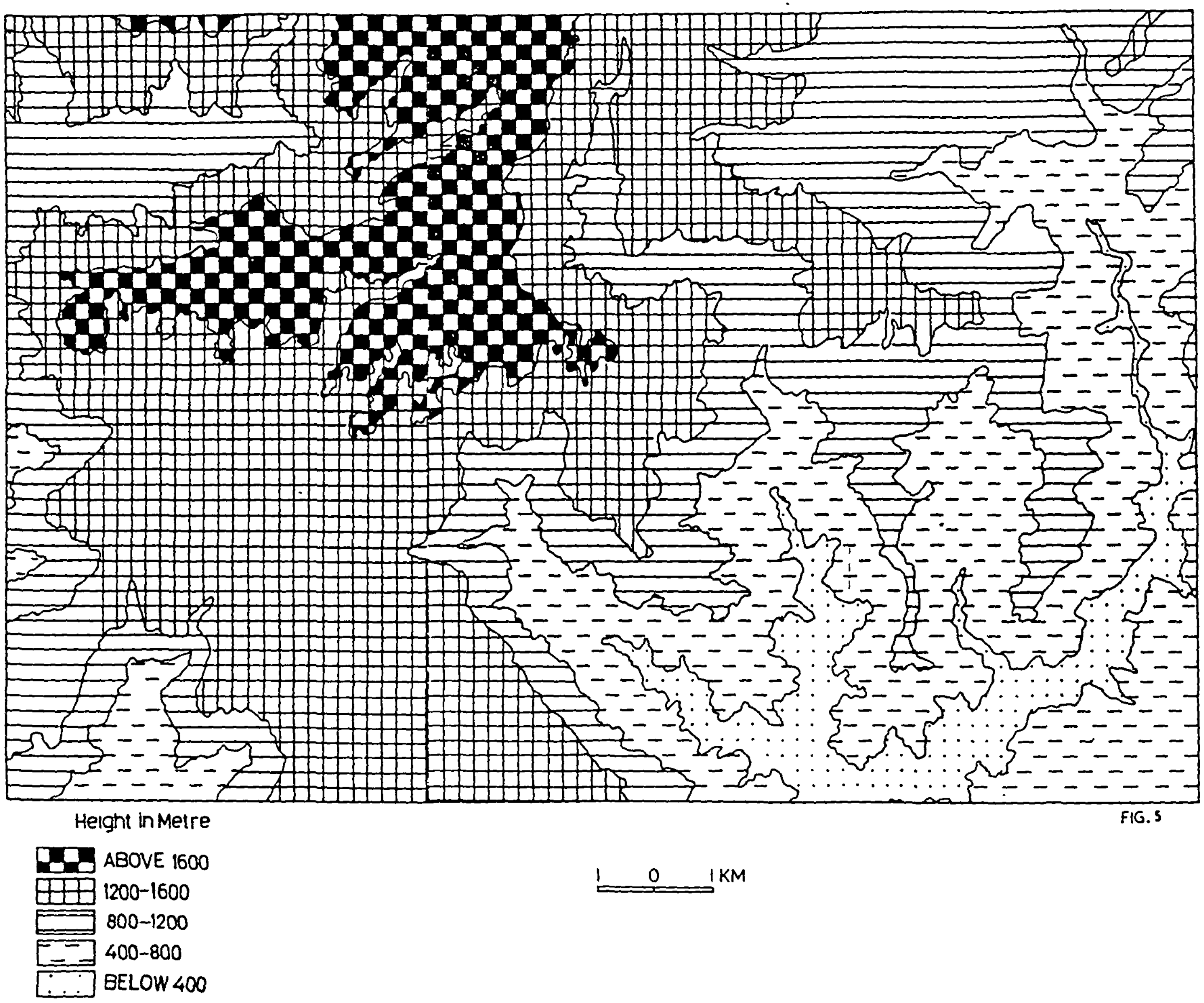

FIG. 5

28% (73.47 Sq.Km.), and 400-800 m covering 23% (60.67 Sq.Km.) of the total area respectively. The terrain between 1200-1600 m and above 1600 m categories represented by limestone rocks known as Cherrapunji plateau. Minimum area is under the group of 400 m covering 7% (17.47 Sq.Km.) of the study area. Maximum concentration of this zone is towards south-eastern part of the study area. Generally it lies in Wah Tymsun catchment area and its tributaries. Lithologically the low land area category is represented by gneissic complex.

Absolute Relief

The absolute relief, a function of geotectonics constructive and destructive processes, provides clues towards estimating the intensity of forces at work. The absolute relief has been determined by dividing the study area into grids of one Km^2. Absolute height in each grid has been recorded from spotheights, tringulation points wherever available and from the maximum contour value passing through the grid (with contour interval 20 m). These absolute heights are plotted at the centre of the grids and the area contoured with contour interval of 150 m. Figure (6) reveals 9 categories of absolute relief in the area ranging from below 600 m to above 1650 m. Table 7 shows category-wise area distribution.

Table 7: Category-wise distribution of absolute relief

Absolute relief category	Area in Sq.Km.	Cumulative in Sq.Km.	Area in percent	Cumulative area in percent
Below 600	8.0	8.0	3	3
600 - 750	16.0	24.0	6	9
750 - 900	18.0	42.0	7	16
900 - 1050	27.0	69.0	10	26
1050 - 1200	22.0	91.0	8	34
1200 - 1350	30.0	121.0	12	46
1350 - 1500	40.0	161.0	16	62
1500 - 1650	67.0	228.0	26	88
Above 1650	32.0	260.0	12	100
Total	260.0		100	

CHERRAPUNJI
ABSOLUTE RELIEF

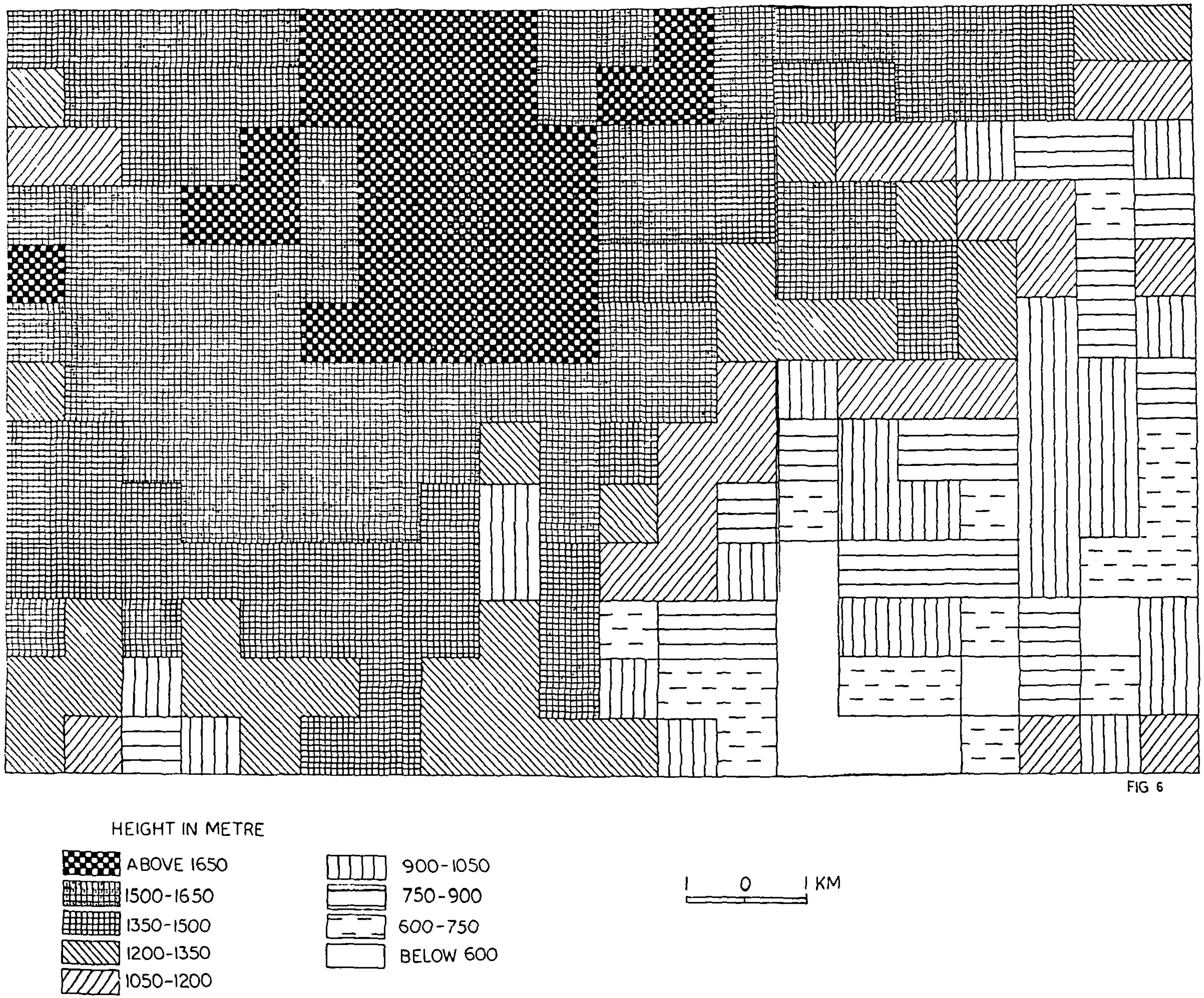

FIG 6

Distribution Pattern of Absolute Relief

Table 7 indicates that the area with absolute relief 1500-1650 and above forms 26% (67.0 Sq.Km.) of the total area. Three major absolute relief categories viz. 1200-1350 m covering 12% (30.0 Sq.Km.) 1350-1500 m covering 16% (40.0 Sq.Km.) and more than 1650 m covering 12% (67 Sq.Km.) of the total area respectively are revealed from the table. The lowest absolute relief category is < 600 m covering 3% (8 Sq.Km.) of the study area. This category includes very small patches of the study area.

From the Figure (6) it is revealed that the absolute relief above 1650 m is found in the northern portion of the study area. Three major absolute relief categories viz. 1500-1650 m, 1350-1500 m and 1200-1350 m covering the northern, southern, north-west portion of the study area. It is covering more than 50% of the study area. The absolute relief categories viz. 1050-1200 m, 900-1050 m and 650-900 m covering the south-east portion of the study area. The minor absolute group 600-750 m and below 600 m is found in southern portion of the study area.

By this above discussion we came to know that the major area lies in the category of high to moderate absolute relief. The analysis of absolute relief gives a very clear conception of the nature and distribution of relief of the area under study. It shows a general comparison of the various parts of the study area and helps in determining the stages of development.

Relative Relief

The relative relief gives more regional character to the physical landscape than the precise altitude of single peak. In general it denotes the actual variation of height in an unit area with respect to its local base level. According to Glock, relative relief is not strictly a function of elevation above sea level. Relative relief is also known as relative altitude, topographic relief, amplitude of available relief, drainage relief and local relief etc. This method has been used as early as 1911 by Partech and later adopted by Smith, but with connotations as relative altitude or relative relief. It presents a better index of erosion along with the stage of development.

For the analysis of the relative relief the area has been divided into one square Km grids as done in the case of absolute relief. The height difference between the highest and lowest elevation within each grid is computed and recorded at the centre of the grid (with contour interval 20 m). The area is contoured with contour interval of 100 m (Figure 7). The figure reveals 8 categories of relative relief ranging from less than 100 m to above 700 m. The

Table 8: Category-wise distribution of Relative Relief

Relative Relief Category in m	Area in Sq.Km.	Cumulative area in Sq.Km.	Area in percent	Cumulative area in percent
Below 100	24	24	9	9
100 - 200	29	53	11	20
200 - 300	21	74	8	28
300 - 400	37	111	14	42
400 - 500	47	158	18	60
500 - 600	67	225	26	86
600 - 700	25	250	10	96
Above 700	10	260	4	100
Total	260		100	

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RELATIVE RELIEF

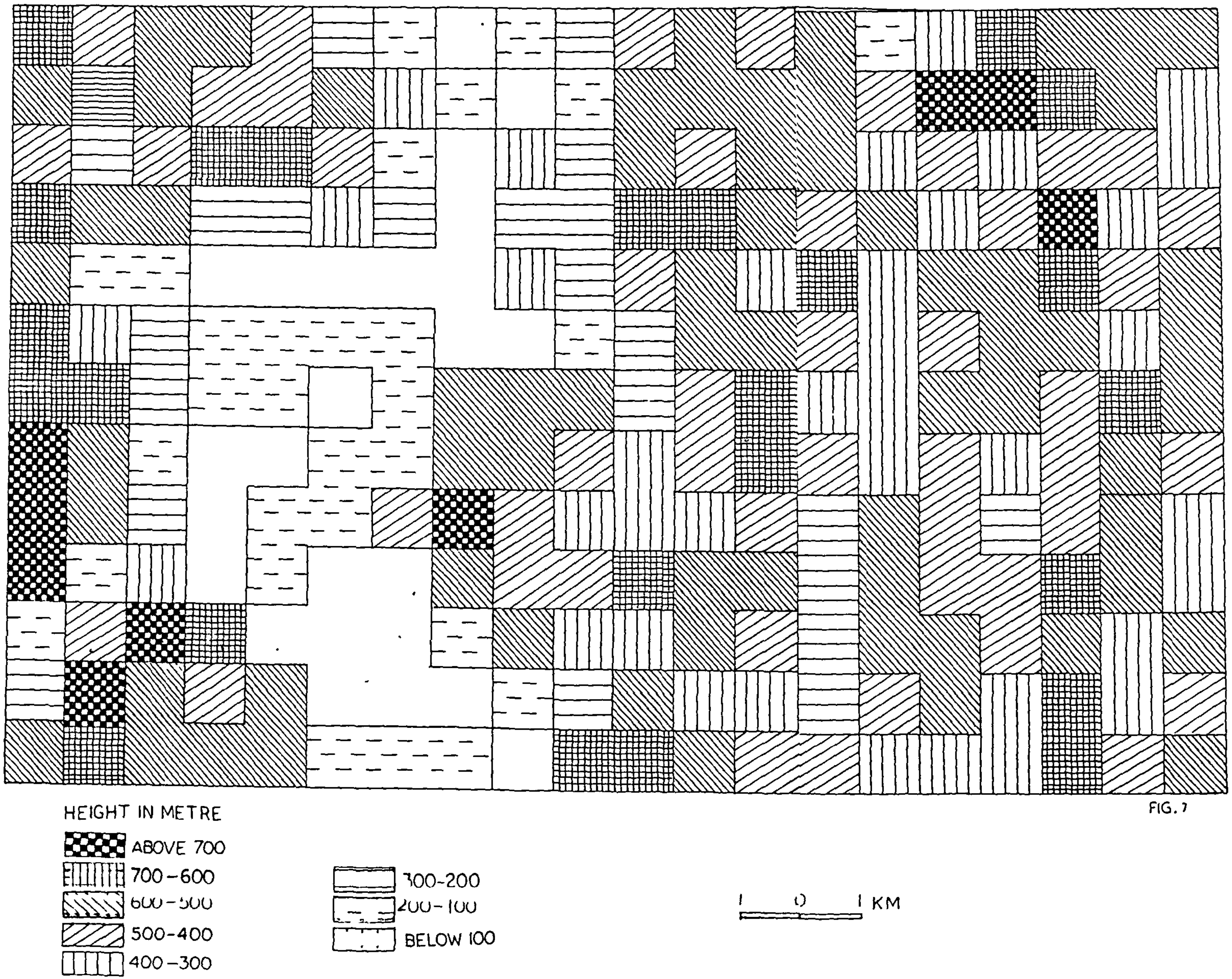

FIG. 7

category-wise area distribution is shown in the Table 8. The area of each category is calculated by Planimeter.

Distribution Pattern of Relative Relief

Table indicates that the area with high relative relief 600 - 700 m forms 10% (25 Sq.Km.) of the total study area. It occurs as isolated patches in the part of the study area. Two major relative relief categories 400 - 500 m covering 18% (47 Sq.Km.) and 300 - 400 m covering 14% (37 Sq.Km.) of the total area are revealed from the table.

The spatial and areal distribution of relative relief categories are evident from the table that the high relative relief has covered the western granite rock surface of the study area. Another significance feature observed in the study area. That 28% of the area is covered under low category i.e., 200 - 300 m, 100 - 200 m and has maximum 100 m. The cumulative percentage about 60% of the area assumes a relative relief of more than 400 m. The relative relief of 600 - 700 m, 500 - 600 m, 400 - 500 m and 300 - 400 m covered the major part of Shillong group of rock in western and northern portion of the study area. Here the undulation plateau surfaces exhibiting higher absolute relief and low relative relief. From this discussion we know that the relative altitude gives more regional character to the physical landscape. It presents a better index of erosion along with the stage of development.

Slope Analysis

Introduction

Slope and relief are two basic but separate concepts in the study of landforms. After analysing the relief, it appears to be necessary to evaluate and analyse the distribution mapping and development of slope. Slopes are important landforms for geomorphologists, pedologists and engineers. Slopes form by erosion, deposition or a combination of both processes. Soon after a slope is formed, it is subjected to alternation by weathering, erosion and mass movement.

Slopes are fundamental elements of the landscape (King, 1962). The slope elements of an area reflect the evolutionary history of the existing landscape. In general slope is often used to refer to the angle which any element of the landscape makes with the horizontal. Slope is also measured in grade or gradient.

Elements of Slope

Slope are perceptible inclination visible on mountain ranges, ridges, scarps, plateau section, flanks of valley etc. Commonly, slopes are classified in terms of slope profile which is a slope belt of unit width extending from drainage divide at the upper extremity, down to a lower terminus which is commonly a stream channel or a natural discontinuity such as terrace, pediment or cliff. A slope profile is best drawn along the down gradient line orthogonal to topographic contours. A slope profile may have a variety of forms. Geometrically, slopes may consist segments which are concave, upward, convex upward, straight or rectilinear and complex (Savigear, 1956 & Young, 1964, 1964 in Faribridge, 1968). Young (1972) has classified slopes into ten classes based on their inclination, as given below:

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

Importance of Slope Analysis

The primary aim of slope analysis is to identify slope elements in an area. Since slope elements are the product of certain processes operating on the earth surface, their study helps in understanding the landform evolution in that particular area. There is increasing awareness of the practical value of slope studies with regard to proposed and existing developments in hilly areas (Anon, 1978).

Slope exerts their influence on development of soil, loss of soil by soil erosion, mining operations, agricultural practices and development of communication network.

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

Methodology

The measurement of slope has been a matter of great interest for earth surface. The earth surface slopes in different directions with different values, so a linear expression does not give the true picture of slope in an area. Thus a spatial distribution of slope variation giving average slope is preferred over linear expressions though at the cost of exact slope values. The major contribution in this field are made by Wentworth (1930), Smith (1935), Raisz (1937), Miller (1949), and Strahler (1956). Some methods are very time consuming and results obtained are also not satisfactory. However the method suggested by Wentworth (1930) for 'general and random' determination of average slope over an area from a contour map is quite satisfactory, and has been adopted for the slope analysis in the area.

The formula devised by Wentworth is given below:

Average slope = Tan Θ = N x CI/3361

Where, N = Average number of contour crossing in an area per square mile.
CI = Contour interval in feet.
3361 = A constant value.

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

Slpe in degree = Tan Θ = V x N/0.6366K*

Where, V = Vertical contour interval in metre or in feet.
N = Number of contour crossing per sq.km. or per sq. mile, and
K = Constant, 1000 for metric units and 5280 for feet and miles i.e. British units.

The area has been divided into one Sq.Km. grids and the number of contours crossing per Sq.Km. i.e. per grid is counted (contour crossing per side of the grid is divided by four = contour crossing per grid). With the above modified Wentworth's formula, average slope per grid is computed (the value obtained by the formula is converted into degree). These average slope values obtained have been classified into 9 categories with an interval of 5°. These 9 categories were further classified into five qualitative groups as per Young's classification. The spatial distribution of the 9 categories of slopes are shown in Fig. (8). The frequency distribution of slope in the area is given in Table 9.

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*0.6366K becomes 636.6 for metric system (0.6366 x 1000) because 1 Km = 1000 m. 0.6366 is the mean of all possible values of Sin Θ (where Θ is the horizontal angle between the contour and the grid line 0.6366K becomes 3361 in f.p.s. (0.6366 x 5280) because 1 mile = 5280 feet.

Table 9: Frequency distribution of slope values

Slope (°)	Frequency of Grid	Percentage of frequency	Cumulative fre- frequency	Cumulative % of frequency	Slope category
Below 5	1	0.39	1	0.39	Level to gentle
5 - 10	17	6.54	18	6.93	Moderate
10 - 15	32	12.31	50	19.23	Moderately steep
15 - 20	10	3.85	60	23.07	
20 - 25	24	9.23	84	32.30	Steep
25 - 30	73	28.07	157	60.38	
30 - 35	72	27.69	229	88.07	Very Steep
35 - 40	30	11.53	259	99.61	
Above 40	1	0.39	260	100.00	
Total	260	100.00			

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AVERAGE SLOPE

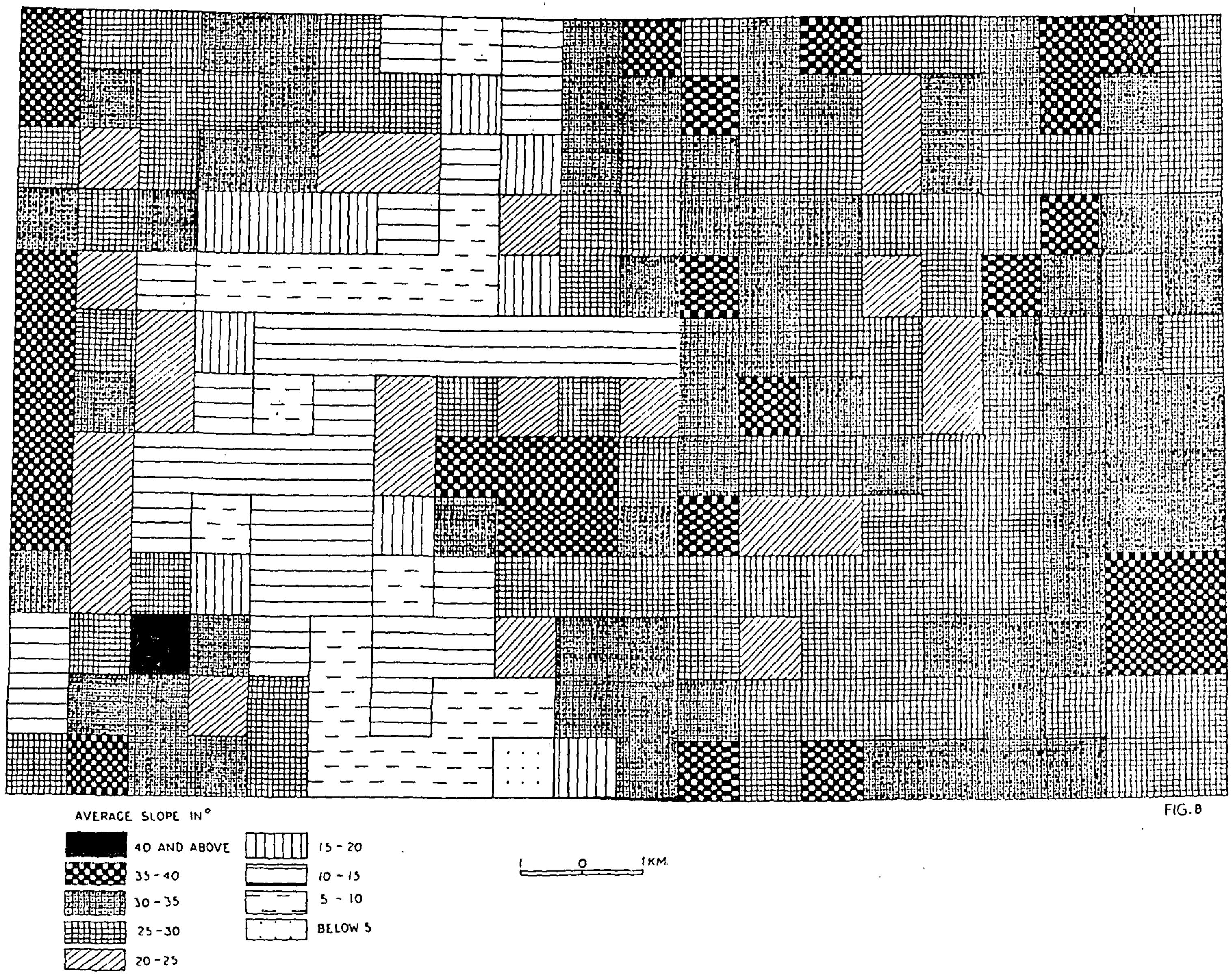

FIG. 8

The table (9) reveals the distribution pattern of frequencies as per various slope categories in the area. It is seen that the category of very steep slope (30° to above 40°) has (39.62%). Similarly the level to gentle slope category has the minimum slope frequency (0.39%). However the contribution of moderate slope frenquencies is (6.54%). Remarkably the category of moderately steep to steep slope (10° - 30°) category constitute maximum slope frequencies (52.46%). The area-wise slope distribution is given in Table (10).

The figure (8) reveals that the slope frequencies have uneven distribution. The category-wise area slope distribution is discussed below.

Level to Gentle Slope

This group (below 5°) has small coverage (0.39%) mainly confined in the southern part of the area (Fig. 8). Significantly, this is the sector where the Wah Tymshun is located and the plain has started. The area exposes mostly alluvial terraces. The conspicuous landforms in the sector are the high level terraces.

Moderate Slope

This group (5° - 10°) have areal coverage of (6.54%) and occurs in patches in the north-western and south-western

Table 10: Area-Slope distribution

Slope (°)	Area in Sq.Km.	Cumulative area in Sq.Km.	Area in %	Cumulative % area	Slope Category
Below 5	1	1	0.39	0.39	Level to gentle
5 - 10	17	18	6.54	6.93	Moderate
10 - 15	32	50	12.31	19.23	Moderately steep
15 - 20	10	60	3.85	23.07	
20 - 25	24	84	9.23	32.30	Steep
25 - 30	73	157	28.07	60.38	
30 - 35	72	229	27.69	88.07	Very Steep
35 - 40	30	259	11.53	99.61	
Above 40	1	260	0.39	100.00	
Total	260		100.00		

corner of the area. However, Sylhet limestone rocks are found in this grade of slope.

Moderately Steep Slope

This group (10° - 20°) have coverage (16.16%) and occurs in patches in the western and souther-western corner of the area. It shows uneven distribution. Fig (8) reveals that the gradient are suitable for agricultural purposes and encourages permanent settlements. These slope categories indicating undulating uplands. These are well drained by Umstew, Umlong and Wah Tymshun rivers with its numerous tributaries. It has been observed that both shifting and sedentary cultivation are done on this slope zone.

Steep Slope

This group (20° - 30°) has a spatial coverage of (37.30%). It shows in the south-eastern corner and eastern flank of the area. The Shillong group of rocks are confined in this steep slope. This part is thickly forested. Some forest settlements are also found here. Fig. (p. 2).

Very Steep Slope

This group of slope (30° - 40°) and above 40° covers a very significant coverage (39.61%) in the north eastern, south-eastern and western corner of the area. It is confined in the eastern proximity of the confluence of Wah Rew and Um Stew river.

No continuous vegetation is found in this area. The weathered rocks are slipping and rolling. The area having such slopes cannot be utilized for agriculture and settlement. Very few settlements are found in this area.

The relationship between AB Relief, Relative relief and slope is seen from the distribution pattern of frequencies of slope in different categories of absolute relief and relative relief. It is evident that the level to gentle slope category (0° - 5°) have low frequency distribution (0.39%) occupies areas with 1200 m to 1350 m height groups of absolute relief and below 100 m height group of relative relief.

The moderate slope category (5° - 10°) has (6.54%) is distributed in height groups of 1350 - 1500 m and 1500 - 1650 m of absolute relief and 100 - 200 m of relative relief.

Moderately steep slopes (10° - 20°) has the frequency distribution of 16.16%. The slope frequency of this class is seen in height groups of 1500 - 1650 m of absolute relief and 100 - 200 m of relative relief.

The steep slope category of (20° - 30°) has the dominant frequency distribution (37.30%). The slope frequency of this class is seen in height groups of 750 m - 900 m, and 900 m - 1050 m of absolute relief and 400 m - 500 m and 500 m - 600 m height groups of relative relief.

Remarkably very steep class of slope (30° - 40°) and above 40° has coverage of (39.61%). It confined in 900 m - 1050 m height category of absolute relief and 300 m - 400 m height category of relative relief.

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CHAPTER IV

WEATHERING, SOIL AND MASS WASTING

WEATHERING, SOIL AND MASS WASTING

Introduction

Weathering is the initial phase in the denudational history of any landscape, as rocks must be weathered before the debris can be transported and erosion is very limited unless the agents of transportation are carrying a load of debris.

The physical landscape of Cherrapunji region is the cumulative function of the exogenetic and endogenetic processes acting upon the surface. The prolonged geological evolution both in time and space makes it necessary to identify relict or inherited landforms developed under different climatic conditions of the past. There is no doubt that lithology structure and climate had played a very significant role in moulding the physical landscape and evolution of its present terrain. In most places, bed-rock is hidden from view by a mantle of soil. Soil is the phase through which much of the rock waste of the lands must pass before it is ultimately removed. The movement of rock debris and soil on slopes is subjected to a large variety of processes.

Weathering

Weathering includes a large variety of processes heating, cooling, freezing, the physical action of ice, plants and animals in minute cracks and other forms of mechanical disintegration. It is the disintegration and decomposition of rocks and minerals at the earth surface as a result of physical and chemical action. The intensity of weathering processes appears to be affected by hydraulic gradient occasioned by appreciable local relief.

Factors Controlling Weathering

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

The roots of the trees penetrating along the vertical joints split the rocks and as the roots penetrate deeper, the joints and cracks of the rocks are widened.

Climate

The climate of the study area has been controlled by the seasonal winds (S.W. Monsoon) and altitudes as in other parts of Meghalaya. This region presents a typical monsoon type of climate. In general the climate of Cherrapunji region is quite different from adjoining Shillong plateau by comparatively heavier precipitation. The belt has the distinction of having the heaviest rainfall in the world with an average of 12,000 mm per annum. The season of the study area are as follows:

1. Rainy season - May to September
2. Winter season - October to February
3. Spring season - March to April

In this study more attention is given to the climatic elements, rainfall and temperature with specific reference to their annual course. These phenomena play an important role in the weathering processes.

Rainfall

The area experiences high rainfall. The rainy season begins from May and continues up to the end of September, after which it gradually diminishes.

Its location on the immediate windward side of the Shillong plateau mainly determines its climate. A part of *the* Bay *of* Bengal *branch of monsoon enters the* Sylhet plain lying just to the South of Cherrapunji. This is assumed to be the main cause of high rainfall in the area. Fig.(p.3).

Similarly high rainfall in the catchment of Wah Tymshun increases run off along slopes. Consequently large quantities of material are constantly removed down slope. As a result new bedrock is frequently exposed to physical and chemical weathering. The high rainfall in the area 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.

Temperature

The area shows wide variation in temperature (Fig.9). During months of March and April, the atmosphere gradually warms up and there is the advent of spring. The highest monthly maximum temperature is observed in the month of April. Thereafter on set 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.

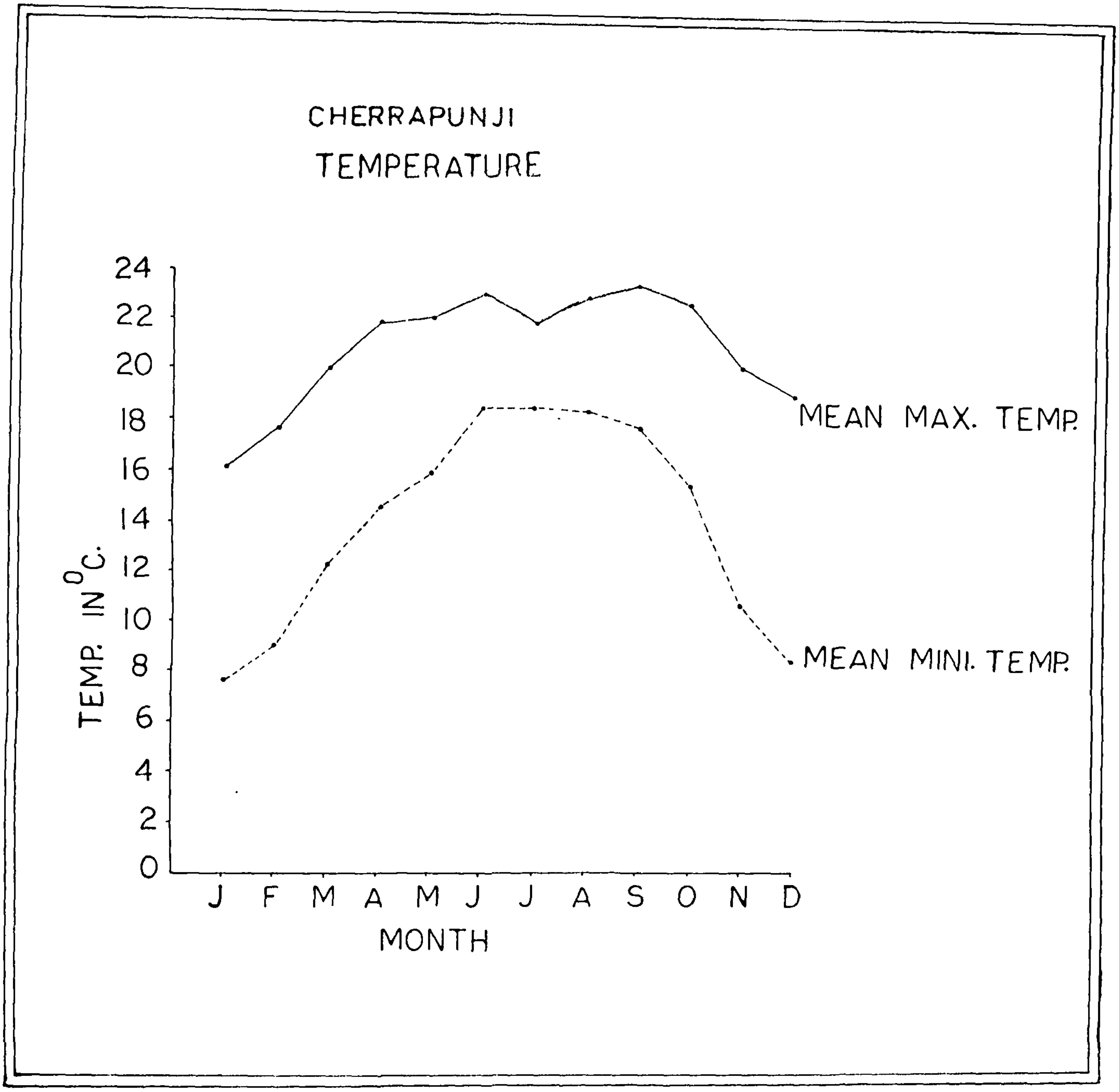
In the present study temperature data are based on daily observations of maximum and minimum temperature. The table 11 also shows that mean maximum in the study area is highest in the month of April (23.91°C) and lowest in the month of January (16.7°C). The mean minimum temperature varies from 8.1°C in January to 18.6°C in April.

Table 11: Temperature in °C at Cherrapunji (1988)

Months	Max. °C	Min. °C
January	16.7	8.1
February	18.9	10.5
March	19.9	12.8
April	23.91	15.9
May	22.7	16.5
June	23.08	18.2
July	22.3	18.6
August	22.8	17.0
September	23.1	17.1
October	23.7	16.2
November	22.4	13.5
December	18.3	9.6

Humidity

Humidity is related to rainfall and temperature. Because of higher rainfall in the area the humidity (Fig.10) normally remains moderate to high (Table 12). In the areas humidity with heavy rainfall helps in chemical decomposition of the sedimentary rocks. Maximum humidity is in the month of June to September. The overall affect is prolonged chemical weathering.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TEMPERATURE
TEMP. IN °C.
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8
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J F M A M J J A S O N D
MONTH
MEAN MAX. TEMP.
MEAN MINI. TEMP.

FIG. 9

Table 12: Relative humidity % at Cherrapunji (0830 hrs and 1730 hrs) 1988

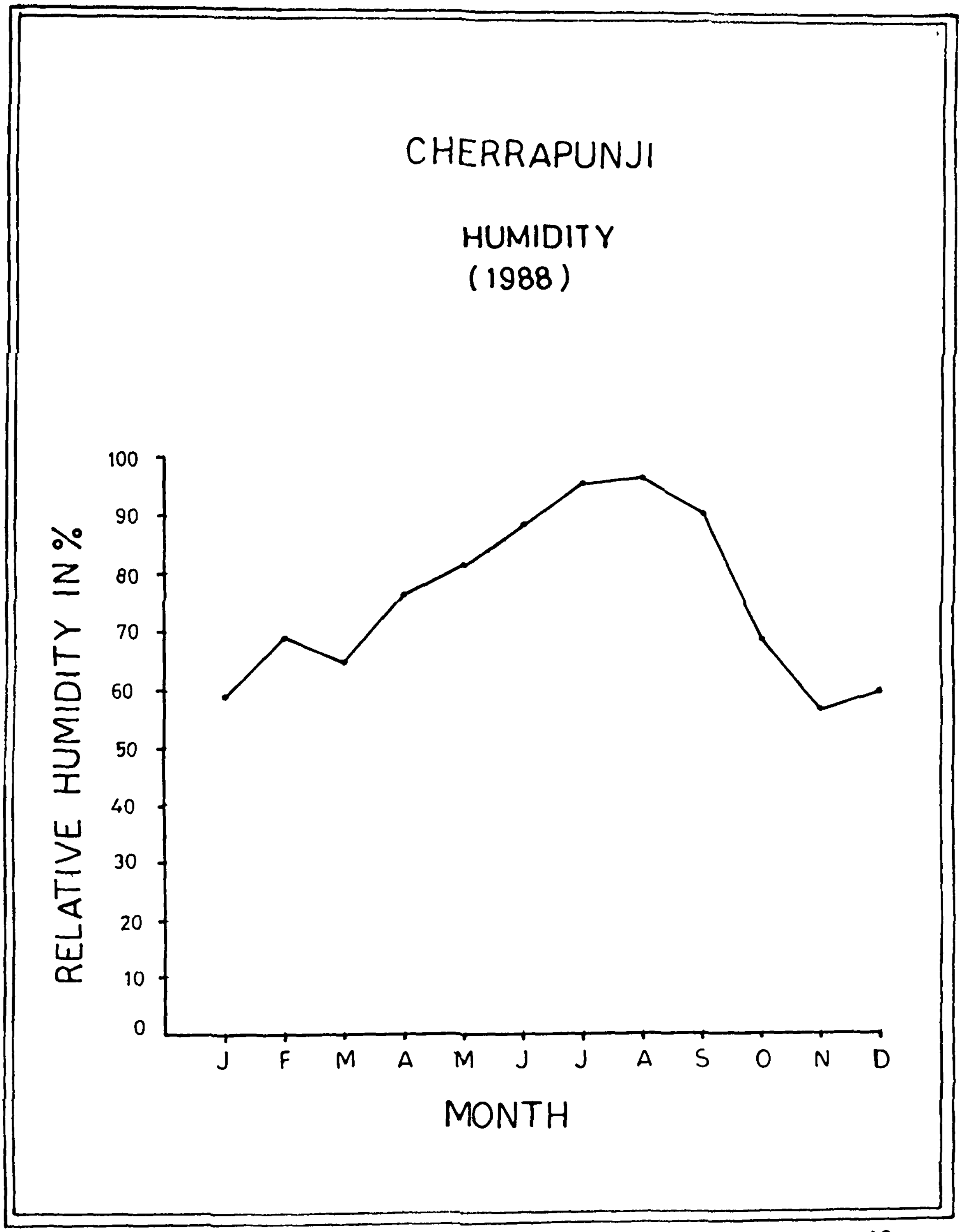
Months	0830 hrs	1730 hrs
January	59	81
February	69	81
March	65	73
April	77	82
May	82	89
June	89	90
July	96	94
August	97	96
September	91	89
October	69	80
November	57	71
December	60	76

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

1. The Cretaceous tertiary sedimentary rocks.
2. Sylhet Trap Group.
3. The Shillong Group.

The Cretaceous Tertiary Sedimentary Rocks

The sedimentary beds of the area divided into different rock formations. The basal conglomerate of the Mahadek formation contains rounded pebbles mainly of massive quartz.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RELATIVE HUMIDITY IN %
100
90
80
70
60
50
40
30
20
10
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

FIG.10

The blocks of coarse brown therria sandstones are seen scattered over the soft Arkosic sandstone of the Mahadek formations and calcareous sandstones of Langpar formation around the study region. The study of limestone of the region shows a complete dissolution of these rocks in water. It is observed that the cave deposits of the area are through the chemical processes. There are some unique development of stalactites and stalagmites deposits inside the cave. At the centre of the cave a huge number of stalactites are hanging on the roof along the joints.

Hence, the above discussion shows that the limestone is highly permeable because of presence of major and minor joints. There is a large surface affected due to weathering.

The Sylhet Trap

This rock consists of basalt, alkali basalt, rhyolite and acid tuff and occurring along the southern part of the study region in a narrow belt running E-W direction. The exposed surface of this rock has been weathered at places. The dolerite is greenish black, hard and is weathered into spheroidal boulders. The final product of basalt dolerites is a rich dark colour soil layer in the area.

The Shillong Group

By far it is the predominant rock type in the area.

The rocks are well bedded and due to alternation of quartzite phyllite and siltstone show differential weathering. The permeability is further enhanced due to the presence of joints and fractures. This subsurface water circulation network has altered the Shillong group of rocks extensively. Cementing material has been leached out at many places.

Mechanical Weathering

Mechanical weathering is the change of consolidated rock to unconsolidated matter. This type of weathering is enhanced by climatic factors. In certain regions plants and animals also act as an agent of physical weathering.

Various processes have been recognised as mechanical weathering by Ollies (1965), Thorenburry (1861), Lobeck (1939) and Sparks (1952).

Weathering as may be expected starts at two places along foliations and joints. Both the vertical and horizontal joints are present in the quartzites and as a result of weathering along those joints. Rectangular blocks and slabs are produced due to disintegration of these rocks. The schist, clay and limestone rocks which are very susceptible to weathering have been eroded away and hence are found exposed on the lower elevations.

Above all the researcher has observed that different rocks react differently to different climatic conditions. This result in the marked contrast in topographic form produced in similar rocks but under unlike climatic environment.

Chemical Weathering

Chemical weathering is the result of change in the chemical composition of rock that is caused by atmosphere agents such as oxygen, water, carbondioxide and organic acids. The following substances are most active chemically. The processes involved in chemical weathering, classified as:

1. Oxidation
2. Carbonation
3. Hydration
4. Dissolution

Oxidation

Oxidation plays an important role in Cherrapunji region. This type of process is most effective in rocks having compounds of iron. Iron occurs in igneous rocks in the form of iron sulphide or pyrite as ferrous oxide or magnetite or as feromagnesian silicates such as mica and harnblende. Oxidation of these minerals produces ferric compounds those which contain more oxygen than the ferrous compounds.

In Cherrapunji area where sedimentary rocks such as sandstones, clays and limestone which have inclusions of ferruginous minerals often show a brown colourization indicating that the minerals underwent oxidation and turned into iron hydroxide. The soft and brittle mica schist, phyllites and other clay rocks which are very susceptible to weathering have been eroded away and hence are found exposed on the lower elevations.

Carbonation

Carbonation involves the formation of carbonates which is very soluble. Iron sulphide is attacked by water containing carbon dioxide and it is changed into carbonate and sulpheric acid. The iron carbonate is soluble mineral and is readily removed in solution. The sedimentary rocks such as limestone or calcium carbonate is also attacked by water containing carbon dioxide and changes to calcium bicarbonate which is many times more soluble than limestone.

Hydration

Hydration means the taking up of water as a chemical constituent. Most minerals which result from the rock decay contain large percentage of water. The combination of these minerals is clay which results from the hydration of feld-spar. Other minerals such as mica takes up water to form hydrated minerals. The taking up of water changes the rock from its original crystalline form. In the study area limestone, sandstone contain abundant unaltered mica when this weather by hydration thus sandstone rapidly break down into its constituent grains. Muscavite however resist weathering longer than quartz.

Dissolution

Complete dissolution of minerals in water is observed in the study area. It is with these rocks that the formation of Sinkhales and caves associated water enriched with carbon dioxides dissolves limestone but then under different environmental conditions readily redeposits the dissolved carbonates.

By this processes the stalactites and stalagmites have developed inside the cave and the entire roof of the cave is being affected by chemical weathering.

Vegetation is also important in governing the rate of removal of weathering products. Failure of the protective root system generally is not uniform under natural conditions, and this leads to uneven erosion.

Soils

The study area shows little variation in respect of climatic factors (rainfall, temperature and humidity). Geologically also the different rock types show gross homogeneous characters and more or less similar uniform weathering phenomena. A physical, chemical, biological and mineral weathering processes alternation of rocks and sediments develop beneath the land surface. For study purposes a soil may be considered as a unit formed at the earth's surface possessing distinctive. The most important factors are climate, second to this is vegetation and precipitation. Generally, pedologists and geologists differ in the definition of a soil. Geomorphologists are concerned with the entire weathered zone from surface down to unweathered bed rock.

The soil has been described along with the type and properties of soils in succeeding sections. In previous section it has already been discussed the various factors which promote weathering processes, which have also a substantial affects on soil formation of the region concerned.

The soils of the study area have developed under varied conditions of geology, relief climate and vegetation. They are of four different types.

1. Red loamy soils.
2. Red and yellow soils.
3. Alluvial soils.
4. Lateratic soils.

Red Loamy Soils

The soils occupy the central part of the study area. They are derived from the weathering of rocks like gneisses and granites. The soils are richer in clay forming minerals but poor in silica. The soils are generally loamy but sometimes vary from clayey to sandy loam. The colour of the soils varies from reddish brown to dark reddish brown. The soils are rich in organic matter and nitrogen but deficient in phosphate and potash. They are usually acidic in character and are suitable for the cultivation of rice, potato and fruits. Fig. (p. 4).

Red and Yellow Soils

The red and yellow soils are found in a belt running from E-W in the southern part of the study area. The yellow colour is due to the higher degree of hydration of the ferric oxides in these soils. The soils are usually fine textured ranging from loam to silty loam and are suitable for rice and fruits.

Alluvial Soils

The soils along the southern fringe near Bangladesh plain are generally found in the river valleys on flat as well as slightly undulating topography. These soils are built up of alluvial material washed down from the hill slopes. These are mainly heavy textured soils. The colour of the surface soils is light yellow to pale brown. The surface soils are compact and very sticky. The texture of the soils also becomes heavier with depth. The soils are highly acidic in character and rich in potash but poor in phosphate. They are being used for the cultivation of rice, fruits etc.

Laterite Soil

This type of soil occurs in narrow belt extending from west to east. They have been formed by the weathering of rocks like quartzites, schist, conglomerate, and granite which are rich in iron. These rocks are generally reddish or yellowish red in colour and have rescicular structure. They are massive and firm and can be cut into large blocks when sufficiently moist. On exposure they dehydrate and become very hard. The laterites have been formed under the continued heavy rainfall as a result of which soil basic constituents have been leached out from the soil only a matrix rich in iron and alluminium oxides and hydro oxides. These soils are poor in organic matter and other fertilising constituents are acidic in reaction. From the agricultural point of view the soils are not very important but can be used for the purpose by a heavy amount of organic matter. Hence it may be added that the terrain has played important role in determining the nature of the soils in the present study area. In general the soils are immature, light in colour and less fertile on the hill tops and are thick mature deep in colour more fertile in valleys and the lowlands.

Mass Wasting

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

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

The intensity of mass wasting depends on such factors like lithology, stratigraphy, structure, topography, climate and organic factors. Different factors being effective in different parts of the region. The dominating types of mass wasting observed in study region are as follows:

i) Debris fall

ii) Rock slides

Debris fall

Debris fall is the nearly free fall of earth debris from the vertical or overhanging face. Debris fall are common in the southern part of the study area. On the highway the exposed vertical faces over the soft Arkosic sandstones and Sylhet trap rock made by road cutting are seriously affected by debris fall. Heavy leaching caused by seasonal rainfall over the highway permeable calcareous limestone and sandstone, acid tuff and basalt rholite (Sylhet trap) are the main reason for this debris fall along the road side of the study area.

Rock slide

Rock slide is the process of sliding or falling of individual rock masses down usually along bedding joints or fault surfaces. It appears that due to action of mechanical and biological weathering along joints, the compactness of rock mass is lost and the boulders fall down the slope under the effect of gravity. It has rolled down along the slopes. These blocks has formed masses of tally below vertical cliffs.

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CHAPTER V

DRAINAGE AND ITS EVOLUTION

DRAINAGE AND ITS EVOLUTION

Introduction

The significance of drainage in the evolution of the landscape has always fascinated geomorphologists, hydrologists and geologists etc. Thus an understanding of both the drainage characteristics and the fluvial processes is very important and basic to understand the evolution of landscape in the area. Fluvial processes concern with the development of the features of an individual valley and the development of a system of drainage, composed of many individual valleys.

Runoff rain water in the form of sheetwash or in concentrated channels forming streams, is the most dominant geomorphic agent in sculpturing the landscape of an area. The activities of streams or running water could be either erosional or depositional. Due to erosion different types of valleys interfluvial ridges are formed depending on the stage of development.

Drainage System

The drainage map (Fig. 11) of the region indicates that the area by and large, forms part of Wah Tymshun river basin. However, the north-western corner of the area forms part of Umiew basin a trunk stream. The southern fringe

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DRAINAGE

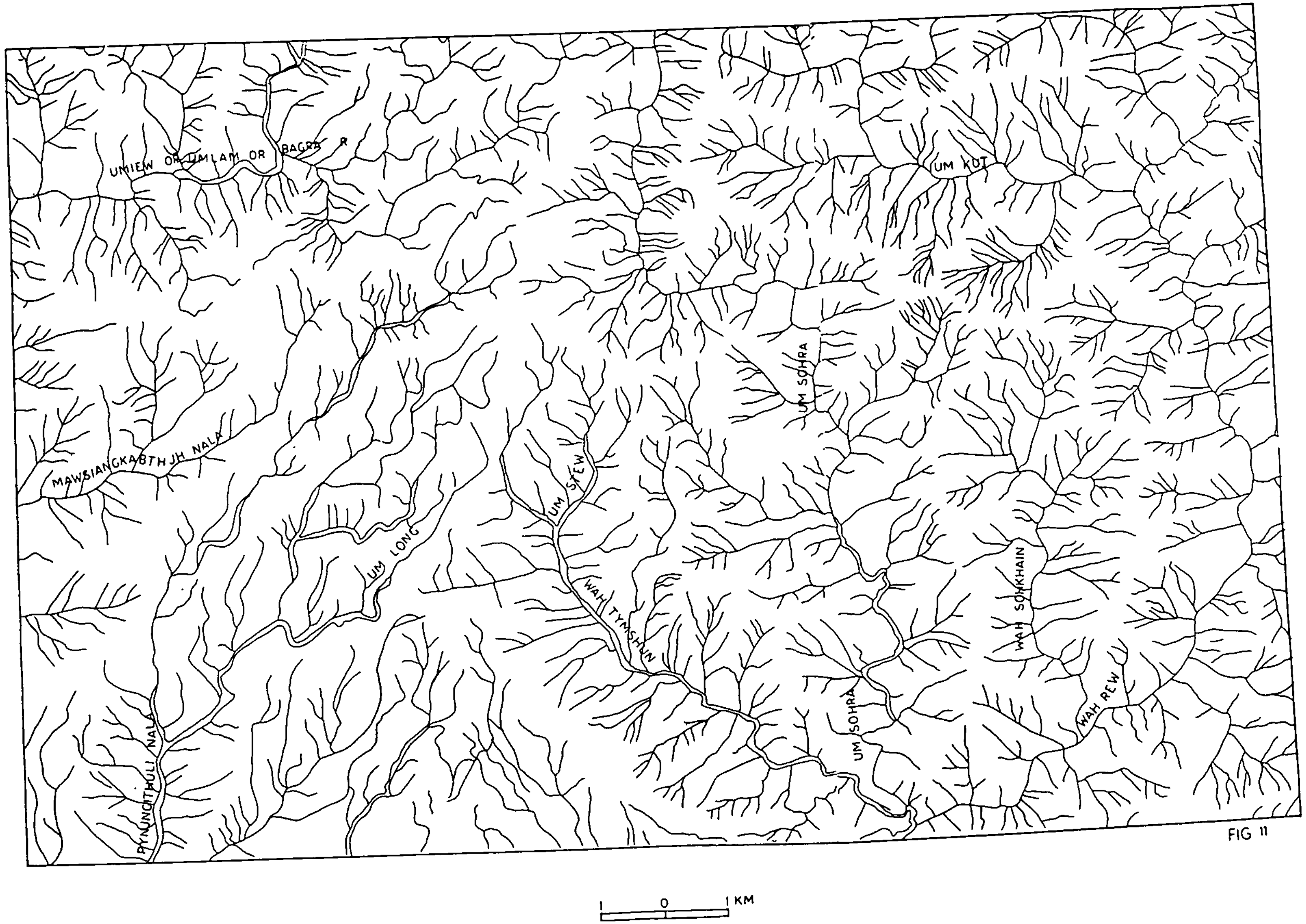


FIG 11

of the area is being drained by Um Sohra and Wah Sohkhain basin (tributary of Wah Rew river). The headwater channel network of Wah Rew, Wah Tymshun, Pynjngithuli nala, falls in the area. To understand the drainage system in the area drainage analysis has been done. Fig. (p. 5).

Drainage Analysis

Drainage analysis is a way to understand evolution of landforms. Analysis of drainage patterns are being studied by more and more elaborate methods. The increasing accurate methods of measuring landforms and geomorphological processes are producing a vast amount of quantitative data. This has to be analysed by numerical methods so that an orderly behaviour may be described from amongst the accumulated data. A glance at the drainage map reveals that the drainage system is to a large extent controlled by the lithology and structure and is running from north to south. Drainage analysis helps in evaluating landforms. Some underground channels in the limestone area are clearly seen.

For the first time Davis (1909) was concerned with the evolution of landforms over a long span of geologic time. Prior to Horton, drainage analysis was treated in a qualitative manner by the geomorphologists. Fenneman (1914) selected the physiographic regions and those delimited for the United States were based largely drainage basin and channel network was transformed from a qualitative way to rigorous quantitative science providing hydrologists with numerical data of practical value. Horton's work was further developed by Strahler (1952, 1957, 1958, 1967) and other workers who developed it further are Schumm (1956), Chorley (1966), King (1966) etc.

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

Methods of Analysis

The main aim of the present study is to examine the evolution, form and features of drainage in Cherrapunjee area. The drainage analysis has been applied to the area drained by given streams and there upon consideration of structural geology although certain gross morphometric attributes mostly relief and degree of dissection were also used.

Wooldridge (1932) defined the facets of slopes forming the intersecting surface characteristics of polycyclic landscape. Playfair (1802) has expressed all components of each basin in proportion. According to him, every river appears to consist a main trunk fed from a variety of branches, each occurring in a valley proportioned to its size and all of them together forming a system of valleys connecting with one another and having such a nice adjustment of their activities that none of them join the principal valley either too high or too low level.

Under the impetus supplied by R.E. Horton (1945) the description of tributaries. For this purpose 1:50,000 scale toposheet was used. However, the area of study, as already stated, comprises parts of Wah Tymshun, Wah Rew, Umiew, and Um Sohra (Fig. 11).

A particular feature of channel network which can be measured directly from the toposheet is termed as an element. Similarly, the quantitative expressing relating two or more element is termed a 'parameter'. The important 'elements' and 'parameters' computed are given in Table (13). The significance of parameter is discussed below.

Stream Ordering

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

Table 13: **Morphometric variables for the area.**

Sl. No.	Element/Variable	Symbol	Units	Dimensions
1.	Stream Order	U	Enumerative	0
2.	No. of stream of order U	Nu	"	0
3.	Total number of stream within the area	$(\Sigma N)u$	"	0
4.	Bifurcation ratio	Rb = Nu/Nu+1	"	0
5.	Total length of stream of order U	Lu	Km	L
6.	Total length of streams in the area	$(\Sigma L)u$	Km	L
7.	Stream length	$\bar{L}u$ = Lu/Nu	Km	L
8.	Stream frequency	Fu = ΣNu/Au	Numbers/Km^2	L^{-2}
9.	Drainage density	Du = $(\Sigma L)u$/Au	Numbers/Km^2	L^{-1}

order merge, a segment of third order is formed and so on so forth. An increase in stream order only occurs when two streams of like order join each other. The hierarchy or ordering of stream network is a function of scale of map or toposheet used.

Stream Number

For the present study toposheet on 1:50,000 scale has been used after all the streams have been assigned their respective orders all the segments of order 'U' are connected to yield the Number 'Nu' of the stream order 'U' in the area. The hierarchical order of prominent streams in the area is given in Table 14 and each stream is discussed below.

Table 14: Hierarchical order of streams.

Sl. No.	Name of stream	Nature of stream	Basin	Location
1.	Wah Tymshun	Trunk stream	Wah Tymshun	Central part
2.	Um Kut	Tributary of Wah Rew	Wah Tymshun	North eastern part
3.	Pynjngithuli	Trunk stream	Umiew	South-western part
4.	Umiew	Trunk stream	Umiew	North western part
5.	Mawsiang Kabthjh	Trunk stream	Umiew	Western part
6.	Um Sohra	Tributary of Wah Tymshun	Wah Tymshun	Central part
7.	Wah Rew	Trunk stream	Wah Rew	South eastern part

Wah Tymshun System

The maximum length of this river system is 13.25 Km in the study area. The river rises from the northern slope to southern slope. The river enters in the study area after receiving several tributaries from the east and west direction. The most important tributary Um Stew is 3 Km in length. The river Um Sohra and Wah Rew join in the lower course and finally reach to the Bangladesh plain. The streams are mostly controlled by the faults and fractures in the sedimentary rocks. Fig. (p. 6).

Um Kut System

The maximum length is 9 Km. The river rises from north-east and flows towards the south-west. It is a major tributary of Wah Rew. It rises in the granite gneiss surface of north-east and flows towards the Sylhet limestone formation. The area is divided into two parts by this river. This river Wah Sohkhain and Wah Rew have joined at an elevation of 800 m and 1000 m. Its long profile shows very gentle slope from its source of origin.

Pynjngithuli System

The stream rises in the Sylhet limestone and has joined with the Umlong at a height of 1200 m. The length of this stream is 14 Km. Over the granite surface it has formed a radial pattern.

Umiew or Umlam or Bagra System

The Umiew or Umlam or Bagra system is an extensive river valley of the northern Cherrapunjee plateau. Its maximum length is 7.25 Km. This river rises from the southern slope of Smit area at an elevation of 1640 m. In many places older rocks like granite have been exposed along its bed. It has separated the study area from the Cherrapunjee platform and then reached the Bangladesh plain near Shella. The important tributaries of this river system are Um Jut and Um Long.

Mawsiang Kabthjh System

The maximum length of river Mawsiang Kabthjh Nala is 6.75 Km in the study area. It is a small stream drain in the western portion of the study area. The long profile shows two important breaks in slope.

Um Sohra system

It is the most important basin of the eastern part of the study area. The maximum length is 17.75 Km in the study area. This river flows towards south over sandstone and limestone surface and finally reaches Bangladesh plain at an altitude of 1240 m. The course of this river is controlled by the rock structures of sandstone and limestone.

Wah Rew System

The Wah Rew river rises from northern slope of study area at an altitude of 1040 m. The maximum length of this river is 17 Km in the study area. This stream drains the north-eastern part of the study area and after flowing towards south it meets the trunk stream Wah Tymshun at an elevation of 620 m. The most important tributary of this river system is Wah Sohkhain and Um Kut. The length of these two tributaries is 8 Km and 9 Km. The stream finally meets with Um Sohra and Wah Tymshun at an elevation of 800 m then it reaches the Bangladesh plain.

Drainage Pattern

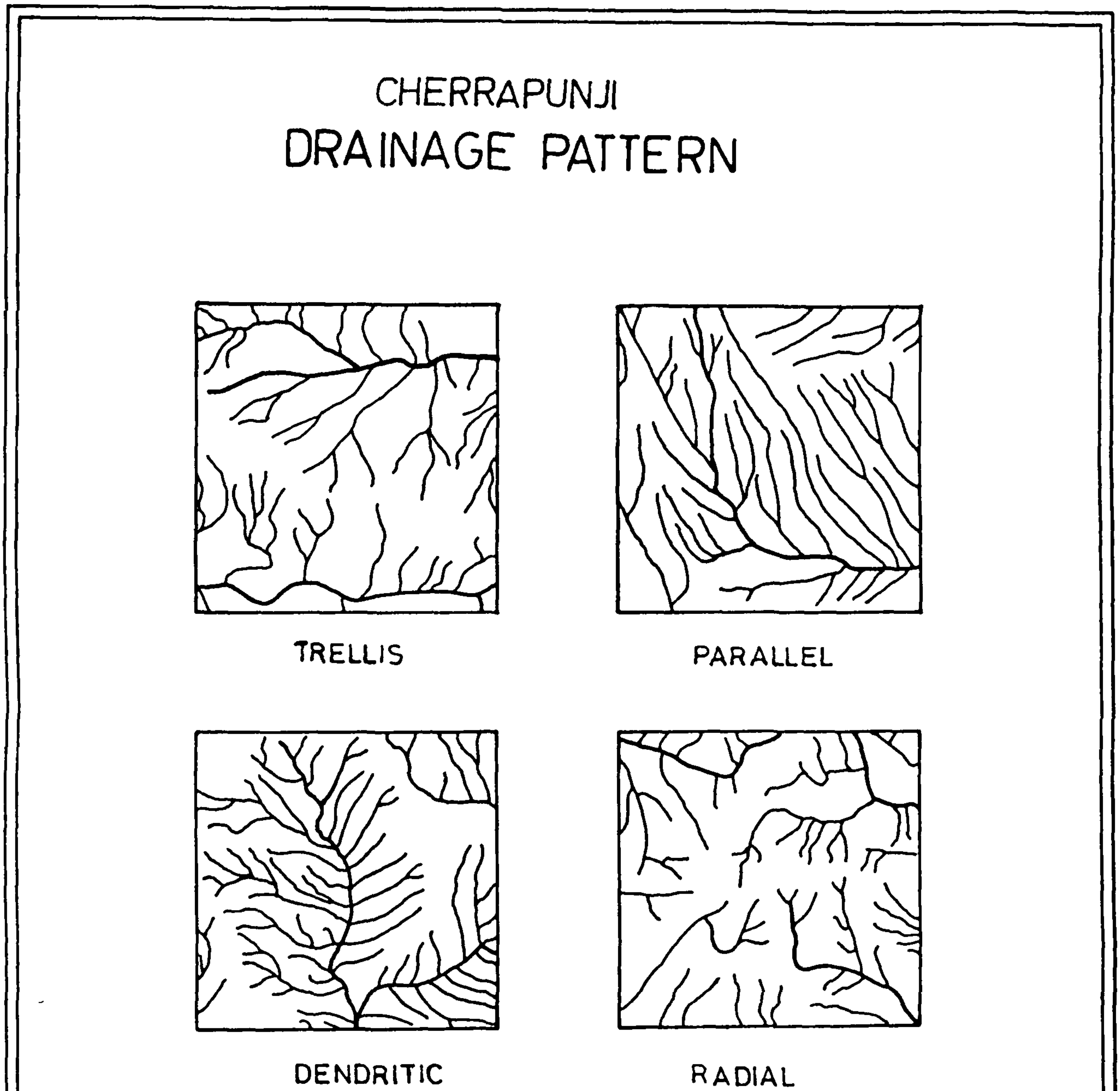
"Drainage pattern refers to the particular plan or design which the stream course collectively form." A study of drainage patterns often reveals a very delicate adjustment with structure and lithology.

The pattern of drainage is one of the most revealing features of landscape and rock type. Drainage pattern reflects the influence of factors like slopes, rock types, geologic and geomorphic history of the drainage basin.

The drainage network of the study area reveals the following four types of drainage pattern (Fig. 12), viz. (i) Trellis pattern, (ii) Parallel pattern, (iii) Dendritic pattern, (iv) Radial pattern.

Trellis Pattern

This drainage network has been observed around northern part of study area which is drained by Um Sohra


CHERRAPUNJI
DRAINAGE PATTERN
TRELLIS
PARALLEL
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RADIAL
0
1
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FIG.12

and Um Kut river systems. In this pattern the streams are sub-parallel, usually aligned along the strike of the rock formations. The major streams frequently take right angle bend to cross or pass between aligned ridges and the primary tributary streams are right angle to the main stream. Well developed joints and faults give rise to such a drainage pattern.

Parallel Pattern

This drainage network has been observed around western part of study area which is drained by Um Long and Mawsiang Kabthjh Nala. In the parallel pattern main streams have parallel courses to the tributaries. This type of pattern is round in sandstone ridges. In the study area the slope increases from south to north. The slope is very steep. A few parallel patterns of drainage are noticed in this area. The Pynjngithuli Nala and its tributaries Um Long show a typical parallel drainage pattern (Fig. 12).

Dendritic Pattern

The dendritic type of pattern is the most common in the study area. This pattern is characterized by irregular branching of tributary streams in many directions almost at any angle like that of limbs branching from the body. The streams in the central part of the study area, for example, Wah Tymshun and its tributary Um Stew belong to this type of category (Fig. 12). The study area is composed of nearly horizontal sedimentary rocks, so there is well developed dendritic drainage pattern.

Radial Pattern

In this pattern streams diverging from a central elevated area. This type of drainage pattern develops on domes, volcanic cones, where there is no effect of differing rock resistance. In the study area such pattern (Fig. 12) are located in the central part. This pattern has developed in the isolated hills.

Drainage Frequency

Stream frequency is the number of streams per unit area. This is one of the important morphometric analysis of the drainage network. Horton (1945) defined stream frequency as the total number of streams in a drainage basin divided by the basin area. It is obtained by dividing the total number of streams to area of the same unit as follows.

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

Where SF is the stream frequency per unit area.

N is the total number of streams in a unit area

A is the unit area.

Drainage map has been prepared from the 1:50,000 topographic sheets of the study area. The total study area is divided into two cm grids north-south and east-west representing an area of one Km^2. The values of stream frequency is placed in each grid following the above formula and choropleth map is drawn.

Table 15: Distribution of Drainage Frequency

Drainage frequency per Km^2	Frequency of grids	% of total frequency	Cumulative % of frequency	Frequency category
Above 20	1	0.39	0.39	Very high
15 - 20	7	2.69	3.08	High
10 - 15	82	31.53	34.61	Moderate
5 - 10	153	58.85	93.46	Moderately low
Below 5	17	6.54	100.00	Low
Total	260	100.00		

The Table 15 reveals that more than half of the study area is covered by the moderately low stream frequency i.e. 5-10 streams per Km^2 in the south, south-west and north-west parts of the study area. The next most important is moderate category 10-15 streams per Km^2 occupy the eastern

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STREAM FREQUENCY

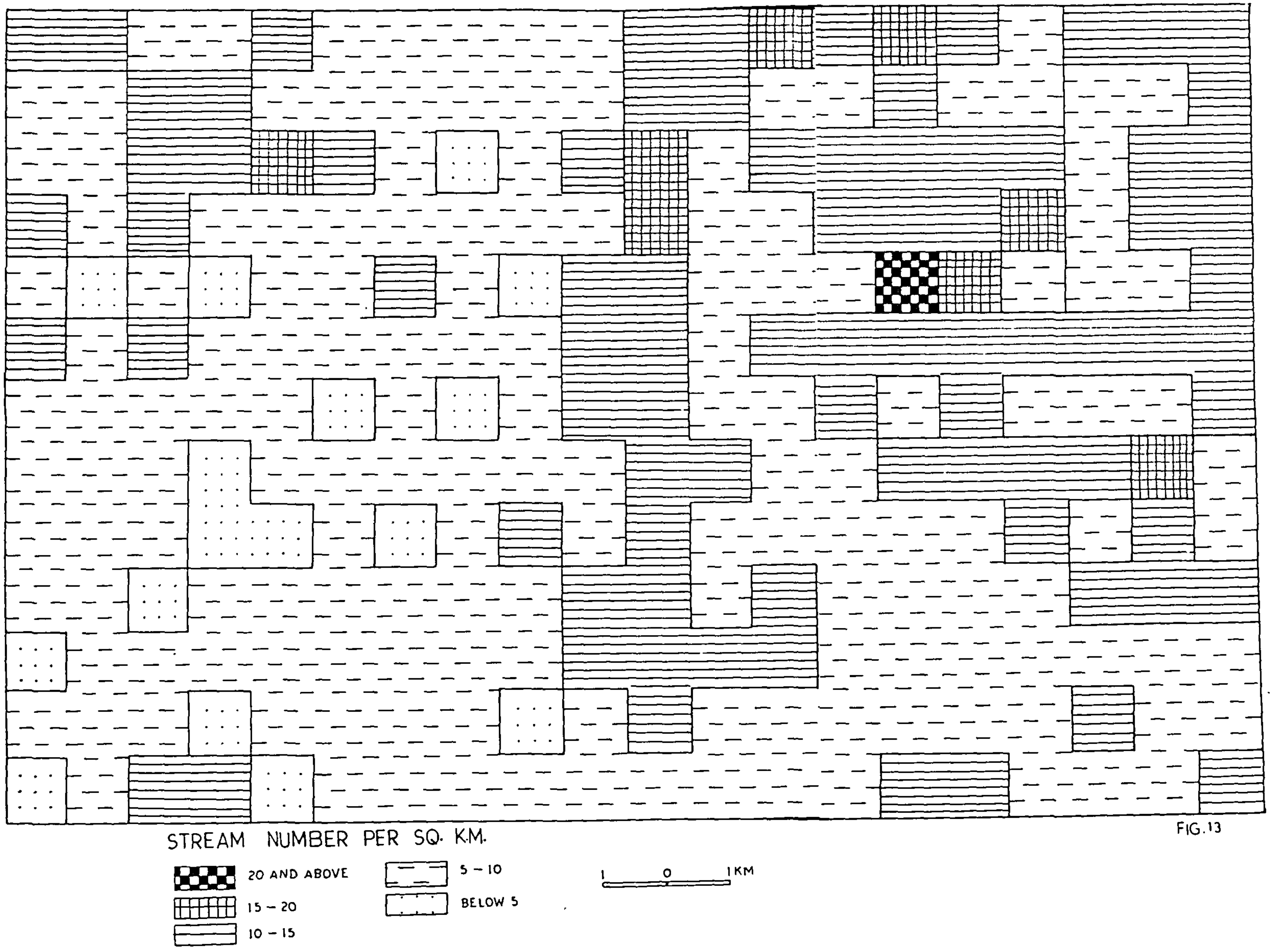

FIG. 13

and central parts of the study area. The areas of high and very high, 15-20 and above 20 streams per Km^2 lie in the northern and central part of the study area. The low stream frequency below 5 is marked in the western part of the study area.

The drainage frequency map (Fig. 13) of the study area shows that the central and northern part covers a higher frequency. The higher frequency is marked due to the high seasonal rainfall and the lithological characteristics of the Pre-Cambrian and Cretaceous Tertiary sediments. Maximum area lies in the moderately low stream frequency. Among the most important factors influencing the drainage frequency is the heavy rainfall in the year (above 11,000 mm) and joints and fractures present in the rocks.

Besides this the sedimentary rocks play important role in the development of drainage frequency. The hard rocks over the Cherrapunjee area does not allow large amount of percolation and hence surface runoff is high, and large number of small streams originate over it.

Drainage Density

Drainage density is one of the most important aspect of drainage analysis. Horton (1945) has used the formula to measure the drainage density which can be obtained by dividing the total stream length by the basin area. It can be expressed in mathematical formula, as such,

$$Dd = \frac{L}{A}$$

Where Dd is the drainage density.

L is the total stream length.

A is the unit area.

The distribution of drainage density has been assessed qualitatively as well as in terms of statistical measures. The drainage density presented by Horton is included in hydrological studies. Grey (1965) told that the pattern and type of natural stream channels determines the efficiency of the drainage system. Drainage density is related to physiographic characteristics such as rock structure, type of rocks and shape of the basin. It is also related to input and output of the drainage basin. The drainage density values varies from place to place. By this we know that the increasing order basins contain a decreasing drainage density.

The drainage map of the study area has been divided into two cm which represents one Km^2 of the surface grids by using the above formula. The total study area is divided into 260 grids which represent the length of streams per Km^2. After that a choropleth map of drainage density is prepared. The drainage density has been classified into five groups (Table 16) ranging from zero to more than 4.

Table 16: Frequency distribution of drainage density.

Sl. No.	Drainage density Km/Km^2	Frequency of grids	% of total frequency	Cumulative % of frequency	Density category
1.	Above 4	11	4.25	4.25	Very fine
2.	3 - 4	39	15.00	19.25	Fine
3.	2 - 3	132	50.76	70.01	Moderate
4.	1 - 2	72	27.69	97.70	Moderately coarse
5.	0 - 1	6	2.30	100.00	Coarse
	Total	260	100.00		

From the figure 14 it is clear that there is a wide variation in drainage density distribution in the study area. It is seen that the category of very high drainage density has lowest frequency distribution 4.25%. Similarly, coarse category shows lower frequency distribution of 2.3%. The frequency distribution of moderately coarse, moderate and fine categories of drainage density is 27.69%, 50.76% and 15.0%. The moderate to moderately coarse categories of drainage density represents 78.45% of the study area. Thus the average density of the area comes under moderate drainage density category.

CHERRAPUNJI

DRAINAGE DENSITY

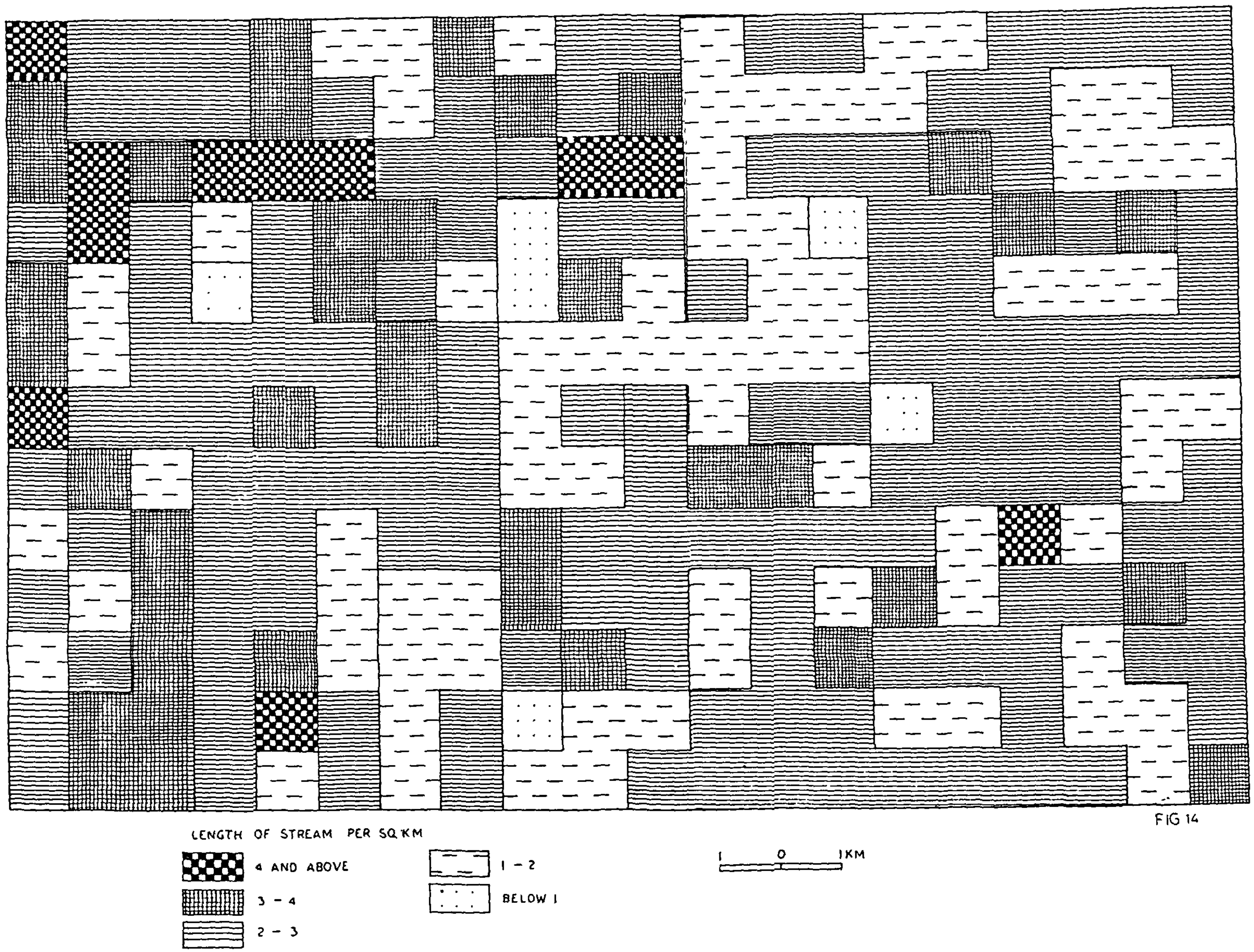

FIG 14

A comparison of drainage density, drainage frequency, absolute relief and relative relief indicates a general correspondence of frequency in the northern half of the area. It implies that the morphometric parameters of the northern half of the area show some variation with the southern half of the area. This fact is corrobrated with distinct change in the landforms between the two halves of the area.

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CHAPTER VI

ANALYSIS OF LIMESTONE TOPOGRAPHY

ANALYSIS OF LIMESTONE TOPOGRAPHY

Introduction

The limestone occurrence is widespread throughout the world. About 20% of the total land area of the world is covered by limestone (Ahmed, 1983). Hence, the study of limestone topography or Karst is one of the most important aspects of geomorphology.

The Karstic landforms depend upon geology, relief climate, height of the water table, drainage etc. The geomorphic significance of rock solution has been previously considered in connection with rock weathering and it contributes to the reduction of land masses particularly in the late stages of the fluvial cycle. In certain regions however solution becomes a dominant process in landform development with resulting production of unique type of Karst topography. Solutional features may develop upon other soluble rocks such as gypsum and rock salt, but in general they are not of major importance because of the limited areal extent of landforms in limestone terrains.

Cvijic divided the limestone topography into three conventional stages of youth, maturity and old age. Youth is marked by the beginning of diversion of surface drainage to subterranean routes. In maturity there is maximum of sinkholes and underground drainage with only major entrenched streams, persisting as surface streams, sinking cracks, swallow holes, blind valleys, compound sinks and dolines by the thousands which typify this stage. Old age is initiated with the beginning of return to surface drainage. Karst windows, Karst tunnels, natural bridges and hums are the most diagnostic features.

The influence of climate upon the characteristics of Karst terrains is well exemplified in some of the differences between the Karst of the humid middle latitudes and that of the humid tropical regions. Heavy annual rainfall in the monsoonal regions along with the large amount of Carbon dioxide (CO_2) provided from decaying vegetation add in much more rapid solution.

Characteristics

The area satisfies the following characteristics which are necessary for the development of limestone topography.

(i) The rocks are massive, crystalline, well bedded and well jointed.

(ii) The height of the area above sea level (or above the level flowing rivers) is adequate for a full circulating of underground water to develop.

(iii) Heavy rainfall takes place in the region which promotes solution.

Types of Limestone

In the study area the Lakadong limestone of Sylhet limestone formation is found overlying the Cherra sandstone and is itself overlain by the Lakadong sandstone. The limestone bed is 20 m to 30 m thick and is found exposed in cliff faces around the Mawmluh-Mawsmai Hills. A reserve of 20 million tonnes of limestone has been estimated in different quarry. Fig. (p. 7) and Fig. (p. 8). Average composition of the limestone of the area is given in Table 17.

Table 17: Average Composition of Limestone

CaO	50.59%
MgO	2.69%
Al_2O_2	0.70%
Fe_2O_2	0.40%
Acid Insoluble	1.77%

The limestone of the stuay area are described as follows:

Sylhet Limestone Formation

The limestone in Cherrapunji is of Sylhet limestone stage. It consists of limestone, sandstone, shale and coal. On the east bank 'of the Um Sohryngkew, ıt is represented by three highly fossiliferous limestone bands separated by sandstones of variable thickness. The thearia formation is conformably overlain by the Lakadong limestone,, the bottom bed of the Sylhet limestone. This area is seen in the Pynsan-U-Bah hill along Umiew river section. Scattered limestone is also found in the Tyllab area in the Bairang hill and along the road section from Mawlong to Ishamati. In the south western portion of Cherrapunji about 30 m thick limestone thickness exceeps. The limestone is highly fossiliferous yielding shells and calcareous algae.

In central places along the western face of the Umstew gorge only a thin limestone bed exists. Limestone caves with stalagtites, stalagmites and sinkholes are quite common in this area. The natural features attract large number of visitors from the different parts. Good exposures of limestone bed are seen in the Umiew and Umsohryngkew river section between Mawlang and Ishamati. Several discontinuous outcrops are found over the Bairang to Bholaganj area.

Prang Limestone

The Prang limestone overlies the sandstone. This type of limestone is well exposed in the Umiew river section near the Shella Bazar and towards the road side from Mawlong to Ishamati near Umsohryngkew river section. The colour of the limestone is greyish to bluish grey.

Theria Stage Limestone

This type of limestone bed at the lower part of the therria stage is only a local development in the Therriaghat area to the east of Bholaganj. Its extension was not traced in the area towards west of Therriaghat but it seems to extend and covers a small area to the east of Umsohryngkew. The lower part of this limestone bed contains good quality argillaceous massive limestone which is suitable for use in cement factory. At places along the southern part of the area the thickness varies. The waste material of the cement factory damaging vegetation along the slope. Fig. (p. 9).

Important Features of Limestone

In Cherrapunji area the rock types and heavy monsoon rainfall has played an important role in developing the different Karst features. Here in the study area small rounded limestone hills are found, scattered all over the region. Some of these have caves, underground channels and different characteristic cave deposits.

Caves

The limestone cave of the study area have similar characteristics like the most important process in the cave evolution. Water enters the limestone through the joint and solution causes to the formation of caves. Movement of water in limestone is controlled by lithological variations and by joints and fault lines. In this cave evaporation of water and carbondioxide takes place Calcium Carbonate dissolve from the limestone is redeposited in a variety of ways like stalactites and stalagmites. In some places stalactites and stalagmites join together.

The entrance of the cave is about 235 cm in height and 235 cm to 290 cm width. It becomes narrower when it proceeds deeper. From the entrance the passage runs horizontally for a few metres and then there is a bifurcation – one passage goes semi-vertically downwards. This is mainly due to the groundwater capacity to descend under pressure head to considerable depth.

On the floor of the cave, some block of rocks are noticed. These are due to the result of cave breakdown. There are some protected forest near the cave. Fig. (p.10).

The Cockpit Karst

Cockpit Karst have seen in the study region. This feature consists of succession of cone like hills with the alternating enclosed conical depressions or cockpits. The depressions and the intervening hills show the uniformity both in area and in height of the ranges. The slopes of the cockpit are steeper on one side than the other. Moreover, the cockpits and the conical hills are symmetrical. The solution of the limestones along joints and fissures causes the cockpit depression. For the first time this idea was put forward by Danes.

The Tower Karst

Tower Karst develops on the bases of the cockpits extend to the underlying rest-level of the water. Solution takes place along the base and sides of the cockpits. Geological and physiological circumstances of the region tend to produce a water table or a spring line for the development of tower Karst. Erosion particularly corrosion by springs and flood waters at the base of the cockpits are responsible for the development of these characteristics. The development of tower Karst in Cherrapunji is usually associated with large scale lateral movements of water.

Sinkholes

By far the most common and widespread topographic feature in a Karst terrain is the sinkholes. In the area sinkholes are found by the hundreds or thousands. Topographically a sinkhole is a depression that varies in depth from a few cm to a maximum of 30 m or more. Among them the most common form is funnel shape and broadly open upward, but others have many variations from this.

Karst Plain

In the northern portion of the study area horizontal or gently dipping limestone strata has developed and known as the Karst plain. Very few streams are able to cross this Karst plain. The sinks of a surface stream usually takes place in a swallow hole, but in some streams the water disappears through alluvial materials. Tributary valleys from the sandstone and short hills descend into the limestone valleys and disappear.

Waterfall

Along the south-east of the cement factory a channel is followed for the observation of the small waterfall along the river course. The bedding plane is 95°-275°/

4°-185°. Both banks of the river course delimited by the first set of joint plane. It seems due to these conjugetive set of joints, block of slabs along bedding plane are coming out forming small waterfalls. Among these the Mawsmai fall of this area is famous which height is near about 200 m in a state scarp form. Fig. (p. 11).

Underground Channel

During the field study two underground channels were found. One undeground channel reappears on the surface near the Mawsmai cave. Fig. (p. 12). The other one is seen near the Mawmluh Cement factory. Fig. (p. 13). Here the whole river disappears and again after about 2-3 kilometres reappear on the surface. A passage has seen in underground channel. Fig. (p. 14).

It seems this channel surface is burried under the debris of scarp which is near the river. Observation indicates the bedding plane and joint plane are crossing to each other which helped for the development of underground channel.

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CHAPTER VII

LANDFORM ANALYSIS

LANDFORM ANALYSIS

Introduction

The classification of terrain is the proclaimed objective of any geomorphological study. The basic concepts involved in such classification are obttained from regionalization principle and constitute the principal concern of the geomorphologists. The most useful type of classification related to those classes which permit the widest range of generalisations. In general therefore the best mode of the classification of geomorphological unit is that which separates the landscape into natural units based on origin, process and form. It is precisely for this reason that the classification of natural phenomena should be chosen from the fundamental and permanent characteristics of the landscape.

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

The study of various geomorphic processes of an area helps in developing geological and geomorphological history. The basic concepts involved in such classification are obtained from regional science. The best useful type of classification are obtained from regional science. The best useful type of classification as pointed out by J.S. Mill (1891) related to those classes which permit the widest range of generalisation.

The discussion of landform explains the qualitative nature and aereal distribution, pattern of major morphometric parameters such as relief, slope, drainage etc. In the following chapter an attempt has been made to classify the present study area into different landform units and to identify their inherent geomorphic characteristics.

Landform is the expression of the geological character and the surface geometry of the earth's crust. In terms of surface geometry, geology and landform units are more or less internally homogeneous and distinct from one another.

Landforms can be described qualitatively as well as quantitatively. Any landscape is nothing more than an existing stage in a great struggle to resist the denudation.

In this connection, the contributions made by Powell (1869), Davis (1899), Gannet (1902), Black Welder (1912) are remarkable. The landform units of almost all orders have been devised but with different nomenclatures and have been termed as natural regions.

The site concept provides on the one hand the flats and slopes, the visible expression of erosional depositional processes and on the other hand, offers units of relatively uniform environment for the development of soils natural vegetation etc, and thus site provides distinction in the landscape.

The land system approach provides a useful framework within which the range of potential in an area can be assessed. Despite differences in terminology and definition there is a general parallelism of thought about the occurrence of distinguishable units of landscape which can be ranked into a hierarchy.

In India similar technique were put forward by Bose, Banerjee, Chatterjee, Singh and Roy Choudhury.

Purpose of the Study

For the classification of the present study area into different landform regions, various maps such as geological map, relief map, drainage map and average slope map have been superimposed. The landform units map (Fig.15) show the different land and surface geometry. To classify the landform units as a basis for land evolutions, future planning and management. It is a preliminary survey of natural resources of the Cherrapunji area in which collection of information on environmental conditions and their interrelationship has been made. This study is similar in basic aims to these originally developed by the Commonwealth Scientific and Industrial Research Organisation, Australia and areal distribution pattern of rock characteristics and morphometric attributes conditioned by diverse agencies. The demarcation of the landform units were based on the morphometric parameters in combination.

Geomorphological measurement involved the examination of form by taking transects through the middle of the each facets along the orthogonal noting the geomorphological characteristics the surfacial material for every facets along each transect.

Landform Classification

The diverse geology and the morphometric characteristics i.e., the occurrence of extensive undulating crystaline high plateau in the north. Moderately high gently dipping sandstone table land in the centre and lowlying dissected terrain in the south lead to the different landform units.. Broadly the landforms of the area could be classified into following geomorphic domains and are described below (Table 18).

Table 18: Landform Classification

Geomorphic domain	Landform Units types
A. Plateau	1. Gently sloping plateau Plateau Relicts Cuesta
B. Denudational Hills	Erosional 1. Moderately sloping hills. 2. Steeply sloping hills Headward erosion, scarp Depositional Recent terraces

The landform units of the area clearly indicate that the plateau or table land hills form a major landform units occupying almost major part of the study area. Hill tracts scattered all over the area form a separate broad landform unit. Their origin is associated with upper-

CHERRAPUNJI
LANDFORMS

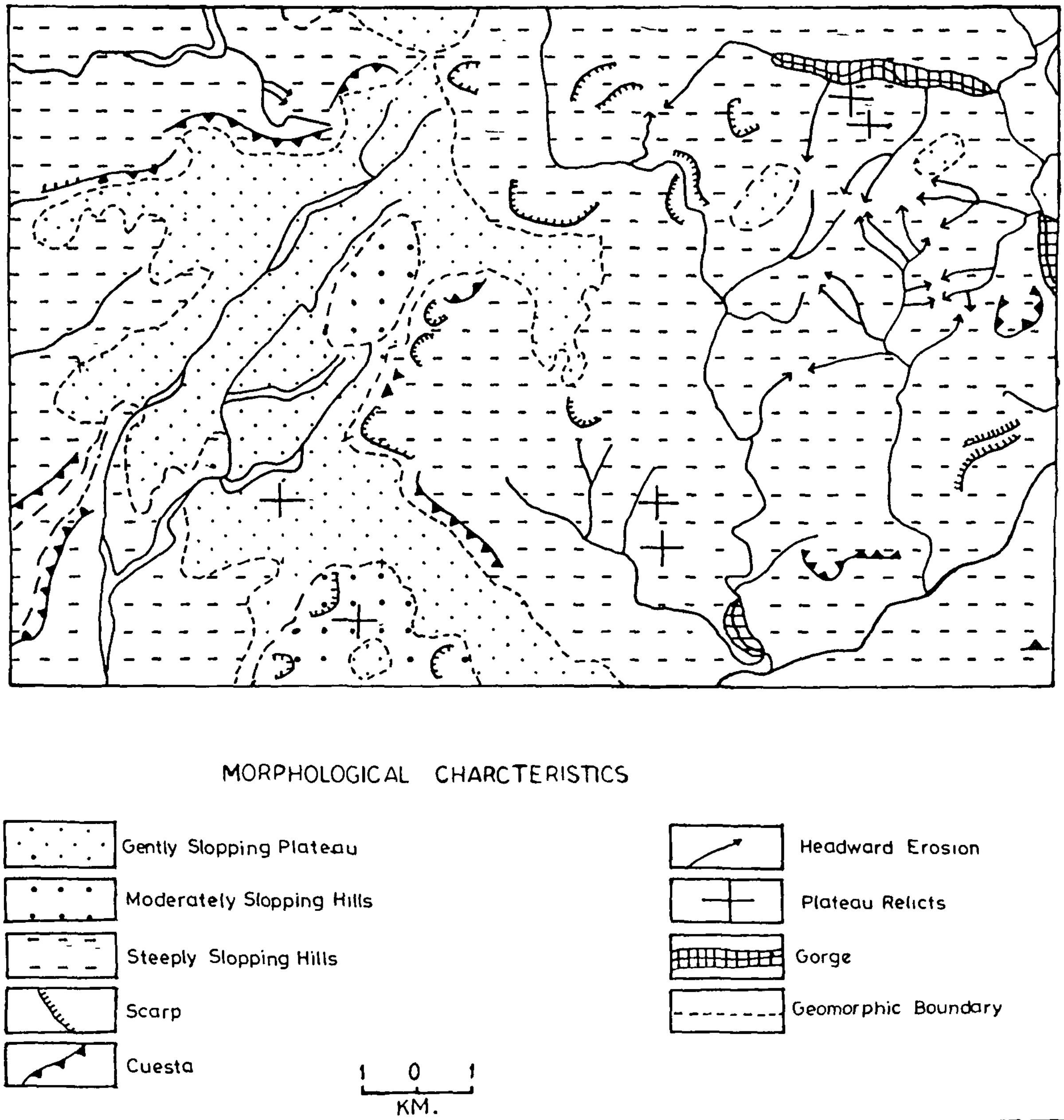

FIG.15

tertiary uplift and their inland extension from scarps. The area also indicates characteristics of differential erosion and structural differences. The scarps occupy a very limited area. The central scarps are less steep than eastern and western scarps. They are clearly associated in their characteristics with structure of their respective work formations.

Plateau Region

The plateau region found in the central and northern portion of the study area. Overall it is confined to Shillong plateau. It is extensive and prominent table land with a relative relief of 200-300 m. It covers an area of 2 Sq.Km. It is extensive and dotted with numerous hill relicts like features and conical hills. It is a region of less dissection and represents different uplifted plantation surfaces and their undulating extension.

The important landform unit within the plateau region are described below.

Plateau Relicts

These occur as small irregular features confined in the Plateau. The Jurassic uplift of the peneplain, rejuvenated the terrain. The relicts are not found always, sometimes it disappears with advancement of erosion. Such relıcts are seen at different levels with an absolute relief of 600-750 m and 1200-1300 m. The main denudational agency in the area is the fluvial processes. The drainage system with its down cutting and headward erosion has a tendency to subdue the tropography.

Cuesta

Tnese are confined mostly along the western and north western portion of the study area. These occur as high level terraces along 600 m contour level. Cuesta are found very scattered in the study area. It occurs in irregular shapes due to headward and lateral erosion by streams.

Moderately Sloping Hills

This type of landform unit is found in the central and southern part of the study area. This landform unit covers 59 Sq.Km. of the area. Their origin is related with Upper-Tertiary uplift and their in land extension from scarps. The area is a region of differential erosion and structural differences. In the northern part of the study area this landform unit has covered some parts of Archaean gneisses and pre-Cambrian rocks while in the southern part the cretaceous Eocene rocks are present.

Steep Sloping Hills

This type of landform unit is found in the central and western part of the study area. This unit covers 199 Sq.Km. more than half part of the study area. Distribution of rocks indicates that the Precambrian rocks have this type of landforms. Major part of this area is between 10° to 40° average slope. It has the range of altitude about 1300 m and separated by Wah Tymsun in the east and by Umiam river in the west. These landforms are formed mostly by shale, marl, limestone, arkose, melted clays and conglomerates of Upper Cretaceous Eocene period. This is an area of moderate to high drainage density. The streams are in its youth stage marked with V-shaped deep valleys with numerous waterfalls.

Scarp

Most of the scarps found with the trend of rocks. The southern face of the scarps are steeper than the northern slopes. These are confined within Shillong Group of rocks forming Cuesta. It is aligned in conformity with the trends of the rock types.

Recent Terraces

Recent terraces are confined by and large along the southern part of the study area and the valley of Wah Tymshun river. The terraces are mostly found on sandstone and limestone area. It comprises very coarse sand, gravels, limestone and clays of mostly Shillong group and subordinate phyllite-phyllitic sandstone etc. The general size of the pebbles vary from 2 cm to 6 cm. The pebbles and boulders show very well roundness. Generally, this terrace has patches rich in sand and gravel. The nature of the terraces indicate wide change of different rivers. The present river bed shows large accumulation of boulders forming channel. The oldest terraces indicate higher energy environment and high influx of larger size boulders. It also facilitates the task of delimiting areas with different types of priorities of effort. Thus land is the stage where its varying areas are depicted and the application of such geomorphological tools in different fields will yield substantial useful results.

Geomorphological Processes occuring in the area

Most of the mentioned landform features such as the undulating plateau with denudational hills mesas and Karst cave deposits, high hills with scarps conspicuous Cuestas and depositional features. Recent terraces of the study area probably affected by recent upliftment in the area and came under the sway of the summer monsoons, recording the high precipitation (above 11,000 mm average annually) and have subsequently evolved by sub-aerial denudation. The prevailing tropical humid climate with heaviest monsoon rainfall, cool moist summers and winter frosts has strongly influenced the operation of geomorphological processes both directly and indirectly.

From very past primitive activities such as shifting cultivation locally called as 'Jhum' involved clearance of forests. burning the slash and cropping for a year or two before the land is abandoned for natural regeneration of plant cover and nutrient recovery before the cropping operation is repeated on the same site.

The most important role of geomorphology is the present land classification is that it offers a methodical system of land differentiation and mapping. By using geomorphological criteria, land can be classified and mapped so that an assessment of environmental variation can be made in a rapid and efficient manner.

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SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The State of Meghalaya is comprised of the Garo, Khasi and Jaintia Hills District representing the north-eastern extension of the Indian peninsular shield. The Cherrapunji plateau is a dissected terrain along the southern part of the Shillong plateau. The plateau like character of the terrain is well developed within Cherrapunji town and to its north with an elevation between 1200 m to 1530 m. Whereas the gorges on the east and west sides go down about 450 m.

The variety of sediments from Archaean to the Tertiary periods forming the region is discernible from the producing surfaces. The formation of Cherrapunji plateau is linked with the structural evolution of the Shillong plateau.

The diverse geology and geomorphic characteristics that is the occurrence of the extensive undulating Shillong Plateau with high hills to the east moderately high gently dipping table land in the central part and the lowlying dissected terrain in the west present a complex variety of landforms.

The Pre-cambrian Shillong group along with the hard quartzite and conglomerate occupying the eastern portion of the study area.

The Cretaceous Tertiary sediments or sedimentary rocks such as sandstone and limestone are lying in the western part of the study area.

The recent deposits or the newer alluvium is occupying in the southern foot hills of the region. The rocks of the Shillong series are the oldest formations exposed in the Umstew gorge. The rocks are mainly composed of metamorphosed sediments and include quartzite frequently micaceous and auto clastic conglomerates.

The geological chronology seems to have similar sequence as that of the Chotnagpur plateau and the Rajmahal Highlands.

The different geomorphological features in any area have relief manifestation on different scales. The relief is based on differences. The important relief analysis includes altitudinal zones, absolute relief and relative relief.

The altitudinal distribution reveals erosion surfaces occurring at different levels. Generally, the maximum concentration of altitudinal zone lies towards south-eastern part in Wah Tymshun catchment area and its tributaries.

The maximum elevation 1740 m of absolute relief lies in the north-western part of the area. The lowest elevation of 600 m occurs in northern part. In general the absolute relief rises towards north. By and large the terrain above 400 m elevation is underlain by Shillong group of rocks.

The north-eastern corner by and large shows higher relative relief. The lowest elevation of 100 m is confined in the central west corner. The relative relief gives more regional character of the physical landscape.

Slopes are the basic features of landscape. The slope profile is not constant. It is subjected to alternation by weathering erosion and mass movement. Slope analysis revealed nine categories of slope (below 5°, 5°-10°, 10°-15°, 15°-20°, 20°-25°, 25°-30°, 30°-35°, 35°-40°, and above 40°) are grouped as per Young's classification. The (5°-10°) category is confined in the western part of the study area. The steep slope category (30°-35°) and (35°-40°) is confined in the northeast and southeast part. Rest of the categories are distributed throughout the area. No vegetation cover is found on steep slopes. The weathering rocks are slipping and rolling along the slopes.

The entire study area experiences heavy seasonal rain and moderate temperature during monsoon and summer months. The region becomes very mcuh prone to the weathering processes. Assisted by heavy rainfall and moderate temperature it forms an important medium to dissolve the pre-Cambrian tertiary group of rocks, minerals and hold them in solution during the process of weathering and transportation over the area under study. The physical and chemical weathering act together at the same time only the intensity of manifestation is different. It depends upon climate, relief, the composition of the underlying rocks and other factors.

The drainage characteristics and fluvial processes are very important to understand the evolution of landscape in the area. The drainage pattern of the study area reveals four types, i.e., Trellis, Parallel, Dendritic and Radial pattern and caste light on the rock type, geological structure, stage in drainage evolutions.

The drainage character and fluvial processes are very important to understand the evolution of landscape, in the area. It is revealed from the table that the northern half of the area has relatively lower drainage frequency and drainage density in comparison to the southern half. Some underground channels are clearly seen.

In the study area well developed caves and developing caves of limestone are found. The Lakadong limestone, Sylhet limestone, Prang limestone and Therria limestone are found there. The lower part of the limestone-bed contains good quality of limestone which is suitable for cement manufacturing. Limestone cave, Karst topography, Caverns are the common features in this region.

On the basis of landform evaluation they have been divided into two geomorphic domains.

1) The Plateau or table lands.
2) Hills.

Each domain is characterized by distinct landforms.

In the plateau domain the important landforms identified are gently sloping plateau, plateau relicts, cuesta. The hill domain depicts moderately sloping hills, steeply sloping hills and scarps.

Recent terraces are confined by and large along the southern part of the study area and along the valley of Wah Tymshun river.

Conclusion

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

1. In the study area the formation of Cherrapunji plateau is linked with the structural evolution of the Shillong plateau. The eastern part is composed of pre-cambrian rocks and the cretaceous-tertiary sediments in the western part. Geological information indicate the pre-cambrian rocks are highly dissected and slopy but the sedimentary rocks have less undulation and thin layer of soil.

2. The relief is based on the differences in elevation. The relief (absolute as well as relative) rises from south to north. The lowest relative relief less than 100 m is confined in the central west corner. The relative relief gives more regional character of the physical landscape.

3. Slopes are the basic features of landscape. The slope profile is not constant. Nine slope categories varying between below 5° to above 40° have been identified in the area. A general pattern of slope rise with rise in absolute relief is observed. But elevation above 1700 m does not have steep slopes.

4. Weathering is the disintegration and decomposition of rocks and minerals at the earth surface, as a result of physical and chemical action. The climate of the area has formed deep chemical weathering and undifferentiated soil profile. Lithology, structure and climate plays a very significant role in shaping the landscape.

5. The drainage characteristics and fluvial processes have played an important role in the evolution of landscape in the area. Drainage density is relatively low in old rocks instead of young rocks. Present study indicates the younger rocks (between 1200 m - 1600 m) has low drainage density.

6. The limestone formation of the study area shows a complete dissolution of rocks in water. It is observed that the cave deposits are mainly due to chemical processes. There are some unique development of stalactites and stalagmites as noticed inside the cave. The lower part of

the limestone beds contains good quality of limestone which is suitable for manufacturing of cement. Small rounded limestone hills of the Eocene period are found scattered in the region. Limestone cave, Karst topography and caverns are the common features in this region.

7. The area has been distinct geomorphic domains (plateau or table land and hill domains), each having its characteristic landforms.

8. Underground channels have developing along weak planes in the limestone rocks. The Karst topography of Mawsmai cave indicates this cave is not yet in the mature stage of development.

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PLATES

Fig. (P.3)

A view of Wah Tymshun Valley in rainy season

Fig. (P.4)

Potato cultivation towards northern part

Fig. (P.5)

River development on horizontal beds

Fig. (P.6)

A view of steep scarp and valley of Wah Tymshun

Fig. (P.7)

Limestone quarry near Mawmluh Cement Factory

Fig. (P.8)

Limestone quarry near Mawmluh Cement Factory

Fig. (P.9)

Waste material damaging vegetation along slope

Fig. (P.10)

Protected forest near Mawsmai Cave

Fig. (P.11)

Mawsmai waterfall

Fig. (P.12)

Outlet of underground channel near Mawsmai Cave

Fig. (P.13)

Cement Factory at Mawmluh

Fig. (P.14)

A passage of underground channel