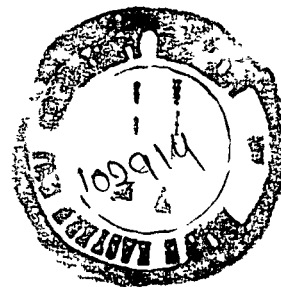


**A STUDY OF ALLUVIAL FANS  
IN  
NORTH BÉNGAL**

**SOMA BHATTACHARYA**

**DISSERTATION SUBMITTED IN PARTIAL FULFILMENT  
OF THE REQUIREMENTS FOR THE DEGREE OF  
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**DEPARTMENT OF GEOGRAPHY  
SCHOOL OF ENVIRONMENTAL SCIENCES  
NORTH EASTERN HILL UNIVERSITY  
SHILLONG, MEGHALAYA  
DECEMBER, 1992**

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PHONE :  
GRAMS : NEHU

# North-Eastern Hill University

Mayurbhanj Complex, Nongthymmai, Shillong-793014

Department of .....  
Geography.

Prof. R.K.Rai,  
Head.

This is to certify that Smti Soma Bhattacharya has carried research work for her dissertation entitled "A STUDY OF ALLUVIAL FANS IN NORTH BENGAL" under my guidance. She fulfilled all the requirements laid down in the Regulation of M.Phil. Programme. The dissertation is the result of her own investigation and neither the dissertation as whole nor any part of it was submitted to any other University/Educational Institute for any research degree or diploma.

Shillong,

The 14 December, 1992.

*R.K.Rai*

( R. K. Rai )  
Supervisor

*Forwarded*  
*R.K. Rai*  
*14 Dec -92*  
Department of Geography  
North Eastern Hill University  
Shillong

## A C K N O W L E D G E M E N T

"Thou that hast given so much to me, give one thing more ← a grateful heart."

George Herbert

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## C O N T E N T S

CHAPTER-I	:	INTRODUCTION	1
		A. General Discussion on Alluvial Fans	
		B. Survey of Literature.	
		C. Objective and research question.	
		D. Study area.	
		E. Methodology.	
		F. Scheme of Study.	
CHAPTER-II	:	CONTROLS OF FAN DEVELOPMENT.	17
		A. Geological and tectonic Characteristics of the area.	
		B. Local Relief.	
		C. Hydrology.	
		D. Climate.	
CHAPTER-III	:	EVOLUTION OF ALLUVIAL FAN AND IT'S CHARACTERISTICS.	39
		A. Evolution.	
		B. Morphology of alluvial fans.	
		C. Drainage pattern and density.	
		D. Fan materials.	
		E. Modes of deposition.	
		F. Stratigraphy of deposits.	
		G. Fan segments.	

CHAPTER-IV	:	PEDOGENESIS AND LANDUSE.	74
		A. Pedogenesis.	
		B. Landuse.	
CHAPTER-V	:	CONCLUSION.	87

## LIST OF FIGURES

- Figure NO. 1. : Development of Alluvial Fans and Shifts in the Location of Erosion and Deposition (After Denny 1967). **2.**
2. : Location of the Study Area. **8 .**
3. : A Rough Sketch of the Study area **16.**
4. : Two Phases in the Development of Alluvial Fans Under the influence of Tectonic Uplift and climate. **18 .**
5. : Geo-Section over Indoganggetic Trough (After Wadia). **20 .**
6. : Geological Map of Darjeeling Himalayas (After Pawde and Saha). **22 .**
7. : Topographical Map of the Study Area (part of Map No 78 B/1 & 78 B/5). **27.**
8. : Climograph. **35.**
9. : Geomorphological Map of Alluvial Fans between Balason River and Sukhia Khola. **40.**

- No. 10. : Longitudinal Profiles along the various fan Segments showing Land-Use. **43** .
11. : Transverse Profiles Showing Drainage and Land-use. **45** .
12. : Relative Relief Map of the Study Area. **47** .
13. : Map Showing Dissection Index of the Alluvial Fan Area. **49** .
14. : Slope Analysis of Alluvial Fans. **51** .
15. : Longitudinal Profiles Along Rivers of the Study Area. **55** .
16. : Map Showing Drainage Density of the Study area. **56** .
17. : Land Use on the Alluvial Fans. **78** .
18. : Cross - profiles Showing Stratigraphy and Land-Use. **80** .

## LIST OF PLATES

- Plate: No. 1. : Overgrazing, step cultivation, deforestation and associated land slides. **29.**
2. : Low discharge of river during winter months through deeply incised valley. **31.**
3. : Incised course of the Lapche Jhora with Terracing. **42.**
4. : Braided course of river characterised by huge sediments. **53.**
5. : Poorly - sorted and immature sediments with subangular and subrounded materials of all sizes. **58.**
6. : Huge boulders carried by flash floods almost choked the river course. **60.**
7. : Huge boulders supplied by landslides and carried further by flash floods. **61.**
8. : Weathered, oxidised, and broken materials. **63.**
9. : Micro slumping on the bank of the incised river. **64.**
10. : Tea Garden in the middle fan. **81.**

Plate No. 11. : Intensive cultivation by terracing on the upper fan surface. 83.

12. : Recent occupation by the Military disturbing the forest cover. 85.

### LIST OF TABLES

Table No .	1.	Geographical succession of the study area.	23.
	2.	Maximum and minimum discharge of rivers.	33.
	3.	Average monthly rainfall at three stations over the study area.	37.
	4a.b.	Characteristics of alluvial fan segments.	72,73.
	5.	Soil characteristics of alluvial fans.	76.

## CHAPTER - I

### INTRODUCTION

#### A. GENERAL DISCUSSION ON ALLUVIAL FANS

Alluvial fans are localised and relatively small scale accumulations of sediment, deposited in the form of a cone that radiates downslope from the point where trunk streams emerge from upland drainage basins into some sort of lowland basins. An alluvial fan may consist of debris-flow deposits, water-laid sediments or both. The highest point on the fan, where the stream leaves the confines of the mountains, is the fan apex. The over all radial profile of an ideal alluvial fan surface (longitudinal profile) is concave, while the cross-fan profile (parallel to the mountain front) is convex. In plan view the deposits is typically fan shaped with contours that are convex outward from the mountain front (Bull, 1977).<sup>1</sup> Some authors have used the term 'alluvial cone' to describe small fans steeper than 20 degrees that are formed by both fluvial deposition and mass wasting, while others have used it as a synonym for an 'alluvial fan'.

Alluvial fans may form along linear mountain fronts, along the sides of major valleys or at the margins of glacier ice. In a geological context the most important environment of fan deposition is fault bounded sedimentary basins where periodic fault movement enables subsidence and hence preservation of the fan sediments to occur. In climatological context they may occur in a variety of climates, including arid, humid glacial, humid tropical and humid temperate with a great variation in their physical characteristics. (Craig Kochel, 1990).<sup>2</sup> Undoubtedly alluvial fans are common in arid and semiarid regions with tectonically active mountains where there is an abundant supply of sediments, but their occurrence is by no means limited

# DIAGRAM SHOWING DEVELOPMENT OF ALLUVIAL FANS AND SHIFTS IN THE LOCATION OF EROSION AND DEPOSITION (AFTER DENNY 1967)

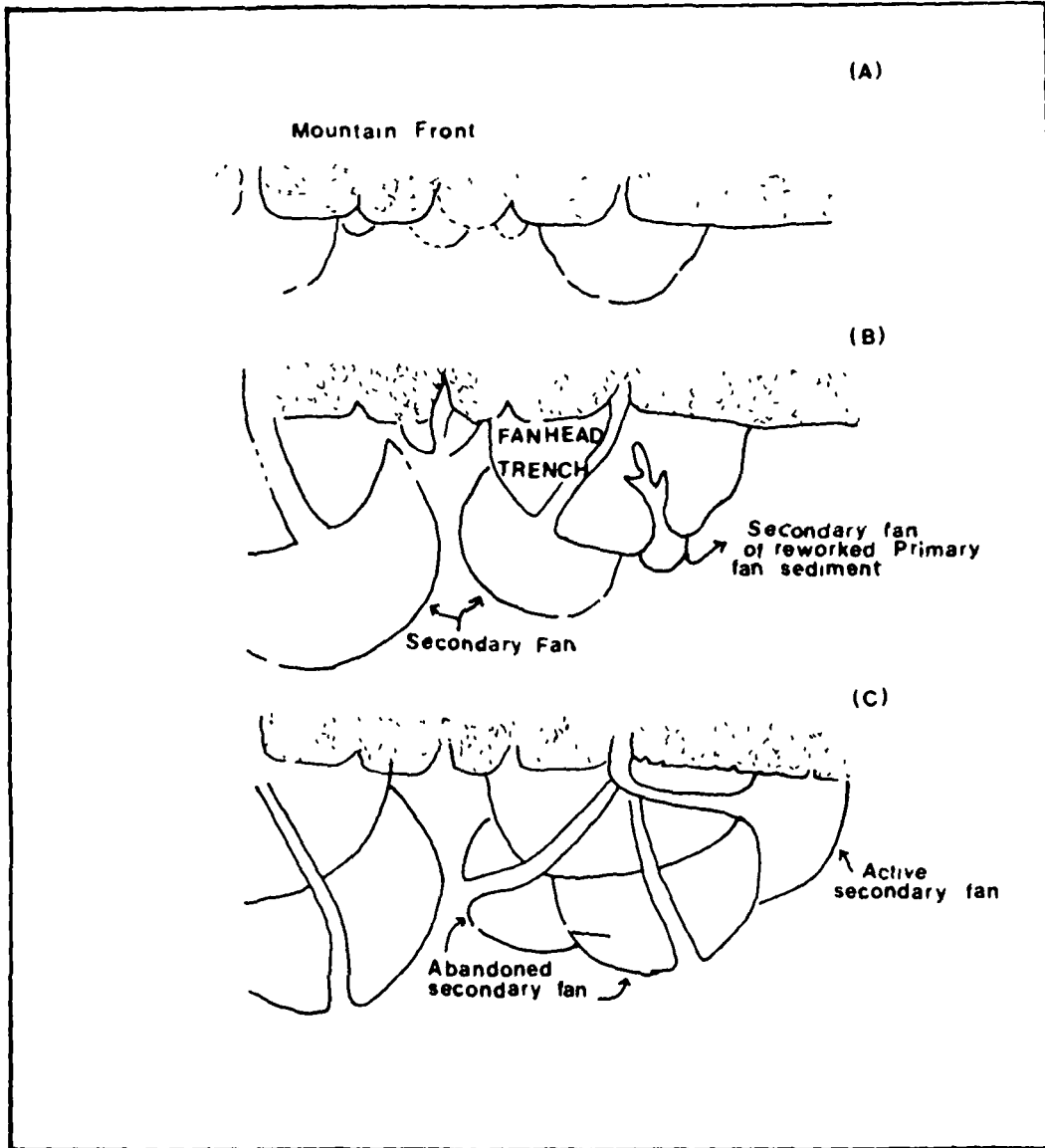


FIGURE NO. 1.

to such environments. Accordingly alluvial fans may be classified into (a) Dry fans, those found in semiarid climates where flow over the fan surface may be regarded as ephemeral and where transport by debris flow is important and (b) Wet fans, those subject to perennial flow and where stream flow is the most important mechanism of transport and deposition. Fans often have stream channels that are incised into the fan surface. The particular case known as 'fan head trenching' generally is deepest at the fan apex and progressively decreases down fan until the stream channel and the fan surface intersect. Trenching at fan head indicated progressive sedimentation down fan as the locus of deposition shifts. (Figure No. 1)

The two primary hypothesis proposed to explain fan development were the evolutionary hypothesis (based on the Davison concept of landscape evolution) and the equilibrium hypothesis (based on equilibrium concepts and a quantitative approach to the investigation of surface morphology and process). Climatic and Tectonic effects are considered as factors influencing fan development in an equilibrium hypothesis. According to researchers who based on evolutionary hypothesis, fans indicate conditions of youth in the geographic cycle and are therefore only temporary features. Fan head trenching according to them indicate maturity and eventual destruction of the fan (Eckis, 1928).<sup>3</sup> According to researchers following equilibrium hypothesis that a state of dynamic equilibrium exists between alluvial fan and their source area (Hack, 1960)<sup>4</sup> and the rate of deposition on the fan was considered equal to the rate of erosion from fan to flood plain. Undoubtedly the evolutionary hypothesis received much less attention than the equilibrium concept. But some researchers are in opinion to integrate useful aspects of the Davison and equilibrium approaches in

explaining alluvial fan problem (Schumm, 1977).<sup>5</sup>

B. SURVEY OF LITERATURE :

Alluvial fan, as a geomorphic feature, however didn't received much attention from geologists or geomorphologists. In 1873 Drew first coined the term 'alluvial fan' in reference to features in the upper Indus basin, appears to have been the first to discuss fans (Lecce, 1990).<sup>6</sup>

The alluvial fan problem was first addressed by the consideration of Davisian evolutionary stages by Eckis (1928). Blackwelder recognised the importance of debris flow in fan construction (Blackwelder, 1928).<sup>7</sup> Blissenbach studied on fan sedimentology and morphology and tried to correlate the rates of change of particle size and surface slope (Blissenbach, 1954).<sup>8</sup> Bull (1964B); Melton (1965); Hooke (1968a); Denny (1967); Beaumont (1972) tried to determine the process involved in fan development from various angles and applied allometric models to support their claim. Their view regarding the process involved in fan development varied widely (Lecce, 1990). Beaty rejected Eckis idea that fans are active features and indicate Davisian stage of youth (Beaty, 1970-1971).<sup>9</sup> He expressed his view that there are physiographically mature fans reaching a steady state of growth or equilibrium condition. Denny contended that state of dynamic equilibrium exists between alluvial fans and their source areas. The rate of erosion on the fan was considered equal to the rate of deposition from fan to flood plain (Denny, 1965<sup>10A</sup>, 1967<sup>10B</sup>). Schumm and Lichty showed that a system in steady state equilibrium (during a graded time span) does not necessarily preclude evolutionary change (over a cyclic time span) (Schumm and Lichty, 1965)<sup>11</sup>.

Lustig explained the influence of climate on fan development. According to him during wet periods aggradation takes place within the drainage basin and below the mountain front. During dry conditions trenching occurs particularly in the upper portion of the fan as debris flow become the dominant erosional agent (Lustig, 1965)<sup>12</sup>. Bull tried to show that the rate of tectonic uplift in mountain areas relative to the rate of stream channel down cutting largely determine the locus of deposition and the thickness of the alluvial fan deposit (Bull, 1964B).<sup>13</sup> Harvey (1984 b), Blair (1987) etc. tried to indicate different depositional process active in fan development through the analysis of vertical stratification sequence and character of sediments (Lecce, 1990). Edward Derbyshire and Lewis A Owen in their paper have shown how quaternary glaciation and tectonic uplift have helped the development of alluvial fans in the Karakoram Mountains (Edward Derbyshire and Lewis A Owen, 1990)<sup>14</sup>. Yugo Ono in his paper Alluvial Fans in Japan and South Korea has divided alluvial fans into two distinct group-the dissected alluvial fans constructed mainly during the last glaciation and the contemporary fans developed by the rivers with steep gradient and high sediment load under the influence of present climate. He dealt in detail fan forming process, morphology and sedimentology (Ono, Y. 1990)<sup>15</sup> R Craig Kochel (1990) studied the development, character and morphology of the humid fans of the Appalachian Mountain dividing them into two distinct group-Debris flow dominated fan and fluviially dominated fans. A.M. Harvey has studied the influence of climatological changes and tectonic factors on the development of Quaternary alluvial fans in Southeast Spain. (Harvey, 1990)<sup>16</sup>

Although alluvial fans occur widely in India they have received

very little attention and those occurring either within or at the foot of the Himalayas have been almost completely ignored. Only recently there is a growing awareness among geomorphologists. Though different writings on Himalayan geology and geomorphology have mentioned the presence of alluvial fans there are no detail research work on alluvial fans only except few. R. V. Joshi studied the development of fluvioglacial fans and cones in the sub Himalayan region during Quaternary period (Joshi, 1977)<sup>17</sup>. Prof. A. B. Mukherjee in his paper 'The Chandigarh Dun Alluvial Fans - An Analysis of process form relationship' dealt in detail how tectonic and climatic changes during Quaternary have influenced the development, morphology and sedimentology of the fans in the Chandigarh Dun area (Mukherjee' 1988)<sup>18</sup>. Lakhsha Hira Dutta in his paper attempts a morphological and locational analysis of alluvial fans in the Brahmaputra Valley in Assam (Dutta, 1984)<sup>19</sup>. Probably this is the first paper dealing with alluvial fan development and morphology in tropical rainy climate, with steep slope, high gradient and heavy load of sediment. K. Gohain and B. Prakash studied the development, morphology, topographical analysis of Kosi Megafan in Northern Bihar (Gohain and Prakash, 1990)<sup>20</sup>. He divided the area into two district part old alluvial plain and young alluvial plain. S. R. Basu and S. Sarkar (1990) have noted how local relief, climate, lithology, hydrology have controlled the development of alluvial fans since their formation out of the periglacial debris and solifluction materials during the Pliocene Epoch in the foot hills of Darjeeling Himalayas (Basu and Sarkar, 1990)<sup>20</sup>. These few papers only have tried to analyse the characteristics and development of alluvial fans in respective regions of India, leaving a vast region behind their field of research.

C. OBJECTIVE AND RESERCH QUESTION

The Indo-Gangetic foredeep, in front of the high Himalayas, converted into flat plains by the simple process of alluviation keeping pace with subsidence provided ideal condition for the formation of alluvial fans. All most all the rivers debouching from the High Himalayas on to the wide open Indo-Gangetic plain developed a number of alluvial fans. In areas these alluvial fans coalesce to form a piedmont zone. Thus alluvial fans undoubtedly presents themselves as an interesting research topic being a transitional landscape in between the high Himalayas and wide open alluvial plains. The literatures on alluvial fans both in India and abroad are mainly on the alluvial fans of arid or semiarid region and the researchers inted to show that most of these fans are relict geomorphic feature being formed in geologic past, particularly during Plietocene Ice Age. The basic question of this study is 'whether the fans of Humid Eastern Himalayas are also relict? If not, why ? Therefore the main objective of the study is to analyse systematically the development and evolution of alluvial fans with their morphological, and podological characterestics and thus to search out the answer of the basic question. The cultural characterestics and land-use pattern have also taken into account so as to depict the sequenential changes, if any, in case of the further remodelling of the fans, in constant interaction with the growing population and their settlements.

D. STUDY AREA

With the basic research question in mind the researcher have selected an area located at the foot of the Darjeeling Himalayas, in the state

## LOCATION OF THE STUDY AREA

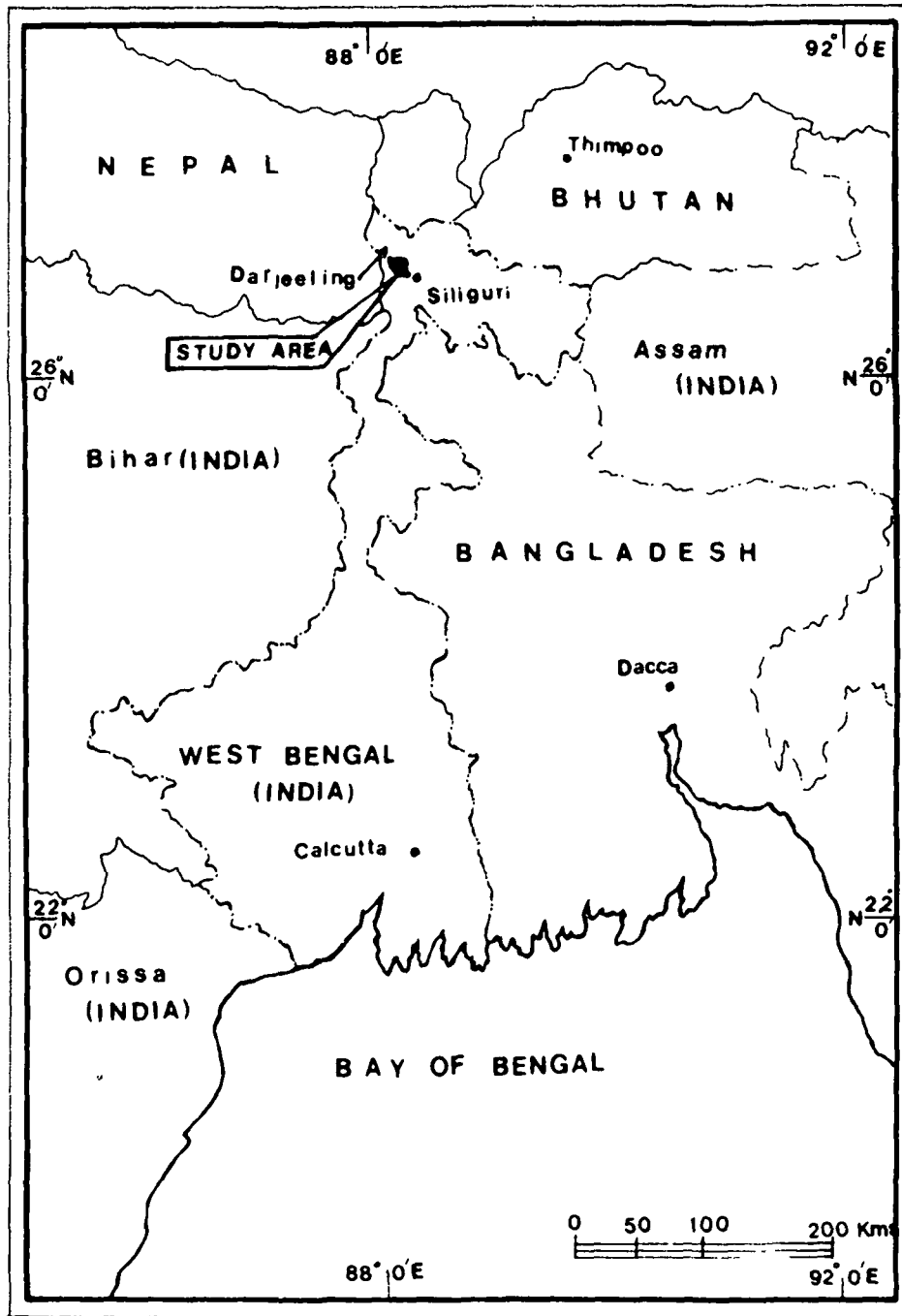


FIGURE NO. 2.

of West Bengal, India (Figure No. 2). Relief, climate and tectonic characteristics of the area are most suitable for fan development and all the rivers have developed alluvial fans at the point where they emerge from the upland drainage basin to the alluvial plains of Bengal. These fans coalesce to form a piedmont zone. The fan between the rivers Balason and Rohini, bounded by latitudes  $26^{\circ} 45' N$  to  $26^{\circ} 51' N$  longitudes  $88^{\circ} 14' E$  and  $88^{\circ} 21' E$  selected for detailed study (Topographical Map No. 78 B/5 and 78 B/1). The area is on the Right bank of Tista, the main river of this region. The important streams of the area are the Balason, the Rakti and the Rohini. The Rakti and the Rohini are tributaries to the Balason which ultimately joins Mahananda. Both Rakti and Rohini have smaller tributaries locally known as Jhora or khola. The important among them are the Rangsung Khola tributary to Rakti and the Sukhia khola tributary to Rohini. All these rivers at the point of debouchure from the high Himalayas have deposited huge unassorted sediments which form the subject matter of this study. The total area of study is about  $42^2$  kilometer.

#### E. METHODOLOGY

To fulfill the objective and solve the basic problem of the study the researcher has followed a definite methodology. As a whole the methodology has been divided into three distinct parts

though they are inter-related and interdependent :-

- a) pre-field method
- b) field method
- c) post field method

a) Pre-field Method - This include mainly the library works regarding information of geology, physiography, climate, soil and hydrology of the study area and study of other relevent literature presented by previous workers in the respective field. Datas and informations have been collected from various Government Publications, memoris and records mainly of G.S.I., National Atlas and Thematic Mapping organisation etc. The informations and datas collected from these sources have been used as the basic raw materials for the proposed dissertation. Toposheets helped in identification of the locataions of alluvial fans. After having the pliminary informations with the help of toposheets of the study area and previous literatures the next step was to visit the field to collect data and evidences.

b) Field Method - In the geomorphological survey and research work much stress is given on the evidences and informations obtained during field work. Survey with the help of dumpy level was done to determine the slope of the alluvial fans from base to edge. Field observations of column of alluvial fans is a much important thing.

Identification of numbers of layers, thickness of each layer, dip of bedding planes (if any), sedimentological details of each layer, gradation, lamination of cross bedding (if any) was observed and studied in detail. Moreover, the dip of the older rockbed of which the fan rests and its relation with the fan deposit was also determined during field study. Schematic diagrams and rough sketches were drawn, and photos were taken to illustrate the evidences. Stress was given on hydrological characteristics i.e., volume and velocity of rivers, the nature of flow within the river bed etc.

c) Post field method - The post field method concentrated mainly on the assimilation and interpretation of the different evidences which have been collected in the course of prefield and field studies. With the help of morphometric analysis (Average slope, Relative Relief, Drainage Density etc.) and different profiles (Longitudinal and transverse) the geomorphological characteristics of the area was studied.

#### F. SCHEME OF STUDY

The researcher has planned to complete the study in the following manner. The entire dissertation paper will contain five chapters including the introductory chapter. The first or introductory chapter comprises of six subtopics all together. They are the general discussion on alluvial fans, survey of literature, objective and research question, location of the study area, methodology followed and the scheme of study respectively.

The second chapter gives an idea regarding the fan forming or controlling factors. This chapter includes four subtopics - wide geological and tectonic characteristics of the area, local relief, climate, and hydrological characteristic. All these four has been taken as major factors influencing fan formation of the area and have been dealt in detail.

The third chapter deals with the evolution of alluvial fans and its' characteristics. This chapter includes the following sub topics - evolution, morphology and drainage pattern of the alluvial fans, fan materials, modes of deposition of fan materials, stratigraphy of deposits and fan segments. Morphology and drainage pattern of the fans have been studied with the help of different morphometric maps and profiles.

The fourth chapter explains the pedogenesis and landuse over the fan area as the fans being a transitional zone between the hills and plains gives a completely different pedogenesis and landuse pattern.

The fifth or last chapter contains the concluding remarks. It is actually a summing up of all findings and an attempt to answer the research question.

REFERENCES :

1. Bull, W.B. 1977. The alluvial fan environment. Progress in Physical Geography, 1, 222-270.
2. Kochel, R.C. 1990. Humid fans of the Appalachian Mountains. 109 pp. Alluvial Fans, A Field Approach, Edited by A.H. Rachocki and M. Church, John wiley and sons.
3. Eckis, R. 1928. Alluvial fans in the Cucamonga District, Southern California, Journal of geology, 36, 111-141.
4. Hack, J.T. 1960. Interpretation of erosional topography in humid temperate regions. American Journal of science, 258-A, 80-97.
5. Schumm, S.A. 1977. The Fluvial System. Jhon wiley and sons, New york, 338pp.
6. Lecce, S.A., 1990. The alluvial fan problem, 5pp. Alluvial Fans: : A Field Approach, Edited by A. H. Rachocki and M. Church, Jhon Wiley and Sons.
7. Blackwelder, E. 1928. Mudflows as a geologic agent in semiarid mountains. Geological Survey of America Bulletin, 39. 465-484.
8. Blissenbach, E. 1954. Geology of Alluvial fans in semiarid regions, Geological Society of America Bulletin. 65, 175-190.

9. Beaty, C.B. 1970- 71. Age and estimated rate of accumulation of an alluvial fan, White Mountains. California, U.S.A. American Journal of Science, 268. 50-70.
- 10.a. Denny, C.S. 1965. Alluvial fans in the Death Valley region, California and Nevada. U.S. Geological Survey Professional Paper, 466. 1-62.
- 10.b. Denny, C.S. 1967. Fans and Pediments. American Journal of Science, 265,81-105.
11. Schumm, S.A. and Lichty, R.W. 1965. Time, space and causality in geomorphology, American Journal of Science, 263, 110-119.
12. Lustig, L.K. 1965. Clastic sedimentation in deep Springs Valley, California. U.S. Geological Survey Professional Paper, 352-F,131-192.
13. Bull, W.B. 1964B. Geology of segmented alluvial fans in Western Fresno Country, California. U.S. Geological Survey Professional Paper, 352-E,89-129.
14. Derbyshire, E and Owen, L.A. 1990. Quaternary alluvial fans in the Karakoram Mountains. Alluvial Fans: A Field Approach edited by Rachocki, A.H. and Church M. (27-54). Jhon Wiley & Sons.
15. Ono, yugo 1990. Alluvial fans in Japan and South Korea, Alluvial Fans: A Field Approach,., edited by Rachocki, A.H. and Church, M. 91-108. Jhon Wiley & Sons.



16. Harvey A.M. 1990. Factors influencing alluvial fan development in South East Spain, Alluvial Fan : A Field Approach. edited by Rachocki, A.H. Church, M 247-270, John Wiley & Sons.
- ✓ 17. Joshi, R.V. 1977. Development of fluvio-glacial fans and cones in the Sub Himalayan Region during Quaternary Period and their archaeological significance, Studia Geologica Polonica 52, 195-205.
- ✓ 18. Mukherjee, A.B. 1988. The Chandigarh Dun alluvial fans : An analysis of form process relationship, Geomorphology and Environment, 1988.15-47.
- ✓ 19. Dutta, L.H. 1984. Alluvial fans in the Northern Brahmaputra, Transactions of the Institute of Indian Geographers, Vol.6, No.2, 1-14.
20. Gohain, K. and Prakash, B. 1990. Morphology of the Kosi Megafan, Alluvial Fans : A Field Approach edited by Rachocki, A.H. and Church, M. 151- 178. John Wiley & Sons.
21. Basu, S.R. and Sarkar, S. 1990. Development of alluvial fans in the foothills of the Darjeeling Himalayas and their geomorphological and pedological characteristics, Alluvial Fans : A Field Approach edited by Rachockki, A.H. and Church, M 321-334. John Wiley & Sons.

A ROUGH SKETCH OF THE STUDY AREA

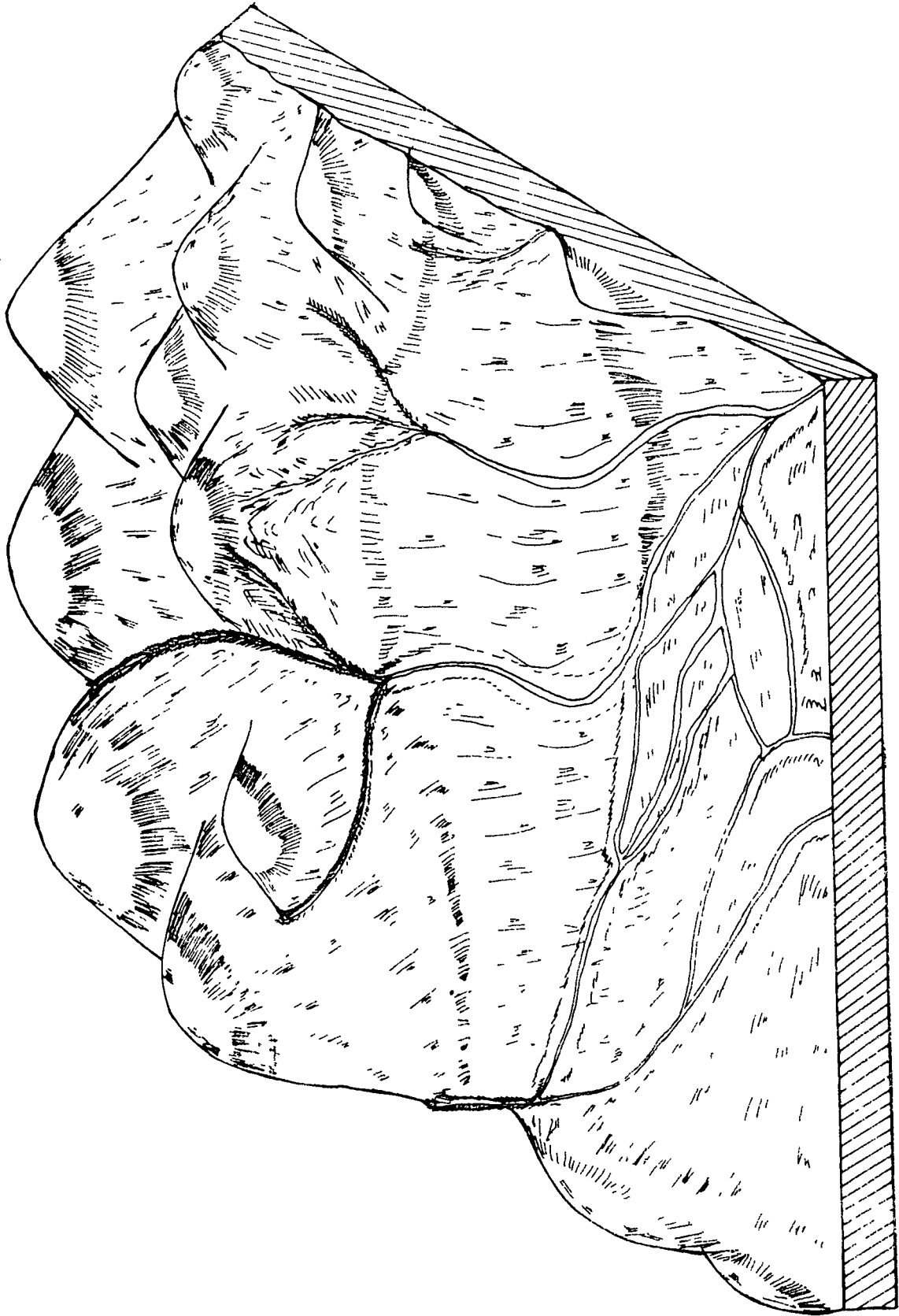


FIGURE NO. 3.

## CHAPTER - II.

### CONTROLS OF FAN DEVELOPMENT.

The development of alluvial fans and their geometry are strongly controlled by several factors. They may be classified as : - (a) Geological and Tectonic characteristics, (b) Local relief, (c) Climate, and (d) Hydrological characteristics of the area. There may be dominance of a single factor but normally all of them is equally responsible for genesis and shaping of the fans, as in the case of present area of study(Diagram No. 3).

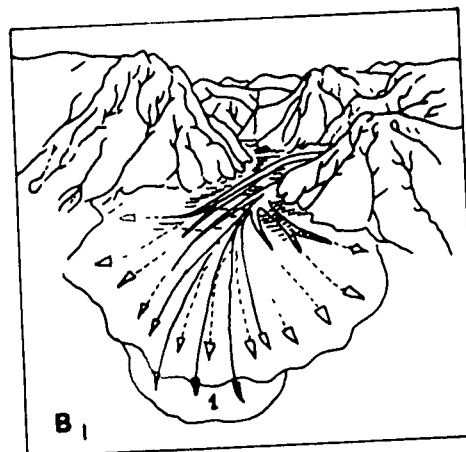
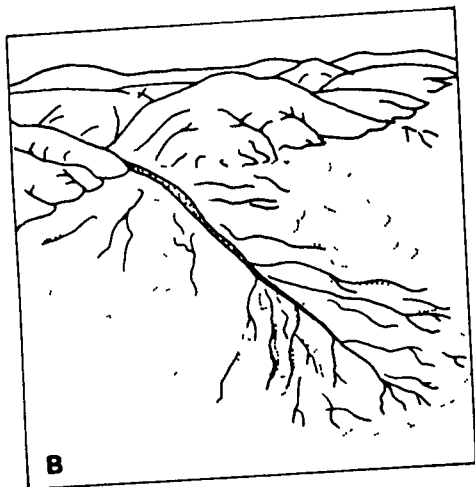
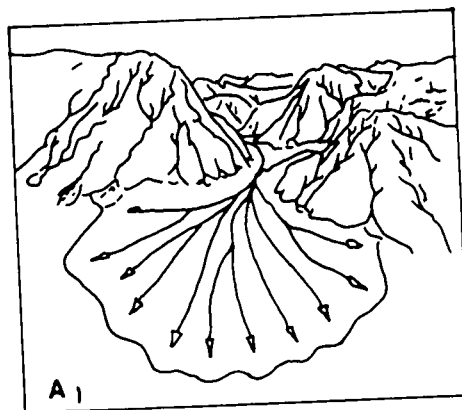
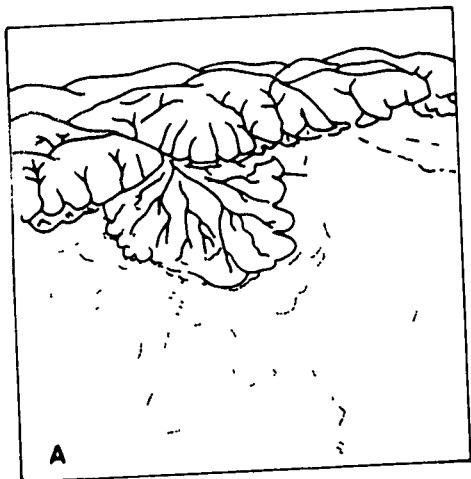
#### A. GEOLOGICAL AND TECTONIC CHARACTERISTICS OF THE AREA

The study of Geological and tectonic characteristics of the area is important for the study of alluvial fans as the tectonic characteristics determine the rate of channel down cutting and supply of fresh debries and lithology of the area determines the character of the debries thus influencing the shape of the fan and its pedogenesis.

The Tectonic influence on the development of alluvial fans is considered in terms of fan entrenchment, fan segmentation and the sedimentology, shape and thickness of both modern and ancient alluvial fan deposits (Lecce, 1990)<sup>1</sup>.

Beaty has stated that although alluvial fans may form in areas where tectonic uplift is not an important factor, they are especially prominent where uplift of mountainous regions provides a

# TWO PHASES IN THE DEVELOPMENT OF ALLUVIAL FANS UNDER THE INFLUENCE OF TECTONIC UPLIFT AND CLIMATE



Two phases in the development of alluvial fans under the influence of tectonic uplift (A) Area of deposition adjacent to the mountain front (B) Area of deposition shifted downfan due to stream channel entrenchment (From Bull 1968)

The formation of alluvial fans under the control of climate in an equilibrium hypothesis (A) Aggradation during more humid or pluvial periods (B) Trenching during a subsequent drier climate period intersection point moves downfan & mudflows & other infrequent density lows transport sediment to the lower reaches of the fan building it outward into the valley (From Lustig 1965)

continual supply of fresh debris from steep drainage basins. The rate of tectonic uplift in mountain areas relative to the rate of stream channel down cutting largely determines the thickness of the alluvial fan deposit, locus of deposition and the degree of entrenchment at the apex (Beatty, 1970)<sup>2</sup>. According to Bull where the rate of channel down cutting at the mountain front exceeds the rate of uplift of the mountain mass; the fan-head becomes entrenched and the locus of deposition moves downslope from the fan apex (Bull, 1977)<sup>3</sup> (Figure No. 4).

All the main rivers of the study area like the Balason, the Rungsung, the Rakti, the Rohini and the Sukhia have formed alluvial fans of great thickness at their debouchers, and all the rivers show deep fan head trenching. The transverse cross sections across the study area indicates clearly that the apex area of the fans have been entrenched deeply and at places it is about 30 metre deep. To explain this great thickness of the fans and deep fan head trenching it is necessary to study the past tectonic history of the area.

The most dominant feature of the geography of India, in the Pleistocene period is the depression in front of the newly raised mountains. The origin of this depression is undoubtedly connected with the origin of the Himalayas. According to the renowned geologist Edward Suess this Indo-Gangetic depression is a foredeep, in front of the high crustal waves of the Himalayas (Wadia, 1976)<sup>4</sup>. The foredeep is of variable depth, converted into flat plains by

# DIAGRAMMATIC SECTION ACROSS THE INDO-GANGETIC SYNCLINORIUM

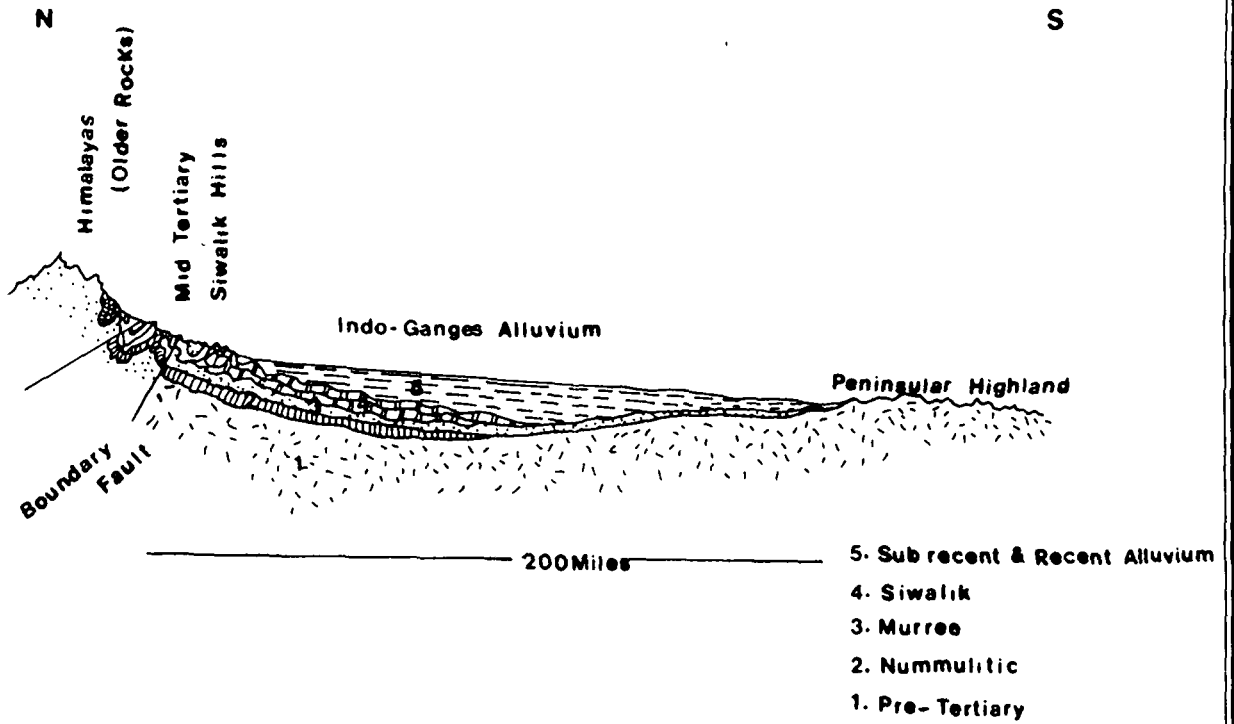
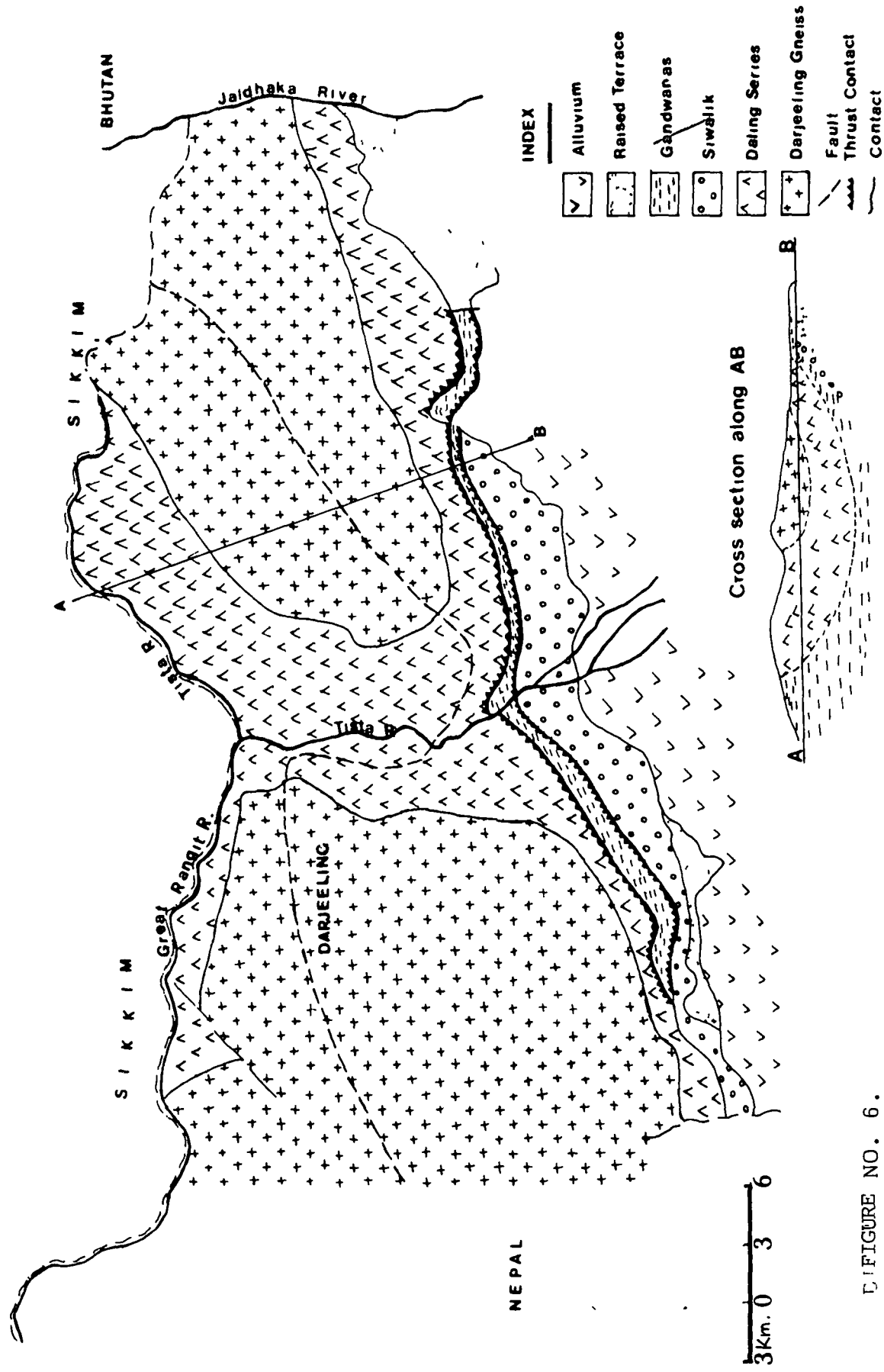


FIGURE NO. 5.

the simple process of alluviation. The northern rim of the IndoGangetic trough is under considerable tectonic strain due to this progressive sedimentation and downwarping. The amount of subsidence is highest along the foot of the mountains (Figure No.5). This Neo-tectonic movements of Post-Pliocene age have important influence in the formation of alluvial fans at the foot of the Darjeeling Himalayas. Isostatic adjustments are still going on in this orogenic belt, therefore the region is geologically unstable. The Himalayas have not attained their maximum elevation but are still rising. The alternations of level have lately taken place, that results in the recent rejuvenation of the river Balason and its tributaries.

Lithology of the surrounding area is a major controlling factor as the fan materials are supplied from the surrounding regions. Proceeding northwards from the southern plains the foot hills show a rather low relief, usually comprises the raised terraces which represent the older flood plain deposits of the Himalayan drainage. Northwards, these are generally followed by the Siwalik, Gondwana and the rocks of the Daling series and Darjeeling Gneiss Group (Figure No, 6.) The following stratigraphic succession is observed in the area —

# GEOLOGICAL MAP OF THE DARJEELING HIMALAYAS



C. FIGURE NO. 6.

Table No. 1

Recent	Alluvium	Younger flood plain deposits of the rivers and nalas comprising sand, gravel, pebble etc. and soil covering the rocks
Pleistocene	Raised Terraces	Sand, clay, gravel, pebble, boulders etc. representing older flood plain deposits.
Pliocene to Lower Pleistocene	Siwalik	Micaceous sandstone with siltstone, clays, lignite lentils, etc.
Thrust		
Permian	Gondwana	Quartzitic sandstone with slaty bands, seams of graphitic coal, lamprophyre sills and minor bands of limestone.
Thrust		
Precambrian	Daling 'Series'	Slate, chlorite-sericite schist
	Darjeeling Gneiss	Golden silvery mica schist, carbonaceous mica schist, garnetiferous mica schist, coarse grained gneiss. (Pawde and Saha 1976) <sup>5</sup> .

Raised Terraces :- These usually from a fringe bordering the hills , on which the apex or upper part of the alluvial fans are

generally situated. These comprise of gravels, pebbles and boulders mixed with ferruginous sand or clay. The formation is somewhat consolidated, stratified and shows evidence of upheaval at places.

Siwalik :- The foothill belt exposes the rocks of the Siwalik system, varying in age from Middle Miocene to Lower Pliocene. These comprise brownish, buff, grey to bluish grey, micaceous sandstones, siltstones and shale with rare lenses of lignite. The sandstones show well developed laminations. The top beds of this formation are usually pebbly and contain rounded to subrounded pebbles of quartz having either a random orientation or aligned parallel to the bedding of the rock. The Siwalik sandstones exhibit well developed current bedding and graded bedding. The composition of the Siwalik deposits shows that they are nothing else than the alluvial detritus derived from the subareal waste of the mountains swept down by the numerous rivers and streams, and deposited at their foot. The plane of contact of Siwaliks with the older formations is a thrust plane of a high angle reversed fault, known as the Main Boundary Fault. The thrust shows moderate to steep dips. often at the contact of the Siwalik with the Gondwana, the rocks are indurated, shattered and silicified and at places due to these effects it is difficult to draw the exact boundary between the Gondwanas and the Siwaliks.

It is interesting to note that according to many geologists the deposition of the Siwaliks along the foot hill of the then

Mountain chain may be of the nature of alluvial fans which is also suggested by the lithological character of the siwaliks and also by present day geomorphic features. The fans coalesce in the later period to form a zone of sedimentation and then affected by tectonic activities. The thrust boundary of the Siwaliks with the older rocks also supports this fact, as subsequent subsidence and faulting at margins of basin of sedimentation is a very common feature.

Gondwanas : - This comprise greyish to brownish, medium grained, felspathic and micaceous sandstones with shales and seams of coal which have undergone some metamorphism of Permian age. Due to this effect of this metamorphism sandstones have become quartzitic, shales have become slaty and the coal has become graphitic. The rocks are intruded by sills of lamprophyre and quartz, which have also undergone deformation. Often minor bands of limestone are noticed within this formation.

The Gondwana is thrust over the Siwalik and this thrust or a high angle reversed fault is known as the Main Boundary Fault. The thrust shows moderate to steep dips. Often at the contact of the siwalik with the Gondwana the rocks are indurated, shattered and silicified and at places due to this the boundary between the Gondwanas and the Siwalik is not easily detectable.

Daling Series and Darjeeling Gneisses : - The Gondwanas are overlain by the rocks of the Daling Series and the Darjeeling Gneiss

Group of Pre-Cambrian age along a thrust. The Dalings comprise mica-schist, greenish fissile slate and phyllite with bands of quartzite. The most impressive geological feature is the progressively increasing metamorphism of the Dalings upwards. As one ascends the hills from the bottom of the Tista river, the clay slates are found to pass, more or less gradually, through mica-schist to gneiss, known as the Darjeeling gneiss. The Darjeeling Gneiss group comprises the golden silvery mica-schists, carbonaceous mica-schist, garnetiferous mica-schist and the coarse-grained gneiss.

The rocks of the Daling Series and the Darjeeling Gneiss group have also been thrust over the Gondwana as the Gondwana is thrust over the Siwaliks. This thrust contact is also moderate to high dips. This is due to this over-thrusting towards the south the Siwaliks and Gondwanas exists only in strips of few kilometres, rocks of Daling series and Darjeeling Gneisses resting almost along the border of the alluvial plains.

B. LOCAL RELIEF :

Relief plays a dominating role in the formation of alluvial fans as dominant break of slope is essential for the formation of fans. According to Prof (Dr.) S.R. Basu, the primary condition for the formation of fans at the base of the mountains is a sudden change of slope where the emerging streams become unconfined and the hydraulic conditions require deposition of sediments being transported (Basu, 1989)<sup>6</sup>.

TOPOGRAPHICAL MAP OF THE STUDY AREA IN  
( PART OF MAP NO 78<sup>B/1</sup> & 78<sup>B/5</sup> )



FIGURE. NO. 7.

There are two distinct physical regions in the area under study- the hills and the plains of terai. The slope is from north-west to south-east. (Figure No. 7).

The hills of the area rise abruptly from the Terai plains, and the elevation increases north-west ward. Change of slope from mountains to foothills is sudden and abrupt, being about  $15^{\circ}$  from the mountains to the foothills. The mean elevation of Terai is 91.44 metre above sea level while some of the hills within the district rise to more than 300 mtrs. Terai lies between the mountains and the plains and is traversed by numerous small hill streams. It is a sort of neutral country being composed neither of the alluvium of the plains nor of the rocks of the mountains, but for the most part of alternating beds of sand, gravel and boulders brought from the mountains. The landscape of the Terai is gently undulating with prominent break in slope at places though the general north-west, south-east slope is maintained everywhere. Actually the fans are located within this Terai region.

The study area is surrounded by the second and third order spurs of the Singalila and Chola ranges, which constitute a gigantic amphitheatre enclosing the whole of Sikkim and Darjeeling, rising at places to more than 2500 mtrs. The northern portions consist of hard gneissic rocks capable of resisting denudation to a considerable extent while the southern portion comprise comparatively soft, thin, slaty and half



PLATE NO. 1.

Overgrazing,

step

cultivation,

deforestation and associated land slides.

schistose rocks, which are less resistant to erosion. Manebhanjan - Sukhiapokhri - Ghoom range extending from latitude  $26^{\circ}57'N$  to  $27^{\circ}00'N$  and longitude  $88^{\circ}00'E$  to  $85^{\circ}20'E$  is the main range here

This surrounding hill section is very much prone to landslips and erosion. Heavy rainfall, decomposition of rocks steep and unprotected hillslopes and high angle inclination of the bedded rocks in the same direction as the hill slopes some of the factors causing fall of boulders, sliding of rockmasses and soil creeps. Particularly the landslips of 1951 and 1968 are worth mentioning (Banerjee, 1980)<sup>7</sup>. These landslides and soilcreeps particularly during heavy rains, help continuous supply of fresh materials necessary for active fan formation. Over grazing, deforestation and step cultivation in the lower-slopes are the other factors contributing heavy erosion and landslips ( 'Plate' No. 1)

C. HYDROLOGY :

The Balson is the main river of the study area. The Rakti and the Rohini Khola are the two important tributaries to the Balason. The Rungsung is a tributary to the Rakti and the Sukhia is a tributary to the Rohini. All the rivers flow in a north-westerly to south-easterly direction ( 'Figure' No. 7).



PLATE NO. 2.

Low discharge of river during winter months

through deeply incised valley.

The Balason rises from Lepchajagat Peak on the Ghum saddle and flows south almost parallel to the  $88^{\circ}15'E$  meridian till it reaches the plains at an altitude of 300 meter and then turns south-east where it's valley is larger than that of Mahanadi. Here in the plains the rivers due to decrease in velocity meanders through a wide basin through distributaries, and build innumerable sand bank and chars through which the distributaries flow in a braided channel. Just below the mountains the river flows through a deep incised valley (about 30 mtr.). At the sides of the valley very good exposures of stratified sands and gravels are found. The river has innumerable tributaries. Among them the Rakti and the Rohini are the two important left bank tributaries. The Rungsungh Khola is tributary to the Rakti Khola and the Sukhia Khola is tributary to the Rohini Khola. All of them have scooped out deep gorges though they have very small catchment areas in the hills. The Rakti, in particular cuts a cliff ranging from 20 to 30 mtrs. composed of stratified sand and waterworn gravel (Plate No. 2)

All of these streams have deposited huge amount of debris at the point where they come down from the hilly region to the plain. The main cause for the deposition of a large amount of debris in the alluvial fan region is the decrease in the velocity of flow of the stream as a result of fall in gradient. Carrying capacity of stream is directly dependent upon the velocity (Sixth power law), and as a result fall in velocity initiates immediate deposition of load and the subsequent spreading of the stream water from the apex

of the fans. On the fan surface the trunk stream feeds distributory channels and water discharge diminishes along its course. Moreover, as the fans consists of relatively permeable sediments additional discharge is lost because of downward percolation of stream water. These discharge losses in downfan direction promote an increased sediment concentration within the water sediment mixture during flow of any type. This leads to sediment deposition on fan surfaces.

The discharge of streams on the alluvial fans depends upon the amount of rain on the fan surface and adjoining hills. Maximum discharge is found during the rainy season and minimum discharge found in winter (Plate No. 2) and the difference between maximum and minimum discharge is very high indicating strong seasonal distribution of rainfall. The following table shows the maximum and minimum discharge of rivers in three respective places : - Table No. 2.

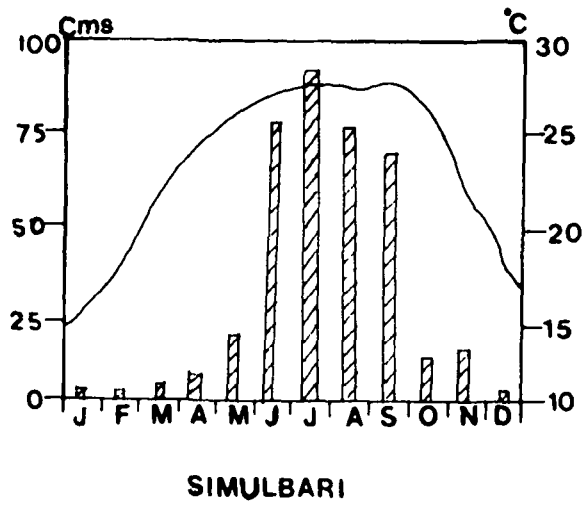
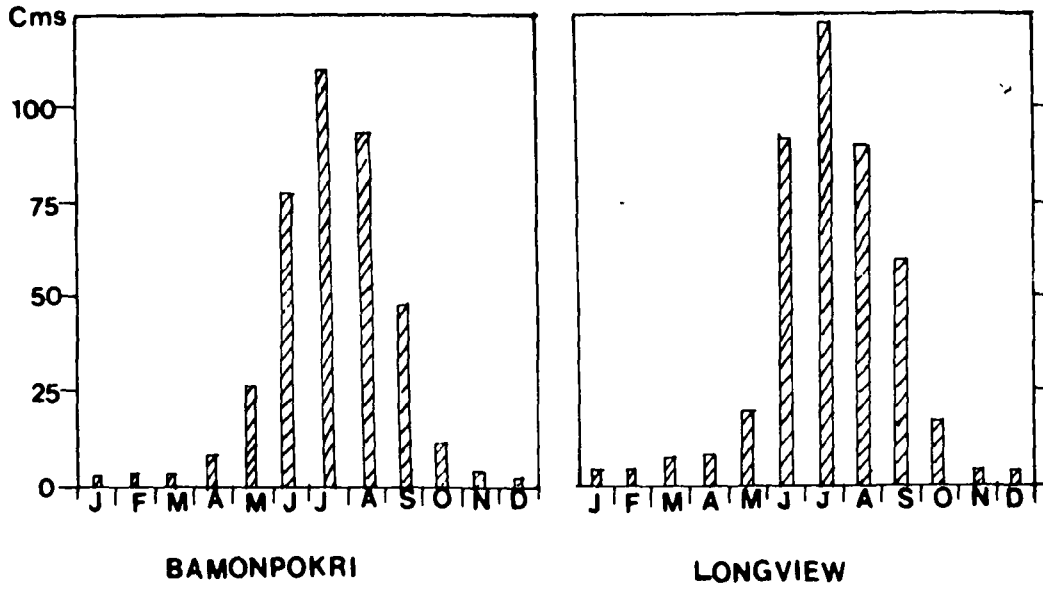
Rivers	Place	Discharge(m <sup>3</sup> 5').	
		Maximum	Minimum
Balason	Dudhia (260m)	1,500	2.15
Rakti	W.Simulbari (205m)	150	0.31
Rohini	E.Simulbari (208m)	160	0.40

Besides the five main streams there are innumerable small streams which are mostly seasonal and locally known as Jhoras. They carry rainwater during the months of rain and remains almost dry during rest of the year. The number of such tributaries is highest in the upper fan part. Along the hillslopes the tributaries are parallel to each other and along domal hills the streams shows a centrifugal pattern.

D. CLIMATE :

Climate is one of the most important factors influencing fan formation. Climatic change influences the development of alluvial fans by inducing variability in the magnitude of fluvial process which in turn influences alluvial fan features. Lustig concluded that fans tend toward equilibrium in adjustment to different climatic conditions. Lustig believed that fan aggradation occurs regardless of climatic regime. During wet periods aggradation takes place within the drainage basin and below the mountain front (Figure No. 4A1). During dry conditions trenching occurs in the upper portion of the fan as debris flow become the dominant erosional process. This causes fan head entrenchment and the shift of deposition down fan, but the fan still builds out from the mountain front (Figure. No. 4B1) (Lustig, 1968).

# CLIMOGRAPH



DE FIGURE NO. 8.

To explain the evolution and formation of alluvial fans of the study area it is necessary to deal with both the past and the present climate of the area. Nearly 1 million years ago during the Pliocene epoch there was a great refrigeration of climate, culminating in what is known as the Ice Age or glacial age. The higher parts of Darjeeling Himalayas undoubtedly experienced wide-spread glaciation and the ice sheets came down along the hillslopes to distances far more south than their present limit. The region lying beyond the margins of glaciers experienced a periglacial climate being followed by a cold pluvial climate.

Then after melting and gradual regression of the ice sheets with gradual warming of the globe the climate changed and now the area is experiencing a very hot and humid Tropical monsoon type of climate (Am.). This type of climate is generally characterised by strong seasonal distribution of rainfall. About 80% of the annual rainfall occur during the south-west monsoon i.e. from June to October, July being the wettest month. Whereas the rest of the year remain dry receiving only 20% of the total rainfall (Figure No. 8). On account of the hilly nature of the terrain there are sharp variations in rainfall, generally increasing north-wards. The highest mean annual precipitation has been recorded at Long-

view Tea Garden (4280).9mm) and lowest at Simolbari Tea Garden (3690.3mm) signifying that the apex zone of the fans receives more precipitation than the distal part. The following shows the average monthly distribution of the rainfall on three stations over the fans -

Table No. 3.  
RAINFALL IN CM.

Stations	J	F	M	A	M	J	J	A	S	O	N	D
Bamonpokhi	3.0	2.0	4.5	9.0	25.3	80.0	109.0	85.5	48.0	12.0	3.0	2.0
Longview	5.0	5.9	8.5	10.0	20.5	93.5	122.0	89.0	59.0	17.0	3.9	2.9
Simolbari	1.9	2.0	2.9	8.5	17.0	75.0	87.0	72.0	65.5	11.0	14.0	1.9

This table shows clearly that there is an exceptionally heavy concentration of rainfall during the monsoon months particularly during the months of June, July, August and September. This heavy precipitation being added with other factors is undoubtedly influencing the geomorphic features of the study area. This peculiar concentration of heavy rain during a particular part of the year is responsible for the fact that the fan building process has not been stopped here. Formation and its further modification has continued.

The factors influencing fan formation and morphology have been dealt in detail in this chapter. In the following chapter the geomorphology and the characteristics of the fans

will be dealt in detail along with the influence and effect of these fan forming factors.

REFERENCES :

1. Lecce, S.A. 1990. The Alluvial Fan Problem. Alluvial Fans, A Field Approach; edited by Rachocki, A.H. and Church, M. 12-13. Jhon Wiley and Sons.
2. Beaty, C.B. 1970 Age and estimated rate of accumulation of an alluvial fan, White Mountains, California, U.S.A. American Journal of Science, 268, 50-70.
3. Bull, W.B. 1977. The alluvial fan environment. Progress in Physical Geography, I, 222-270.
4. Wadia, D.N. 1976. Geology of INDia, 364-389.
5. Pawde, M.B. and Saha, S.S. 1976. Geology of the Darjeeling Himalayas, Geological Survey of India Miscellaneous Publication. No. 41.
6. Basu, S.R. 1989. Geomorphic characterertics of alluvial fans is India. Geographical Thoughts. 18-22.
7. Banerjee, A.K. 1980. West Bengal District Gazetteer, Darjeeling. Govt. of West Bengal. 39-47.
8. Lustig, L.K. 1965. Clastic Sedimentation in Deep Springs Valley, California. U.S. Geological Survey Professional Paper, 352 -F. 131-192.

## CHAPTER III

### EVOLUTION OF ALLUVIAL FANS AND IT'S CHARACTERISTIC.

The rivers of the study area i.e. the Balason, the Rakti, the Rohini and the Sukhia have formed a thick cover of poorly stratified and unassorted sediments at the base of the foot-hills, termed as alluvial fans. Along  $88^{\circ} 14' E$  and  $88^{\circ} 22' E$  meridians the mountains have extended upto parallel  $26^{\circ} 47' North$ . In between these two extended spurs of the mountains the alluvial fans are located in an elongated form from about  $26^{\circ} 45' North$  to about  $26^{\circ} 50' North$  (Figure ~~7~~ No. 7). These alluvial fans coalesce to form a peidmont zone. The evolution, materials, modes of deposition of materials, morphology and stratigraphy of the alluvial fans are strongly influenced by factors like tectonics and lithology, local relief, climate and hydrology as discussed in the earlier chapter.

#### A. EVOLUTION :

During Plietocene Ice age huge materials were loosened by the process of alternate freezing and thawing. These Periglacial debries and solifluction materials were brought down by gravity and fluvial action during the period of gradual

# GEOMORPHOLOGICAL MAP OF ALLUVIAL FANS

BETWEEN BALASON RIVER & SUKHIA KHOLA

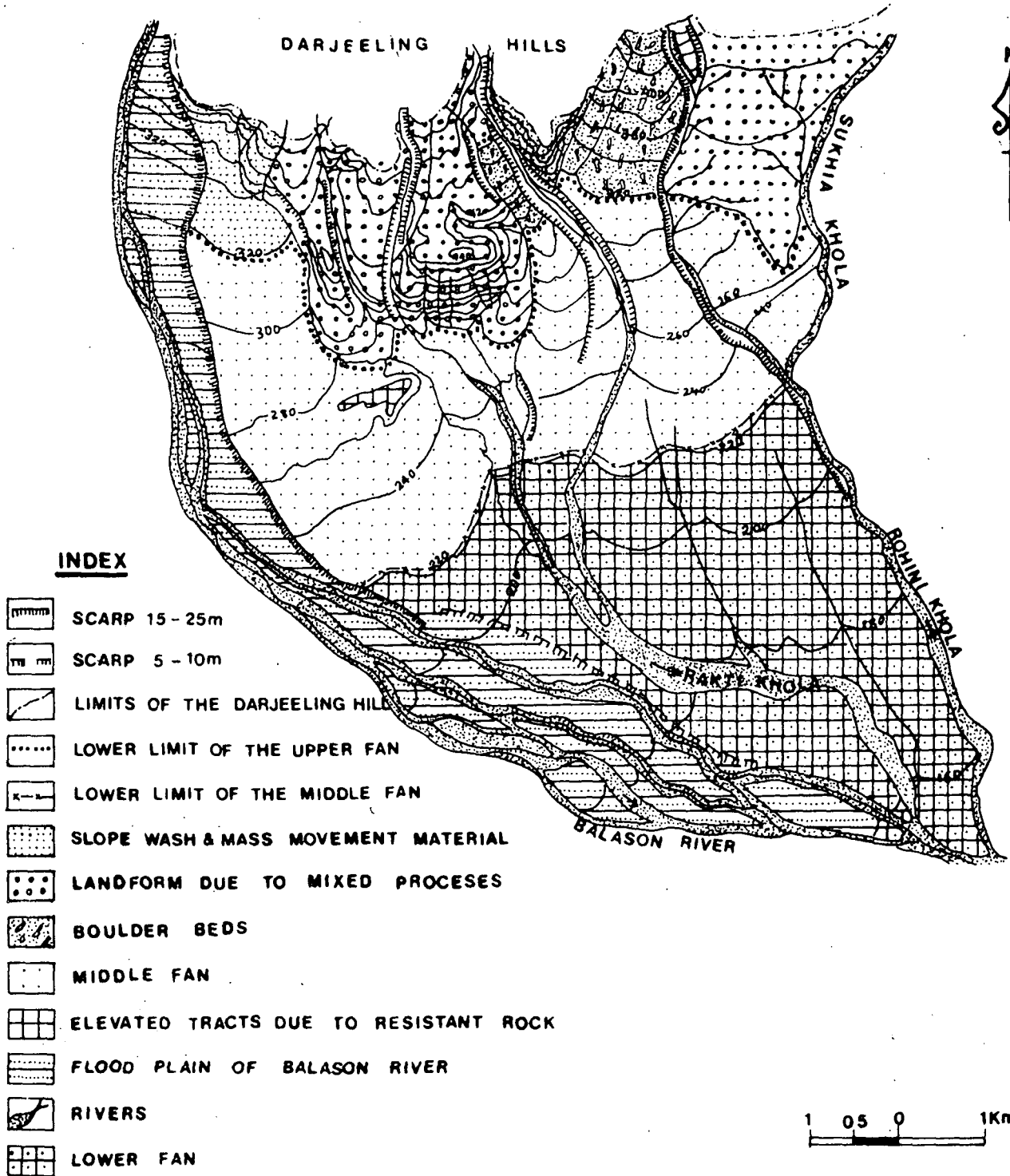


FIGURE NO. 9.

warming of the globe and deglaciation by ice melted water and were deposited at the base of the hills. This was the starting point of the formation of the fans. When the supply of ice melted water ceased the rivers then build up a channel over the loose materials and thus the fan head trenching started with shift of locus of deposition down fan and the fan progressively elongated. The area is now situated in tropical monsoon climatic zone, huge rainfall during the summer month helps and modification, transportation and redeposition of sediments, thus modifying fan shape and morphology. Moreover strong seasonal distribution of rainfall helps some what stratification of fan material with distinct layering of coarser and finer ones, as evidenced along the entrenched valleys of the rivers.

B. MORPHOLOGY OF THE ALLUVIAL FANS :

Morphology of the <sup>a</sup>Alluvial fans have been studied with the help of different morphometric maps vide Relative Relief, Dissection Index, Drainage Density, Slope Analysis and Longitudinal and Transverse profiles. Geomorphological map (~~Figure~~ No. 9) of the area shows that the upper part of the fan area is characterised by close-spaced contours, high relief, steep gradient, deep fan head trenching whereas the middle part shows somewhat low relief with low gradient, characterised by somewhat distant contours and low degree of trenching.

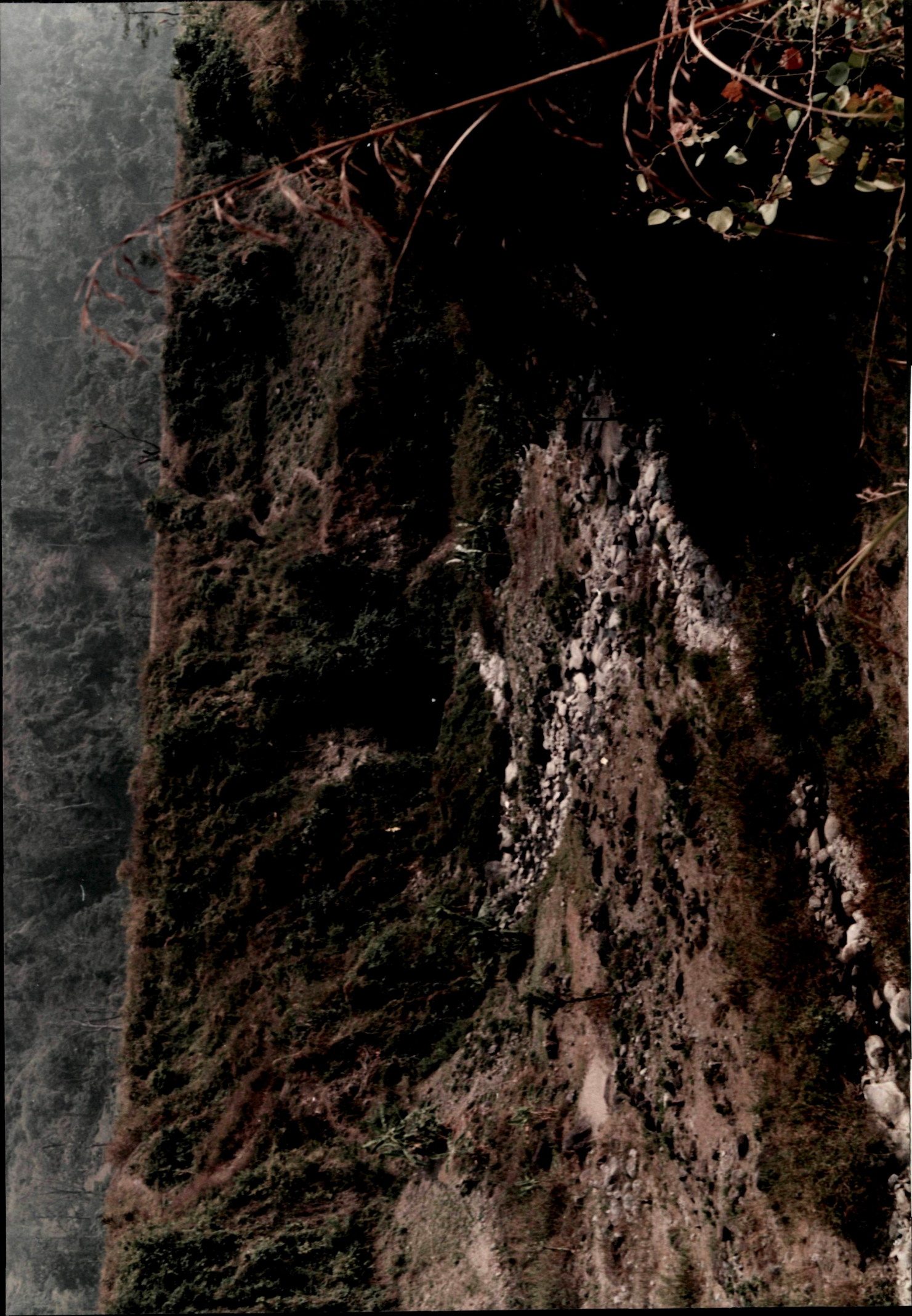
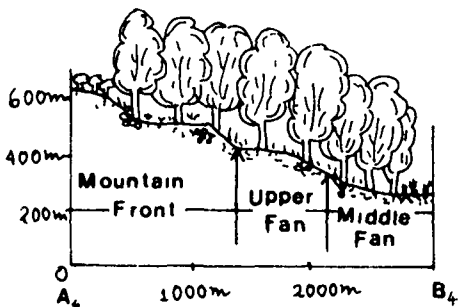
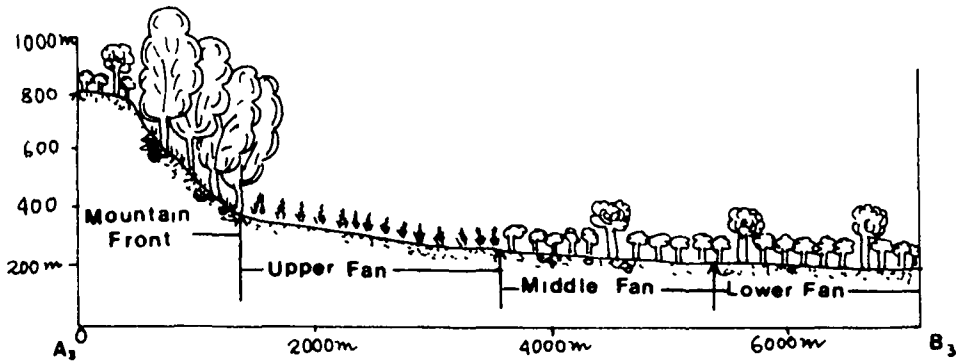
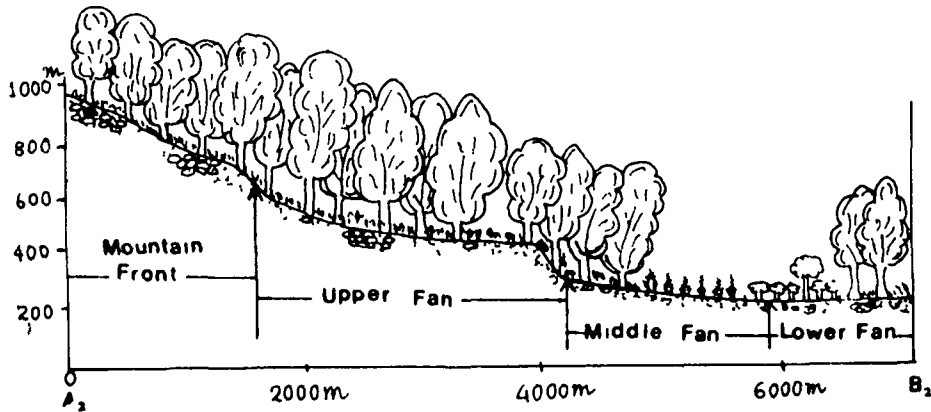
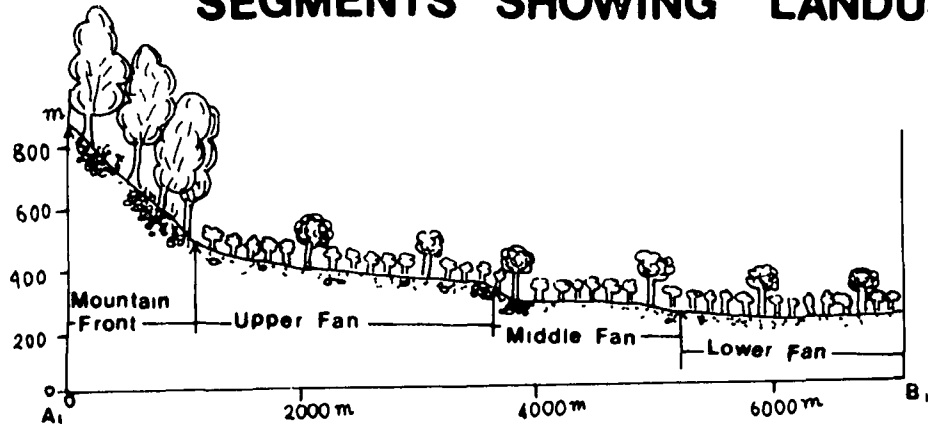


PLATE NO. 3. Incised course of the Lapche Jhora with Terracing.

# LONGITUDINAL PROFILES ALONG VARIOUS FAN SEGMENTS SHOWING LANDUSE



## INDEX

	FOREST
	CULTIVATED LAND
	TEA GARDEN

FIGURE NO. 10.

Terracing is also found here and two distinct terraces undoubtedly indicates rejuvenation in the course of river due to changes in tectonic features ( Plate No. 3). The Lower part of the fan is characterised by almost flat surface with widely spaced contour, very low gradient and wide river valley. The contour height varies in the upper fan between 320 M to 460 M whereas in the middle fan between 200 M to 300 M and in the lower fan between 200 M to 160 M. The transverse and longitudinal profiles over the fan shows very clearly its change in morphology from head to base.

Four Longitudinal Profiles in between the river Balason and the Rungsung ( $A_1B_1$  Figure No. 10); the Rungsung and the Rakti ( $A_2 - B_2$  Figure No. 10), the Rakti and the Rohini ( $A_3 - B_3$  Figure No. 10) and the Sukhia ( $A_4 - B_4$  Figure No. 10) show three distinct steps in front of mountain with distinct change in gradient. The steps have been termed as the upper, middle and lower fan progressively. Only the area in between the River Rohini and its' tributary Sukhia shows only two steps, the upper and the middle fan. Later the fan segments will be dealt in detail.

Four Transverse profiles have been drawn over the area to study the gradual change in topography from head to base. The upper most section ( $X1 - Y1$  Figure No. 11) is across the upper fan starting from west of the River Balason to East of

# TRANSVERSE PROFILES SHOWING VARIATION IN MORPHOLOGY & LANDUSE ACROSS FAN AREA

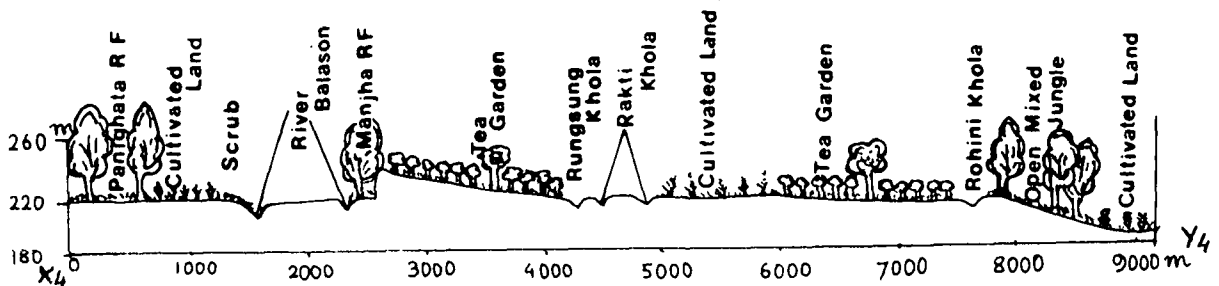
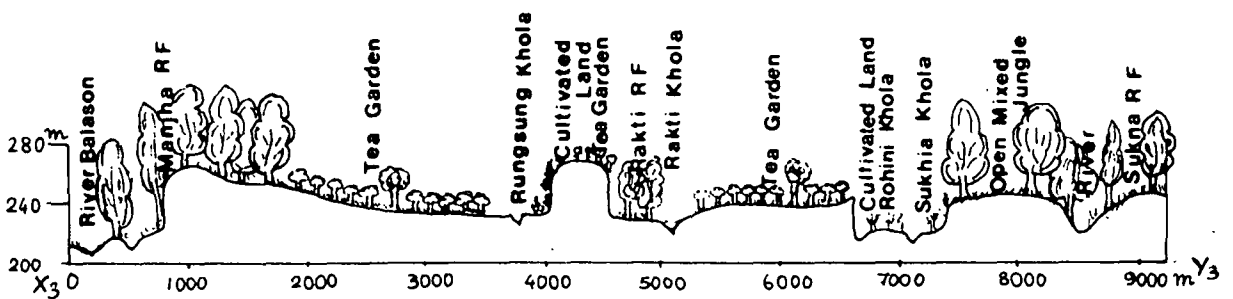
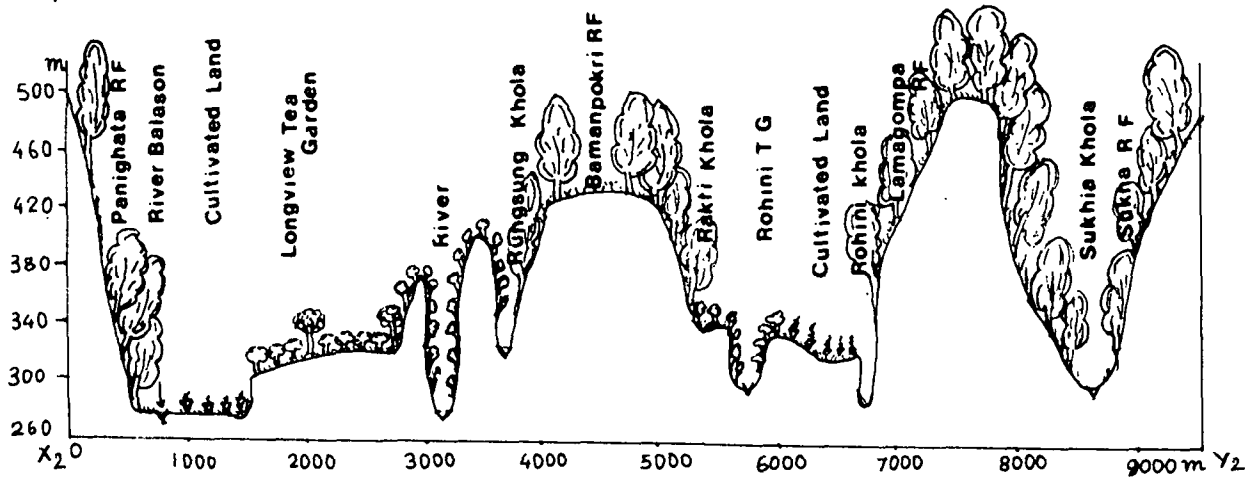
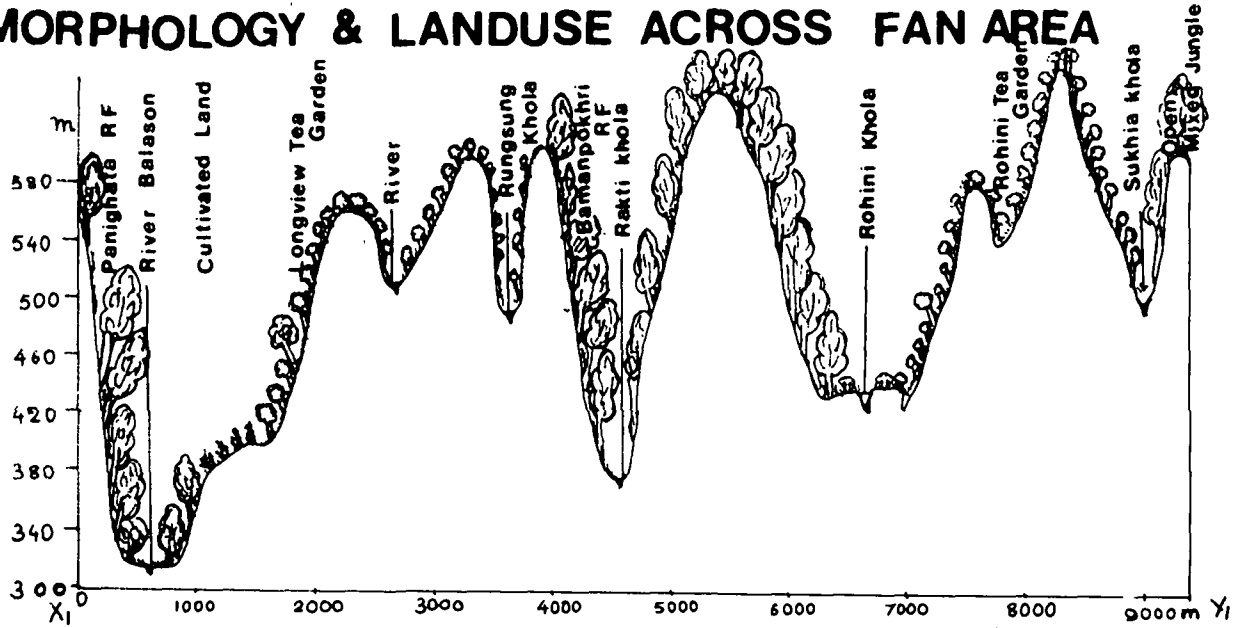


FIGURE NO. 11.

river Sukhia. The next two i.e.  $X_2 - Y_2$  and  $X_3 - Y_3$  (Figure No. 11) are on the middle fan, again from west of the Balason to East of Sukhia and the last one i.e.  $X_4 - Y_4$  (Figure No. 11) is across the lower fan, again starting from West of the Balason to East of the Rohini as the Sukhia, tributary to the Rohini meets the Rohini before reaching the Lower fan. These four profiles shows a very distinct and clearcut differences in relief between the upper, middle and lower fan. The section across upper fan ( $X_1 - Y_1$  Figure No. 11) shows deep fan head trenching. The rivers have entrenched their valleys at places upto 200 m. The total area is badly dissected by the valleys and intervening highlands particularly the valleys cut by the main rivers the Balason, the Rakti, the Rohini are deeply incised into poorly assorted and poorly stratified sediments. The next two profiles ( $X_2 - Y_2$  and  $X_3 - Y_3$ , Figure No. 11) are across the middle fan, one over the upper portion of the middle fan and the other over the lower portion of the middle fan. The former shows deep incision, the valleys entrenched for about 100 m. The latter shows that the river valleys though not entrenched deeply are bounded by low scarps of 20 to 40 m height. The inter fluves are gently rolling lands. The last transverse profile across Lower Fan ( $X_4 - Y_4$  Figure No. 11) shows an almost flat topography with very little slope. The main river valley of the area i.e. the valley of the Balason river is bounded by low scrap of 10 m. The river valleys are wide and open. These

RELATIVE RELIEF MAP OF THE STUDY AREA (MAP NO 78 B/1 & 78 B/5)

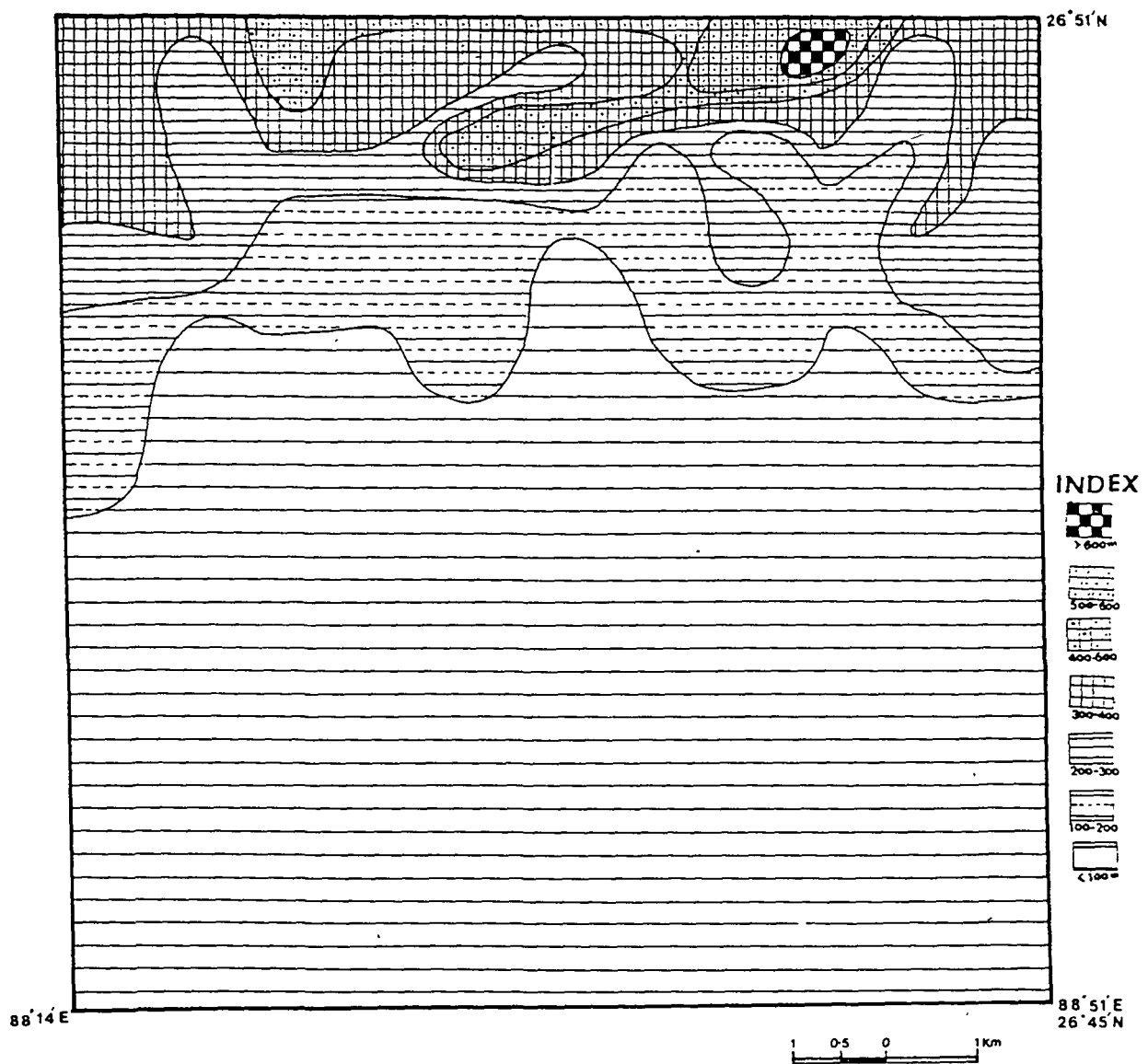


FIGURE NO. 12

profiles undoubtedly proves the fan head trenching and shift of locus from upper to lower one. Locus of deposition shifts gradually from head to base with progressive sedimentation and downcutting. As soon as the valley is entrenched it indicates that the fan formation has been stopped there only modification is on process and the locus of deposition has been shifted. Shift of locus of deposition downfan indicates progressive elongation and enlargement of the fan area.

The nature of terrain of the study area has been studied with the help of Relative Relief map (Figure No. 12). According to Smith's method the entire study area has been divided into 1 cm. sq. grid and with help of the difference between maximum and minimum relief the isopleths have been drawn. The map clearly shows that difference in terrain pattern exists in the upper, middle and lower parts of the fan. The relative relief varies between 200 mtr to 600mtr. in case of upper part of the fan, the central part showing a very complicated pattern, than the eastern and western margin. Whereas the middle part shows a relative relief varying from 0 to 100m. Only the western part show some what greater relative relief up to 300mtr as the valley of Balason is bounded particularly in the western side by steeply rising scraps in front of a south ward progresing spur of the High Himalayas. In the lower fan relative relief is 0. Therefore it is quite clear from the Relative Relief Map that the terrain is rough in the upper part

MAP SHOWING DISSECTION INDEX OF THE ALLUVIAL FAN AREA

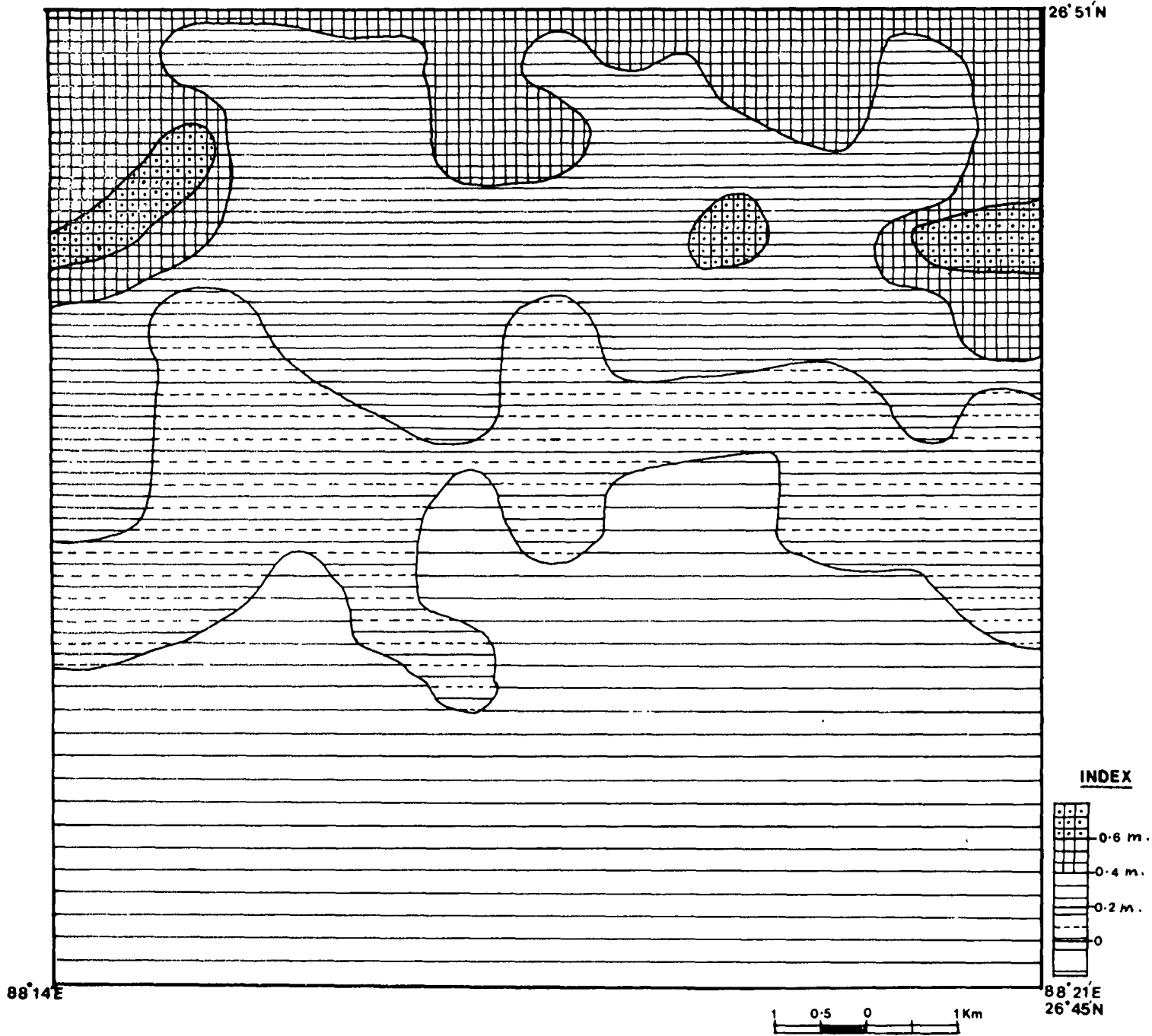


FIGURE NO. 13.

where deeply entrenched valleys and steeply rising scarps have resulted in a high relative relief. Again the central part showing a greater relief than the two sides supports the general geomorphic feature of an alluvial fan where the sides are much less higher than the central part. The middle segment of the fan area show relative relief varying from 0-100mtr only indicating a region of much less variation in terrain characteristics, where as the lower part shows a flat terrain, the relative relief being 0 mtr.

A Dissection Index Map (Figure No. 13.) has been drawn over the area to find out of the degree of dissection of the area by the erosional agents and the stage reached by the area. In the upper part of the fan the index varies from 0.6 to 0.8, indicating that the area is deeply dissected by the drainage line. For the middle fan the index varies from 0 to 0.4, indicating a somewhat lower relief with a low degree of dissection by the drainage line, leaving the western section only when the index is upto 0.8 and this is due to the steeply rising and south ward extending spur of the Himalayas rising almost along the western bank of the river Balason. The lower fan segments show a index of 0 indicating an almost flat land with wide open river valleys. Therefore the topographic change from upper to lower fan segments is quite clearly indicated by the dissection index map also.

### SLOPE ANALYSIS OF ALLUVIAL FANS

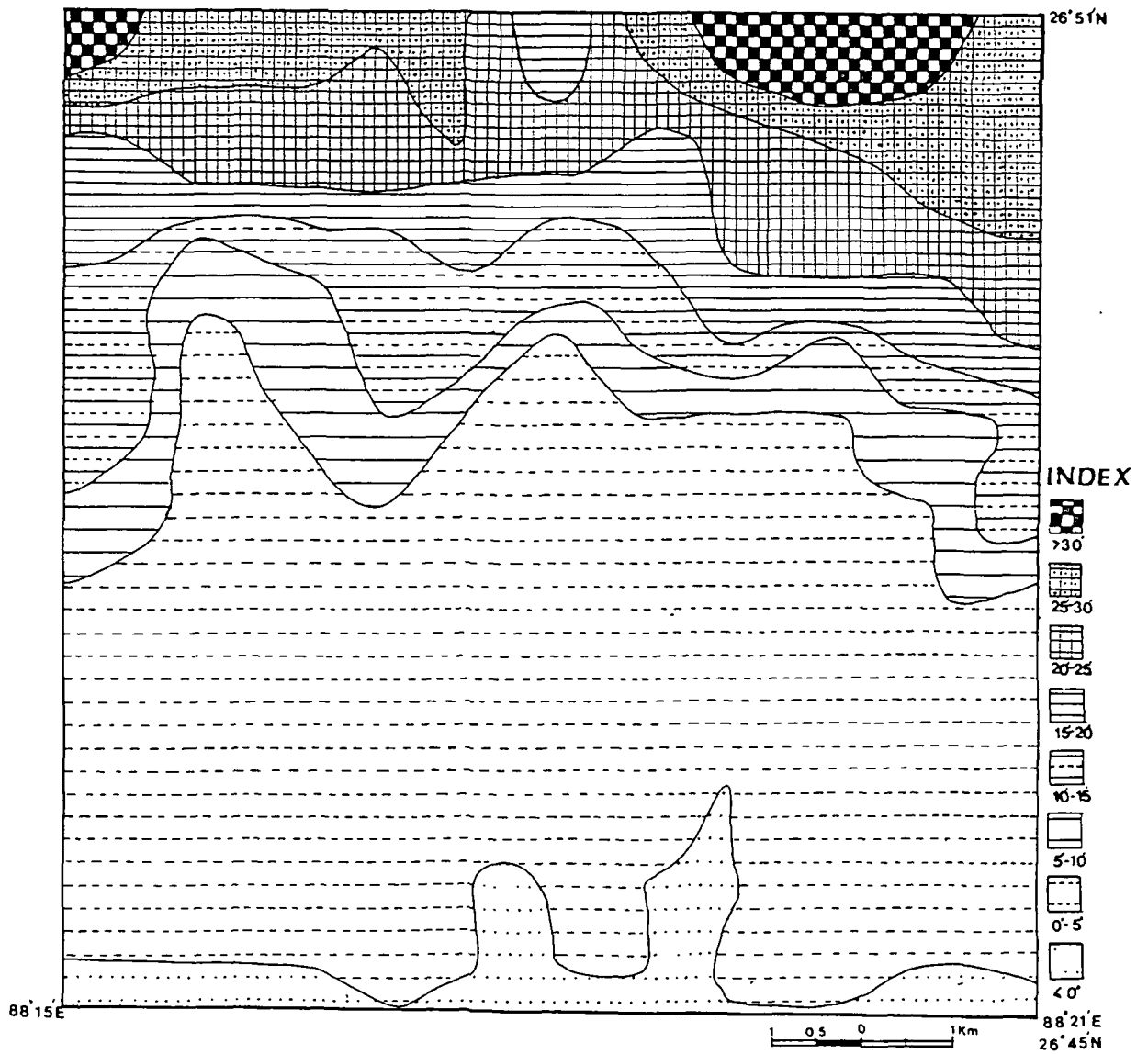


FIGURE NO. 14.

A slope analysis map ( Figure No.14.) has been produced to determine the average slope of the area following Wentworth's method. The slope map shows a general slope from north to south. The upper part of the fan shows a slope varying from  $15^{\circ}$  to  $30^{\circ}$ . The Northern part of the upper fan possess a slope varying from  $25^{\circ}$  to  $30^{\circ}$ , whereas in the southern part the slope varies from  $15^{\circ}$  to  $20^{\circ}$ . The middle part of the alluvial fan shows a slope varying from  $1^{\circ}$  to  $10^{\circ}$ . The slope is greater in eastern and Western end. In the lower part of the fan the slope varies from 0 to  $1^{\circ}$ . Therefore it is quite clear that the gradient of the fan area is steep in the upper part, gentle in the middle part and the lower fan shows an almost flat topography, with very low gradient.

To sum up the general geomorphology of the study area it can be said that all the morphometric maps including the transverse and longitudinal profiles show a distinct and clearcut differences in topography from apex to base thus giving three well defined sections termed as the upper, middle and lower fan segments, or proximal, middle and distal parts.

C. DRAINAGE PATTERN AND DENSITY :

Following the slope of the area the drainage lines are from north to south. The main river of the area is the



PLATE NO. 4. Braided course of river characterised by huge sediments.

Balason and its tributaries the Raktikhola and the Rohinikhola. The alluvial fans under study has been built by the main river and its left bank tributaries between the two south ward advancing spur of the Himalayas. Though many small non-perennial and perennial streams join the Rakti and the Rohini Khola, among them the Rungsung thibutary to the Rakti and the Sukhia tributary to Rohini are important. Along steep slopes in mountain front the streams run parallel to each other and if the area represent a domal pattern then the drainage pattern is radial, as is found arround Durbingaon peak in the extreme north-westrn corne of the study area.

In general the drainage pattern is dendritic. All the main rivers show narrow and deeply entrenched channels at the base of the mountains and in the proximal fan region (Plate No. 2). In the middle part also the channeling exists though the depth of the valleys is much less. The distal or lower fan region is characterised by wide, open valleys through which the rivers flow in innumerable distributaries that seperates and joins thus forming a braided pattern (Plate No. 4). All the streams show a narrow channel of water during the dry months, though during the monsoon the beds are generally flooded with tremendous supply of rain water from the surrounding hills.

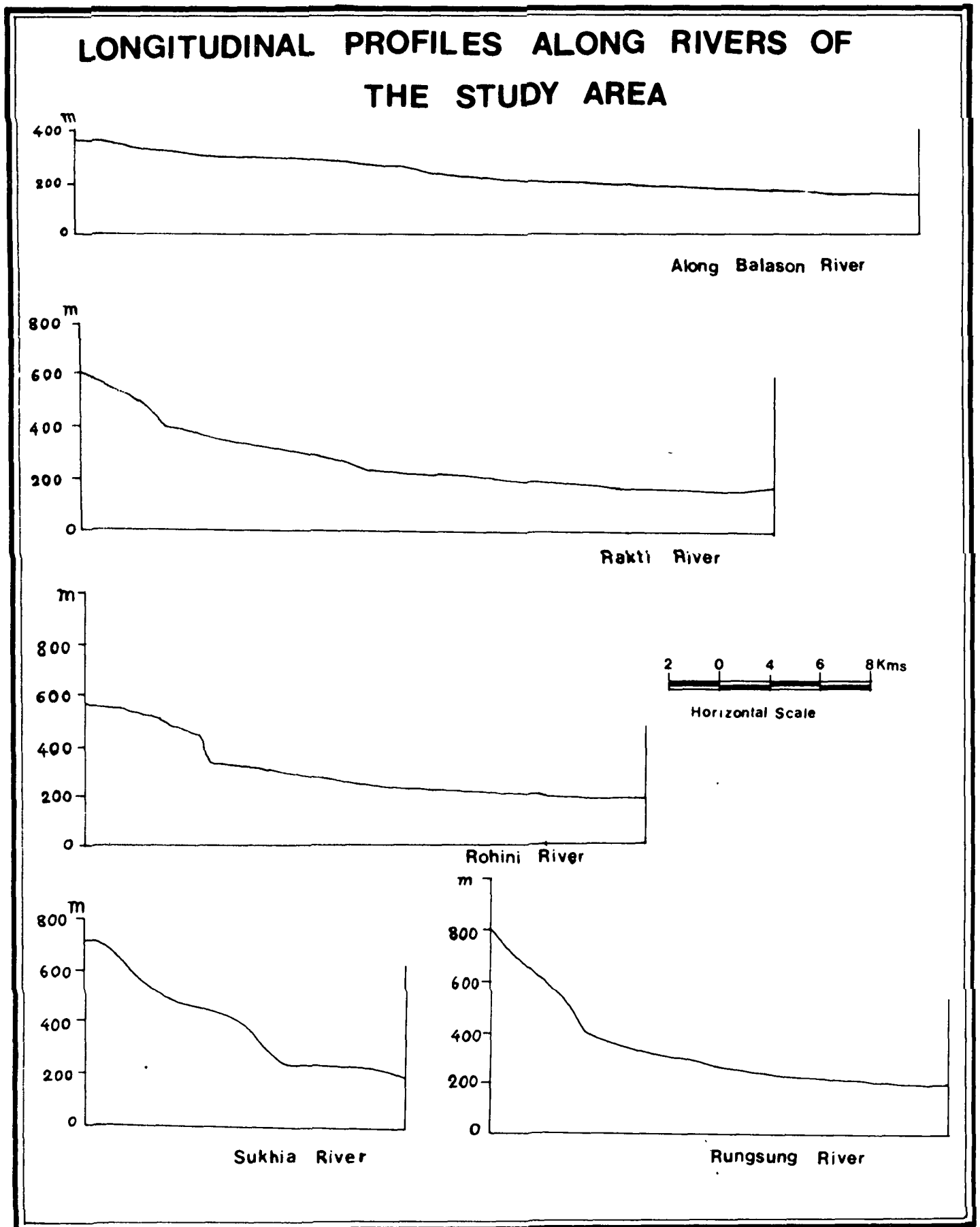
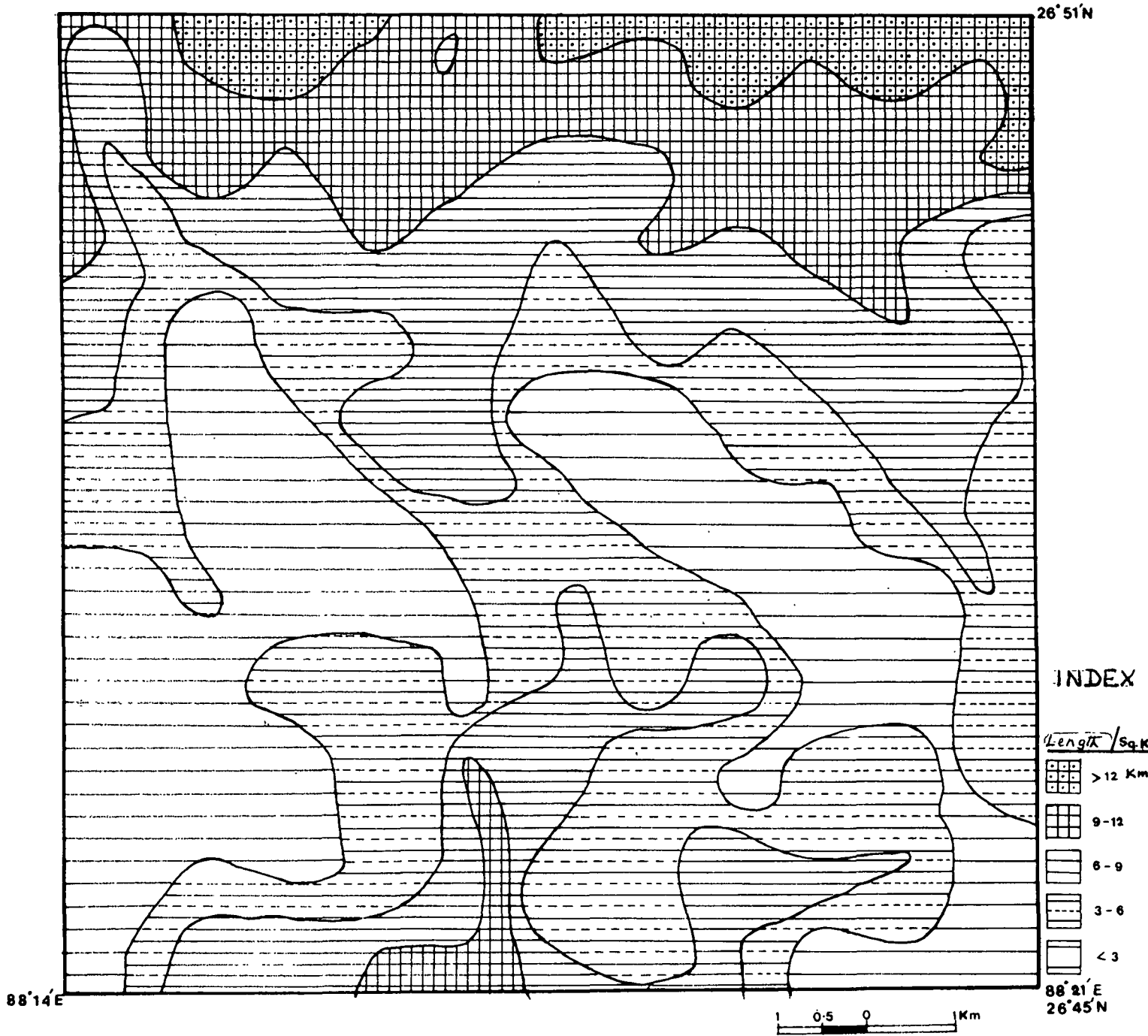


FIGURE NO. 15.

# DRAINAGE DENSITY OF THE STUDY AREA (MAP NO. 78B/1 & 78B/5)



DEIGURE NO. 16.

The Longitudinal Profiles of the four main rivers have been drawn with the help of Rotameter (Figure No. 15). The longitudinal profile of the main river Balason shows a graded manner though minute variations in slope is quite clear and distinct from north to south. The longitudinal profiles of the other four rivers, the Rakti, the Rohini, the Rungung, and the Sukhia, show a sudden drop from the mountain front. The rest of the profiles show a greater degree of gradation though minute variations in gradient is distinct, from north to south, again indicating the three distinct segments of the fan.

A Drainage Density map (Figure No. 16) has been drawn to find out the density of drainage channels over the study area. It is interesting to note that the middle part of the fan shows the lowest density. The density is highest in the upper fan part and in mountain front zone varying from 9 to 12 per sq. km. This is because of the presence of numerous small streams and khors along the foot hills carrying the water of the heavy monsoonal rain of the foot hill region. In the lower fan part the density is again high varying from 3 to 9 per sq. km. this is because of numerous distributaries of the main rivers. The lower fan is almost flat with very low gradient over which the rivers flows in a open and wide braided course with numerous distributaries. The middle fan segment shows the lowest density varying from 1 to 5 per sq.km. This is partly due to the fact that in this part only the main streams exists, and partly due



PLATE NO. 5. Poorly - sorted and immature sediments with subangular and subrounded materials of all sizes.

the fact that the coarser soils and pervious covering allows percolation of water which resurges in the lower fan, causing higher density there,

So, to conclude it can be said the drainage pattern and density also show a gradual change over alluvial fan from head to base.

D. FAN MATERIAL :

In the area of study, the fan deposits are coarse grained, poorly-sorted and immature sediments. Usually gravels, cobbles and boulders predominate with subordinate amount of sand, silt and some clay (Plate No. 5). The coarsest and the thickest deposits occur near the fan heads i.e. in the proximal fan region. Size of material and thickness of sediments decrease rapidly base wards and the roundness of grains increases with increasing distance from the apex of the fan.

The proximal or upper fan region is characterised by huge boulders and gravels along with very fine sands and clay. Particularly the base of the mountains, from where the alluvial fan starts is characterised by huge amount of boulders of extraordinarily large size. The bed of the rivers are almost blocked with such deposits, through which a very narrow channel



PLATE NO. 6. Huge boulders carried by flash floods almost choked the river course.



PLATE NO.7

Huge houlders supplied by landslides and

carried further by flash floods.

of water is flowing ( Plate No. 6). Boulders are mainly of granitoid gneiss, granites and schistose rocks and are elongated in size, indicating a near source deposition. These boulders are mostly supplied by the surrounding hills by debris flow along the bare slopes during heavy rains. In the inter-fluve region also in between the river valleys such big boulders are not uncommon lying amidst deep jungle or fields of step cultivation. The average length of the boulders is 2.6 to 4 m and the width is about 2m. One of such boulder is lying amidst the cultivated land (~~Plate~~ Plate No. 7).

As the rivers have incised their valleys deeply in the proximal region it can be assumed that the occasional large boulders in the interfluve area are the remnants of once extensive deposition only. These boulders are heavily weathered and oxidised and have broken into pieces along foliation or cleavage planes particularly in the case of gneisses and schists. (~~Plate~~ Plate No. 8). The materials are very poorly assorted and unstratified. However micro-slumping with layers of different size materials are found at places along the sides of the deeply incised valleys. (~~Plate~~ Plate No. 9).

In the middle fan region very large boulders are not common, but occasionally large boulders are found varying in length from 1.5 to 2m. and width 1 to 1.5m. Though the boulders



PLATE NO. 8. Weathered, oxidised, and broken materials.



PLATE NO. 9. Micro slumping on the bank of the incised river.

are elongated in shape here also ; the degree of roundness is some what greater than that of the proximal fan region. Boulders are found admist jungle, tea garden or agricultural field, highly weathered and oxidised. Loose sandy sediments dotted with pebbles and gravels are the characteristic deposits in the middle fan. The pebbles or gravels are not much rounded and retain a some what elongated shape though the edges are not sharp (Plate No. 5). This poorly assorted and unstratified sediment is found allmost all over the middle fan as evidenced during the field survey.

The size and shape of the materials are quite different in the lower or distal part of the fan. Here large boulders are totally absent. Fine grained sands, silts and clay with small pebbles are the characteristic deposits here. The broad river valley with braided channel pattern shows a somewhat coarser sand and rounded pebbles and gravels (Plate No. 4). But the intervening region in between the rivers shows a distinct absence of coarser materials. Therefore, it is quite clear that though the alluvial fans are generally formed of poorly assorted and unstratified materials of different size, there is a clear gradation of materials from apex to base. The shape of the materials also vary, the degree of roundness increasing from apex to base.

E. MODES OF DEPOSITION

Field experiences show that flash floods, stream action, stream floods, debris flow are four notable modes of deposition of alluvial fans. (Basu and Sarkar 1990).

Flash flood - Flash flood deposits are occasional and takes place when the river discharge suddenly increases due to high rainfall some reasons. Large amount of water charged with detrital sediments emerge from the high mountains and as soon as it reaches the foot hill region the velocity decreases and the debris sediments are immediately deposited. Mostly such deposits are unassorted, coarse grained sediments and the materials are mostly deposited at or near fan head as flash floods run for only a small distance. - Such a process is often accentuated when the natural dams build across the river due to accumulation of sediments suddenly breaks and the water discharge is tremendous and sudden. According to Banerjee such flash floods modified the proximal fan region in 1899, 1950 and 1968 with accumulation of coarse debris and boulders (Banerjee, 1980)<sup>2</sup>

Stream Action - Alluvial fans are undoubtedly depositional features build by stream due to decrease in velocity and subsequent sedimentation along its path. In the source region over the mountains the trunk stream is fed by numerous tributaries which increases the

discharge of water continually. As soon as the trunk stream emerges from the mountain its velocity suddenly decreases, resulting in deposition of huge amount of debris at the base of the mountain. Thus the fan head becomes thicker and thicker, and the thickness of sediments is highest at the proximal fan. With continual stream action channelisation starts gradually and as soon as it starts the locus of deposition is shifted down fan. Here due to fall in gradient the river spreads in broad basins, through which the distributaries flow. As a result water discharge diminishes along the course of the trunk stream allowing large scale deposition forming sand bars, chars within the river. Moreover, stream deposition is also caused by down-ward percolation of water through permeable fan sediments which causes further loss in discharge.

Stream Floods - This mode of deposition adds material mainly in middle and distal parts of the alluvial fans. The braided river basin with almost flat valley is quite incapable to carry the high monsoonal discharge, resulting the flooding of respective basins. This causes deposition of fine grained sands and silts particularly in the lower and middle fan region. This also causes modification and grading of the materials of the upper fan. In exceptional cases the upper fan is also partly inundated as in the year 1968 when exceptional

rainfall resulted in an exceptional flood condition in North Bengal.

Debris Flows - This is an important mode of deposition in alluvial fan regions, both in humid and arid areas. As already mention in second chapter the area lies in earthquake prone zone and fall of boulders, sliding of rock masses and soil creep are almost regular feature of the surrounding hill section, due to factors mentioned earlier. This region experienced severe shock in 1849, 1863, 1869, 1930 and 1934 which were also invariably accompanied by landslides (Banerjee, 1980). Extensive masses of coarse sediment with materials of all size, moves down the bare slopes of the surrounding hill section during heavy downpour. These materials are mainly deposited in the fan head area and changes the general slope of the fan heads at the foot of the hills. Moreover, these are characterised by huge subangular boulders of 1to 2m. average diameter. The fan head near Bamonpokri and the fan head of the Rakti and Rohini near Merchenbong is characterised by subangular gneissic and schistose boulders( Plate No. 7). Debris flows undoubtedly supply material to proximal fan region but one should keep in mind that these deposits are modified, graded and redeposited in the middle and distal parts, by stream action.

Soil creep and rock slides under the influence of gravity supply materials to the fans during dry season. Creeping of heavily decomposed material along steep, bare surface is a common feature in the surrounding hill section (Plate No. 1). Over grazing and deforestation helps easy movement of soil. Materials are added by this process only to the upper part of the fan.

All the modes of deposition discussed above work together, though differences in their areas of impact is distinct, as debris flows and flash floods are important in supplying material in the proximal region, while stream floods are important in supply materials in the middle and lower fan region.

F. STRATIGRAPHY OF DEPOSITS :

Though the alluvial fan region is mostly composed of poorly assorted and unstratified sediments, however a low degree of stratification is found which reflects the effect of climate and tectonic changes and change in modes of deposition. stratigraphic arrangements of fan sediments are normally found along the deep incision of the rivers, particularly in the upper fan where the incision is about <sup>20 m.</sup> 30. in places (Plate No. 9). The rockbeds stretches almost horizontally over the general base

of the area and parallel to each other . Boulders and pebble beds alternate with sandy, silty and muddy beds rich in organic matter are found. Undoubtedly the pebbles are deposited during the heavy monsoonal rainy season, the rivers being charged with high discharge and extensive load. The finer deposits undoubtedly indicate deposition during dry season. The organic matter is supplied by the seasonal bushes, undergrowths and grasses which generally flourish during the rainy months and dries down during the winter months and mixes up with the sediments. Such stratification is disturbed in places by occasional mass movement and flash flood deposits which superimpose upon normal sequence. Huge boulder beds near Bamonpokri Reserve forest and also near Merchenbong can be sited as example.

In the middle and lower fan such clear and distinct layering of different size materials is not common. In many places along newly cut surface in middle fan, the sediments show very poor stratification, different sized materials are found in a common sandy matrix. ( Plate No. 5). They are easily erodable and completely loose. In the lower fan absence of stratigraphic sequence is due to the continuous use of the land for agriculture.

The formation of alluvial fan is a piecemeal work. At first the materials are deposited just at the base of the

mountain. But with progressive sedimentation and down cutting, the locus of deposition is generally shifted in lateral and down fan direction and this happens when the main rivers starts channeling in the upper part. This progressive shifting of locus of deposition down fan results in interrupted sedimentary sequence over the fan. No where a total stratigraphic sequence has been maintained exhibiting a lateral continuity of deposition over the entire fan surfaces. The stratigraphic arrangement consists of a series of lenses or wedges of sediments.

G. FAN SEGMENTS :

Studying all the geomorphic characteristics through the analysis of morphometric maps and field experiences it can be concluded that the fan area under our study can be divided into three district zone - The upper or proximal zone, the middle zone and the lower or distal zone. Each of these three sections is characterised by distinct geomorphic and drainage pattern. The upper or proximal part just in front of mountains is highly dissected with thickest sediments, deepest incision, steep gradient, extensive sub-angular boulders, high drainage density and stratification of materials. This is actually the first formed fan segment. Along with incision and channeling here the locus of deposition shifted generally down fan where active

sedimentation started and the upper section is now only under processes of modification and gradation by the streams. But the process of mass movements continually add materials to this part.

Thus the middle part gradually developed. This area is characterised by lower relative relief, lower degree of incision, low gradient, lower amount of boulder, low drainage density, and lower degree of stratification than the upper part.

The lower or the outer most area, south of the limiting contour of 200m. is the youngest segment formed and this is the zone of coalescence of all the fans. Frequent flooding of the braided stream channel with deposition of thin cover of sediments which coalesce with each other in the marginal areas. This area is characterised by thinnest sediments, lowest gradient, open, wide, braided stream channel, high drainage density and finer materials with rounded pebbles. The characteristics of the three different fan segments can be put in a tabular form like the following : -

Table No. 4a.

Segments	Area Km <sup>2</sup>	S %	Relative Relief	Dissection Index	Slope	Drainage Density
Upper	11.23	25.80	200M-400M	0.4-0.6	10°-25°	6 - 12
Middle	19.26	45.87	20M-180M	0.1-0.4	3°-10°	3 - 6
Lower	11.32	28.43	0	0	1°	6 - 9

Table No. 4b.

Segment	Materials	Degree of round- -nes of materials	Process	Major Landuse
Upper	Coarse-grai- ned gravels, cobbles and boulders.	Sub-angular	Flash floods debris-flow, solifluction and stream action.	Forests and tea gardens
Middle	Medium-grai- ned sand- slit with occasional boulders.	Sub-rounded	Stream action and stream floods.	Forests, tea gardens, arable, land.
Lower	Fine-grai- ned sand, silt and clay	Rounded.	Stream action and stream floods.	Tea gardens, forests, arable land.

## REFERENCE :-

1. Basu S.R. and Sarkar, S. 1990. Development of Alluvial Fans on the foothills of the Darjeeling Himalayas and their geomorphological and pedological Characteristics. Alluvial Fans - A field approach - edited by Rochocki, A.H. and Church, M. 321-333.
2. Banerjee, A.K. 1980. West Bengal District gazetteer, Darjeeling. Govt. of West Bengal.

## CHAPTER - IV.

### PEDOGENESIS AND LANDUSE.

Alluvial fans form a transitional zone between the high mountains and flat alluvial plains. They present a completely different landscape and morphology than that of the mountains above or plains below. As a result the soil type and character of the area is also different resulting in a completely different landuse pattern.

#### A. PEDOGENESIS :

South of the Darjeeling hills, Red earths or the Red bank soils are developed extensively in the Terai. They generally occupy high grounds in the pliestocene plateaus and terraces in the transition zone between the Darjeeling hills and the plains. At Rohini and Longview spurs of red soil jut into the plains.

The genesis of this red soil is very interesting. Both the climate and the lithology of the rock play an equally important role in the formation of this soil. These soils are formed over the weathered rocks of the Nahun sandstones of the Lower Siwaliks in the Terai and developed extensively on huge Pliesticene deposits of boulders, gravels and clays, which form parts of the transported Darjeeling gneisses. (Banerjee, 1954)<sup>1</sup>.

The area gets a heavy, monsoonal rainfall. The comparative older age of the rocks, a dense forest cover, a warm-humid climate, as also the high content of mineral silicates in the Dalings led to a thorough chemical weathering, with formation of weak organic acids, breaking of silicates with consequent leaching. Seasonal aridity and humidity help the process of laterization. But the pedogenic process here is more in the nature of podsolization than laterization (Banerjee, 1954). These soils may be taken as typical soils formed by weathering, presence of iron oxide, alumina and clay indicates considerable amount of weathering. The Red bank soil is generally highly acidic due to the removal of lime and other bases by weathering and leaching action. This soils, however, is very rich in essential plant foods. It contains high percentage of phosphoric acid, potash, nitrogen and organic matter, compared to other average tea soils of North East India. Most of the land under this soil is occupied by tea garden with high production per acre and the quality of tea is also good. On the other hand cost of production is low.

A number of soil samples were collected from the field and investigated in the laboratory to determine the characteristics. The soil samples were collected from three stations vide Marchenbong, Marionbari tea garden and Saptiguri, located in upper, middle and lower fan respectively. The table number 5 shows the soil characteristics -

TABLE NO. 5

Sample	Locality	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Organic matter (%)	p <sup>H</sup>
M <sub>1</sub>	Marchenbong	0-10	35.2	17.9	39.9	3.23	6.1
M <sub>2</sub>	Altitude: 490 m	10-30	21.3	22.6	50.2	2.91	6.3
M <sub>3</sub>	Slope : 15-17° towards SSE	30-60	61.5	11.3	24.3	1.03	6.5
M <sub>4</sub>	Marionbari tea	60-90	73.9	8.9	15.7	0.51	5.9
Ma <sub>1</sub>	garden	0-10	28.3	20.3	44.7	3.73	5.6
Ma <sub>2</sub>	Altitude: 282 m	10-30	20.3	16.3	58.5	2.97	5.9
Ma <sub>3</sub>	Slope: 3° towards SSE	30-60	18.7	14.4	62.3	2.00	6.2
Ma <sub>4</sub>		60-80	47.3	11.1	37.3	1.31	6.0
Ma <sub>5</sub>		80-100	69.1	10.3	17.51	0.32	6.0
Sa <sub>1</sub>	Saptiguri	0-10	11.3	40.1	43.1	1.91	6.2
Sa <sub>2</sub>	Altitude: 190 m	10-30	20.1	35.3	39.3	1.72	6.4
Sa <sub>3</sub>	Slope: 1° towards SSE	30-60	25.3	31.4	40.1	0.91	6.2
Sa <sub>4</sub>		60-90	39.3	25.3	33.2	0.63	5.9
Sa <sub>5</sub>		90-120	43.4	20.7	32.9	0.23	6.0

Samples were collected in Feb, '92 and were analysed in Pedology Laboratory of North Bengal University.

The upper and middle fan segments receive high rainfall and have a good vegetal cover, therefore the process of leaching is more active in these two parts. As a result the finer particles of clay and silt moves downward, leaving silica dominated, coarse textured surface soils. The soil samples collected from the upper and middle fans indicate the fact, clay and silt content increasing at a depth of 10 to 60 cm. This is a clear indication of 'B' horizon development within the same depth. The lower fan receives much less rainfall than the upper and middle fan segments and the vegetal cover has also removed due to need of agricultural land. Continuous alternations of surface soil due to ploughing, adding of fresh sediments due to occasional fllooding and overall deforestation hinders profile development here. The samples collected from Saptiguri proof the fact. Here leaching of sand and silt is not prominent which is responsible for non-existence of 'B' horizon.

Presence of deep jungle of deciduous trees and dense seasonal under growth, which usually flourish during the rainy months and dries down during the dry season, helps considerable accumulation of organic matter in the upper and middle fan segments. In the lower fan segment tall trees or bushes is found here and there only, therefore the adding of organic matter is much less in the lower fan. Percentage of organic matter is

# LANDUSE ON THE ALLUVIAL FANS

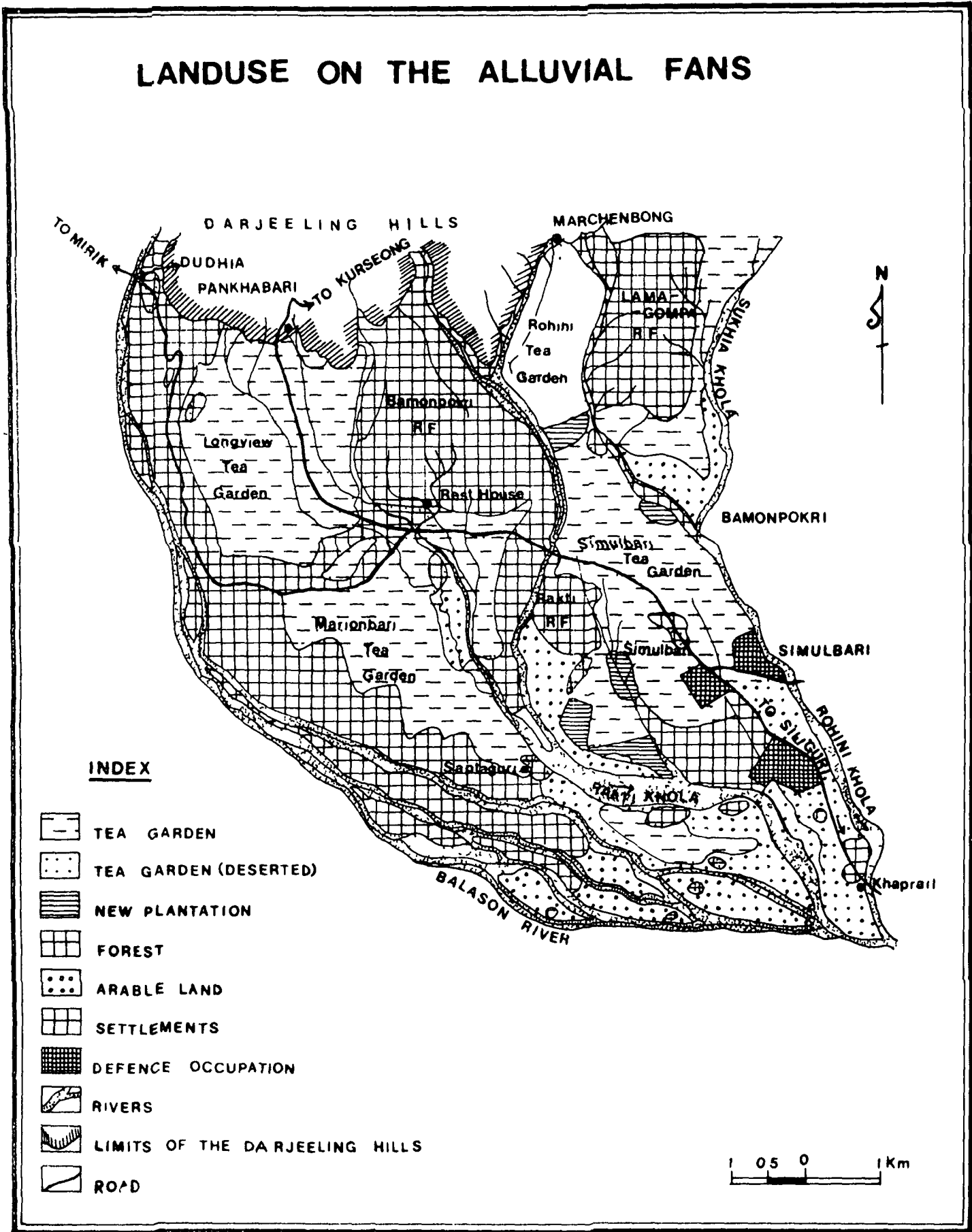


FIGURE NO. 17.

higher by 2 to 3% in the middle and upper fan than the lower. Higher rainfall on the coarse soils of the upper and middle fan segments helps leaching of organic matter from the surface soils down to a depth of 20 to 60 cm. forming a dark coloured 'B' horizons. As a result, mature to semimature soils develop with well defined horizons. This indicates that podsolization is a more active process here than laterization. But such accumulation of organic matter is not found in case of lower fan segments as the supply of organic matter to the soil is limited due to continuous, deforestation, grazing and agriculture.

The colour of soil samples collected from different depths show different shades of brown. This is undoubtedly due to the fact that the soils of the area is highly weathered and oxidised being developed on Siwalik sandstone, and Pliocene boulders, gravels and clays which form parts of the transported Darjeeling gneisses, under conditions of heavy rain.

B. LAND USE :

As the alluvial fans present distinct characteristics in all respect, the land use pattern on the fans is also different from the surrounding areas (Figure No. 17). Over the steep and hilly terrain and along the sandy and gravelly bed of the river Balason forests are found. Bamonpokri reserve forest,

# CROSS PROFILES SHOWING STRATIGRAPHY & LANDUSE

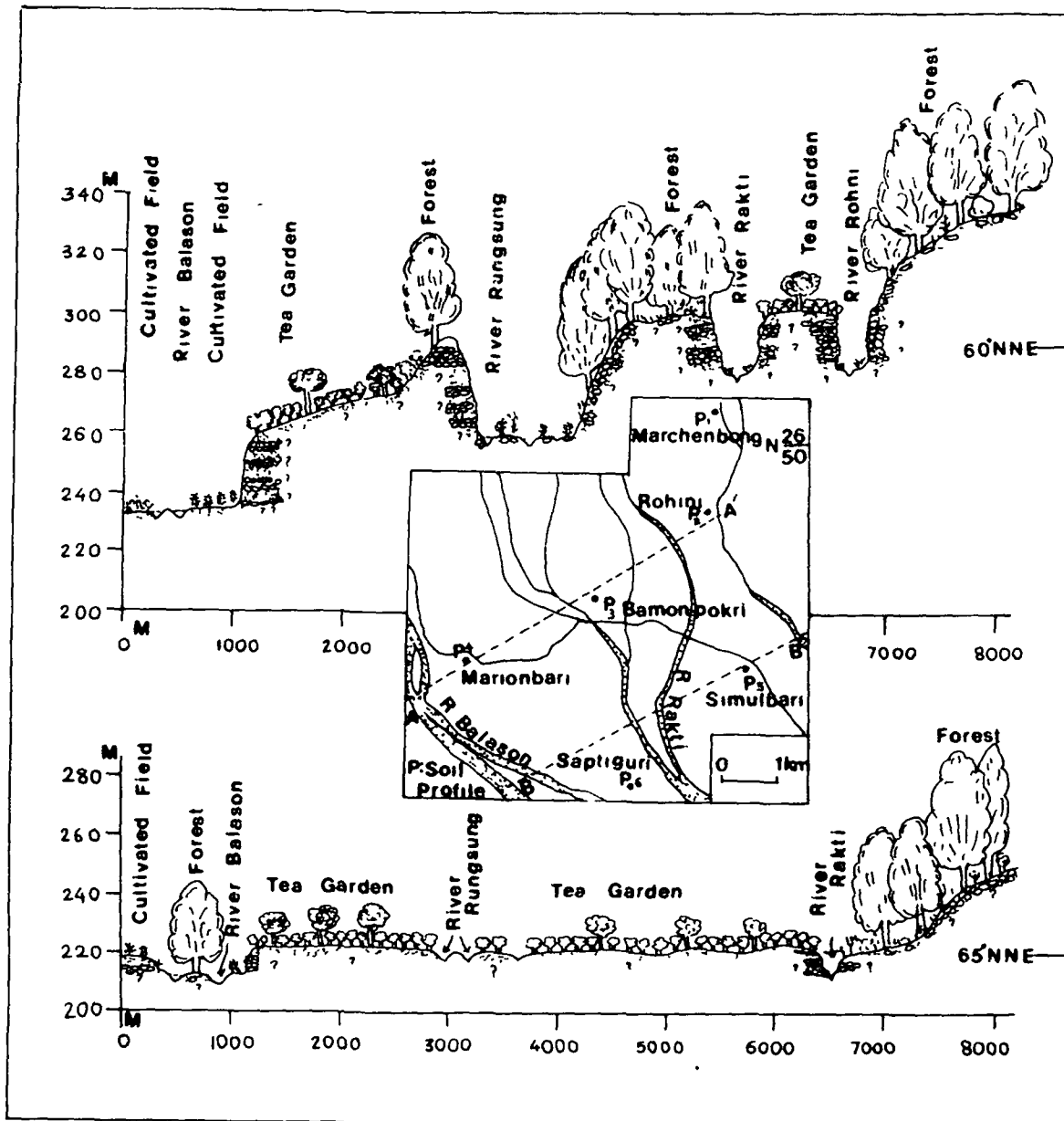
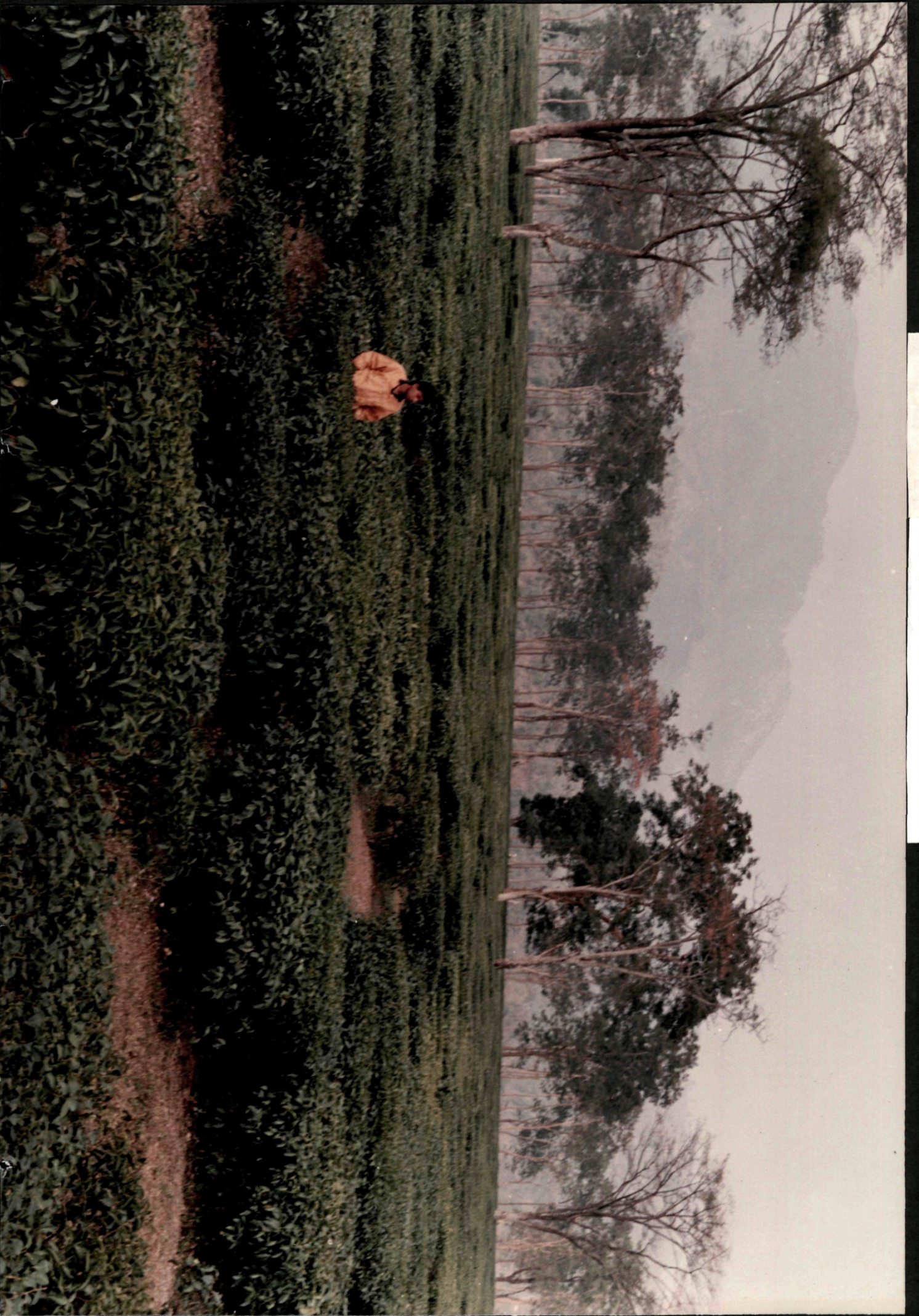


FIGURE NO. 18.

PLATE NO. 10.

Tea Garden in the middle fan.



Rakti Reserve forest and Panighata Reserve forest are the main forests of the area. They are mixed jungle of deciduous trees and undergrowth bushes and scrubs. Mountain fronts and upper fan segments are mostly occupied by forest. At places the forests has extended upto middle fan. (Figure No.10).

The rest of the fan area is occupied by tea garden with small stretches of cultivated land along the rivers of near the villages. The gently undulating topography of the area with permeable, acidic soil and high rainfall helps the cultivation of the India's highest foreign exchange earner crop-tea. All the profiles (Figure No, 10, 11, 18) shows vast stretches of tea garden with occasional shade trees and settlements (Plate No. 10).

About 90% of the land surfaces of the area is occupied either by tea garden or by forests. The rest is the arable land. Greater portion of cultivated land is located on the lower fan. To meet the demand of land for cultivation destruction of forest is a regular feature here which initiates soil erosion and flooding and hinders process of soil profile development. Cultivation is also found in the upper fan region. On the slops of high gradient step cultivation is a prominent feature (Plate)



PLATE NO. 11. Intensive cultivation by terracing on the upper fan surface.

No. 11). The fields of cultivation are found around small villages. Terracing is done by enormous human labour. Rice is the single crop and the poor water holding capacity of soil allows only one crop of rice in a year. In the surrounding hill sections shifting cultivation of jhum type is found. During field survey forest fire was found amidst the jungle on the high slopes. Destruction of forest in this way results in mass movements which supply materials to the fans.

Animal herding is an important occupation of the people of the area. The main animals are cows and goats. Extensive grazing by these animals on terrains of high gradient results in further destruction of forest and soil erosion.

The settlement of the area shows that number of settlement is greater in the lower fan segment. But settlement in the upper or middle fan is scattered small villages only consisting of 10 to 15 huts. Settlements within tea gardens are some what large with factory, hospital, school, bungalows and quarters. Besides small villages, and settlements of tea gardens another type of settlement found over the fan area is military occupation (Plate No. 12). These settlements are growing recently and are destructing forests and vegetal cover thus obstructing the natural environmental cycle of the area.



PLATE NO. 12. Recent occupation by the Military disturbing the forest cover.

REFERENCE :

1. Banerjee, B. 1954. Tea Soils of West Bangal. Geographical Review of India, Vol. XVI. No. 3. 1 - 11.

## CHAPTER V

### C O N C L U S I O N

It has been already mentioned in the first chapter that the basic aim of this paper is to analyse systematically the development and evolution of the alluvial fans with their morphological, and pedological characteristics and thus to search out the answer of the research question - whether the fans of humid Eastern Himalayas are relict? If not, why? Now time has come to assess how far the analyses and studies have been able to sort out the research problem.

The alluvial fans built by the river Balason, the Rungsung, the Rakti, the Rohini and the Sukhia is elongated in form and extends in between two extended spurs of the Himalayas- western one dividing the catchment area of the Balason and the Mechi and the eastern dividing the catchment area of the Balason and the Mahananda itself to which the Balason ultimately joins. The area presents an ideal environment for the development of fans. The high Himalayas, in front of Indo-Gangetic foredeep provided ideal geo-tectonic conditions necessary for fan development. The geometry of the fans have been closely controlled by local relief, climate, lithology, and hydrology since their first formation out of the

periglacial debris and solifluction materials during the Pleistocene Epoch. The factors helping fan formation particularly the tectonic characteristics, relief and climate of the area undoubtedly indicates that the fan forming process are still active here and this fact is also supported by the morphological characteristics of the fans.

From the field experiences and also from the analyses of the morphometric maps it can be concluded that the study area can be divided into three distinct segments -the upper or proximal part, the middle and the lower or distal part. These three parts present completely different characteristics (Table No.4a,b). The proximal part shows steep gradient, deep trenching, boldly rising scarps, huge extensive subangular boulders and moderately developed stratification. Flash floods, debris flows and soil creeps are the main processes of sedimentation here. The middle fan segment presents moderate gradient with low scarps / and lesser trenching, moderately large subrounded boulders and pebbles and less developed stratification. Stream action and stream floods are the two notable process of sedimentation here, along with occasional flash floods. The lower or distal segment present an almost flat terrain with very low gradient, wide, open and braided stream course, fine sediments with rounded pebbles and absence of any stratification of materials. Stream action and

and stream floods are the two notable processes of sedimentation here. The drainage pattern shows a higher density in both proximal and distal part, due to higher number of tributaries in case of the former and higher number of distributaries in case of the latter. Density is low in the mid-fan.

Therefore it is quite clear that fan formation is a piecemeal work and the fan segments are the result of this piecemeal process of sedimentation. The proximal or the upper part is undoubtedly the first formed part, developed as soon as the boulders and solifluction materials were deposited at the base of the mountain during the period of deglaciation by ice melted water. Later during consequent dry season the rivers made their courses easily on loose materials and thus channelisation started. With trenching this part of the fan is abandoned and active sedimentation starts in down fan location. Though subsequent work of remodelling, and gradation continues in the upper part, where mass movements and flash floods continue to add materials. With strating of channelisation and trenching here the locus of deposition further shifts down fan and here the valleys are open, wide and braided. Trenching over the fan is normally taken as an evidence of relictness, but here trenching indicates progressive elongation and enlargement of the fan area. The fans of this tropical humid area with excellent environment for fan formation is not at all

relict, they are actively enlarging their areas at the junction of hills and plains which will undoubtedly emerge into a broad piedmont zone in future.

However, excessive deforestation, increasing arable farming, overgrazing, increasing human settlements are abstracting normal sequence here. The area providing good tea soils occupied by tea gardens mainly. Arable lands with poor fertility due to low water retentive capacity are also found. The unplanned use of the fans has set the vicious cycle of deforestation, soil erosion, mass movements and floods. Deforestation is maximum in lower fan and as a result percentage of organic matter in the soil is minimum here increasing in a northward direction. Deforestation and over grazing leave the slopes bare along which mass movement is on higher scale which changes the slope and morphology of the fans.

To conclude it can be said that in the present area of study with ideal conditions for fan formation, the fan forming process is quite active with progressive enlargement and thickening of fan and this process is undoubtedly influenced by constant human interaction.

## BIBLIOGRAPHY

- Banerjee, A. K. 1980. West Bengal District Gazetteer, Darjeeling. Govt. of West Bengal. 39 - 47.
- Banerjee, B. 1954. Tea Soils of West Bengal. Geographical Review of India, Vol, XVI. No. 3. 1 - 11.
- Basu, S. R. 1989. Geomorphic characteristics of alluvial fans in India. Geographical Thoughts. 18 - 22.
- Basu, S. R. and Sarkar, S 1990.-Development of alluvial fans in the foothills of the Darjeeling Himalayas and their geomorphological and pedological characteristics, Alluvial Fans : A Field Approach, edited by Rachochki, A. H. and Church, M 321 - 334. Jhon Wiley & Sons.
- Beaty, C. B. 1970. Age and estimated rate of accumulation of an alluvial fan, White Mountain , California, U.S. A. American Journal of Science, 268, 50 - 70.
- Blackwelder, E. 1928. Mudflows as a geologic agent in simiarid mountains. Geological Survey of America Bulletin , 39. 465 - 484.
- Blissenbach, E. 1954. Geology of alluvial fans in simearid regions, Geological Society of America Bulletin. 65, 175 -190.
- Bull, W.B. 1964 B. Geology of segmented alluvial fans in Western Fresno Country, California. U.S. Geological Survey

Professional Paper, 352 - E, 89 - 129.

Bull, W.B. 1977. The alluvial fan environment. Progress in Physical Geography, I, 222 - 270).

Denny, C.S. 1965. Alluvial fans in the Death Valley region, California and Nevada. U.S. Geological Survey Professional Paper, 466. 1 - 62.

Denny C. S. 1967. Fan and Pediments. American Journal of Science, 265, 81 - 105.

Dutta, L. H. 1984. Alluvial fans in the Northern Brahmaputra, Transactions of the Institute of Indian Geographers, Vol. 6. No.2, 1 - 14.

Eckis, R. 1928. Alluvial fans in the Cucamonga District. Southern California, Journal of geology, 36, 111 - 141.

Gohain, K. and Prakash, B. 1990. Morphology of the Kosi Megafan, Alluvial fans : A Field Approach, edited by Rachocki, A.H. and Church, M. 151 - 178. Jhon Wiley of Sons.

Hack, J.T. 1960. Interpretation of Erosional Topography in humid temperate regions. American Journal of Science, 258 158-A, 80 - 97.

Harvey A.M. 1990. Factors influencing alluvial fan development is South East Spain, Alluvial fan : A Field Approach, edited

by Rachocki, A. H. and Church, M. 247 -270. Jhon Wiley & Sons.

Joshi, R.V. 1977. Development of fluvio-glacial fans and cones in the Sub Himalayan Region during Quaternary Period and their archaeological significance, Studia Geologica Polonica 52, 195 - 205.

Kochel, R.C. 1990. Humid fans of the Appalachian Mountains. 109 pp. Alluvial Fans, A Field Approach, Edited by A.H. Rachocki and M. Church, Jhon Wiley and Sons.

Lecce, S.A. 1990. The alluvial fan problem, 5pp. Alluvial Fans : A Field Approach, Edited by A.H. Rachocki and M. Church, Jhon Wiley and Sons.

Lustig, L.K. 1965. - Clastic sedimentation in Deep Springs Valley, California. U.S. Geological Survey Professional Paper, 352-F. 131-192.

Mukherjee, A.B. 1988. The Chandigarh Dun alluvial fans : An analysis of form process relationship, Geomorphology and Environment, 1988. 15-47.

Ono yugo 1990. Alluvial fans in Japan and South Korea, Alluvial Fans : A Field Approach, Edited by Rachocki, A. H. and Church, M. 91-108 Jhon Wiley & Sons.

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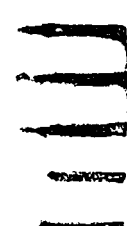
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Pawde, M.B. and Saha, S.S. 1976. Geology of the Darjeeling Himalayas, Geological Survey of India Miscellaneous Publication, No. 41.

Schumm, S.A. And Lichty, R.W. 1965. Time, space and causality in geomorphology, American Journal of Science, 263, 110-119.

Schumm, S. A. 1977. The Fluvial System. Jhon Wiley and Sons, New York, 338 pp.

Wadia, D.N. 1976. Geology of India, 364 - 389.