CHAPTER V

LANDSLIDE & ITS IMPACT ON ENVIRONMENT

5.1 INTRODUCTION

Landslide is the most pervasive of natural problems that undermine the economic and cultural development of the Kurseong Sub-Division of the Darjeeling Himalaya. Records since 1849 show a sharp acceleration in the rate of devastating slide occurrences along with innumerable lesser slips leading to the loss of life and heavy damages to land and property. The situation has deteriorated further in recent years, the last two decades having witnessed the worst landslides on hill slopes and heaviest floods in the valleys of North Bengal plain. A cursory glance at slide statistics gives a fearful idea of the enormity of the damage done in the past and present threat to the life and property. During the last 100 years, over 1000 slides were registered covering an area of over 1000 hectares. More than 1000 lives were lost in addition to the loss of property and environment and the overall economic development of this strategically important region retarded again and again.

Landslides are primarily nature's way of adjusting slope stability. However, the process has been accelerated manifold by human interference. Extensive heedless deforestation, haphazard constructional work, inadequate drainage have led to the establishment of the vicious cycle of degradation, heavy and concentrated rainfall aggravating the problem further. Implementation of the so called developmental schemes for boosting agriculture, forest and industrial growth, tourism, defence and communication on the Himalayan immature geology trigger problems, huge and complex, never encountered before.

The situation had not been so desperate a hundred and fifty years ago, when Darjeeling became the British summer resort. The hills were densely forested with very thin population and the balance of nature was well held. Curiously, Darjeeling's source of prosperity "tea",

Photo. 5.1 Menace caused by Landslides around Kurseong

has also been its bane. The tea gardens were opened at the expense of virgin forests, a practice, which was heedlessly followed till modern times. Tea workers who came in large numbers from adjoining areas took possession of any unoccupied forest land and practised shifting and slope cultivation. Thus, denuded areas between 500 to 2000 meters altitude became areas of highest soil erosion and the site for majority of landslides. The socio-geographical factors have combined with it to produce a site of very diverse sliding phenomena. Many of them endanger settlements, highways, railways and public utilities (Photo. 5.1). The residents of this area and the large influx of tourists are forced to consider themselves as possible victims of landslides.

From the available records (Griesbach, 1899-1900), it is found that the first disastrous landslide occurred on September the 24th. 1899, following unprecedented rainfall. Many episodes of disastrous landslides occurred the following years and many scientists have studied them from time to time (Basu, 1969-70; Bandopadhyay, 1980; Basu & Sarkar, 1985,1987; Dutta, 1966; Ghosh,1950; Nautiyal,1951,1966; Paul,1973; Sen-Sharma,1967,1986; Sarkar,1996; Sinha, Verma & Paul,1975; Sondhi,1966; Starkel et al,1996,1998, Verma,1978; etc.)

The aim of this chapter is to fill in the gaps of information regarding the subject with a view to find the causes of this menace and suggest measures for its prevention. It also aims to identify landslide prone areas, to provide corrective measures and to ensure an all round protection. A number of case studies have also been undertaken.

The methodology employed in this study is rationalistic one, comprising the quantitative determination of the stability factor of slope, analysis of soil, detail tabling of the composition and orientation of geological structures and the examination of geomorphological processes involved in sculpturing land surfaces, together with the study of the nature and extent of human interference. Data have mostly been collected by the investigator through field survey.

Photo. 5.2 Landslide Scars in Hope Tea Garden

Photo. 5.4 Slumping at Paglajhora

5.2 NATURE AND PROCESSES

Landslides occur in almost all types of slopes composed of various rocks in the Darjeeling Himalaya. Composite slides also take place involving soil or talus and underlying rocks. Slope failure is caused by shearing where the plane of shear taking the form of an arc of a circle in section leaving a parabolic outline of the slipped portion (Dutta, 1966). The most common occurrence of landslide is found along the springs (locally known as jhora) where, rock debris get detached from their parent body along the channel. Such channels later while carrying drainage water are generally widened by lateral erosion. Innumerable nalas (drainage channels) on hill slope developed due to slope failure and many landslides in some tea gardens and forests look like scars from a distance (Photo 5.2).

Landslides on rocky surfaces seem to be primarily influenced by the structural elements of the parent rocks. Sliding also occurs in bedding and foliation in rocks, with prominent joints and shear planes along the slope. Observations in the soil-covered slopes reveal that slopes having an angle below 300 were not generally affected by slides. The talus material is formed due to weathering and loosening of rocks along the joints and foliation planes. Such material when dry or in a permanently drained state is stable at an angle of even 45^0 and the stability is not necessarily impaired by occasional wet spell. Slope failure in such materials, however, occurs by seepage pressure of percolating water during heavy precipitation.

The tea garden slopes are generally formed of talus material with thin soil cover. Most of the slides have affected the talus material but at some places sliding along the joints have also been found. Generally, the displaced material scours long channels down the slope, which are visible as scratched scars on hill slopes. The width of these scratched channels originally does not exceed more than 25 meters or so but by subsequent erosion, they are further widened. Thus, once the slide has occurred, it generally remains a permanent feature and often increases its dimension.

Table 5.1

Number of Landslides Registered in Different Rock Types, Slope and Topographic Position

Rock Types	No.of Landslides	Slope angle (degree) & length (meter)	No. of Landslides	Major Land-use	No. of Land slides	Topographic position	No. of Land slides
Sandstone	8	$>55^0$ & >500m	25	Barren (rocky)		Ridge	1
Shale	5	$>55^0$ & <500m	12	Barren (talus)	5	Spur (upper)	17
Phyllite	30	$45\text{-}55^0$ & >500m	33	Degraded grazing land	16	Spur (middle)	15
Schists	31	$45\text{-}55^0$ & <500m	20	Natural grazing land	3	Spur (lower)	4
Slate	3	$35\text{-}45^0$ & >500m	20	Tea garden	20	Valley (upper)	8
Felspathic rocks	4	$35\text{-}45^0$ & <500m	5	Arable land	19	Valley (middle)	12
Granite and Gneiss	18	$25\text{-}35^0$ & >500m	4	Urban area	4	Valley (lower)	19
		$25\text{-}35^0$ & <500m	3	Semi urban area	6	Jhora (springs)	37
Complex geological structure	16	$15\text{-}25^0$ & >500m	4	Rural areas	8	Complex topography	15
		$15\text{-}25^0$ & < 500m	1	Constructional sites	39		
Unidentified	13	$<15^0$ & >500m	0	Dense natural forests	6		

Generally, deforested tracts, tea gardens, urban and settled areas are more susceptible than natural forested tracts. Geologically, the Dalings (phyllites, slates, schists and feldspathic

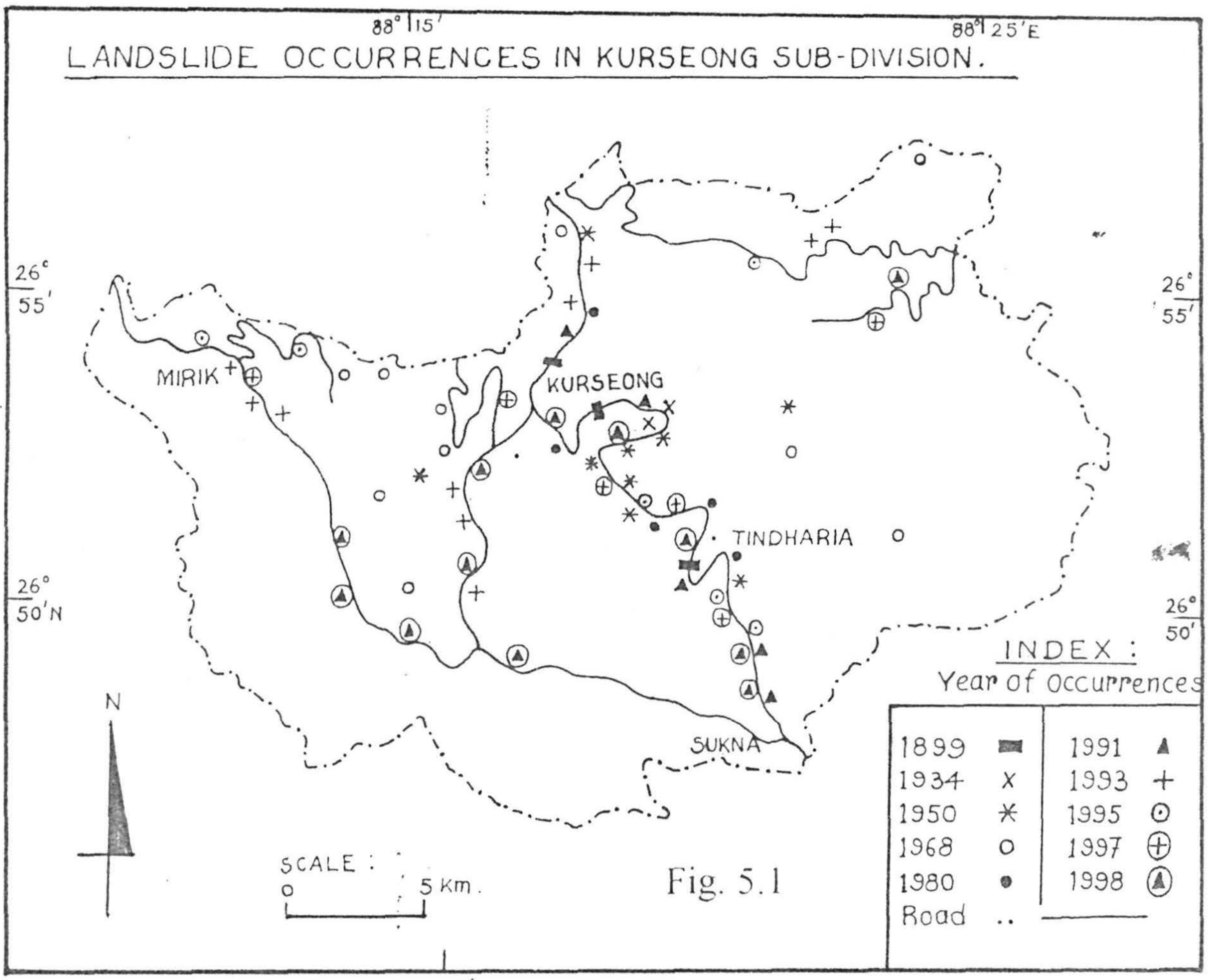

LANDSLIDE OCCURRENCES IN KURSEONG SUB-DIVISION.
88° 15'
88° 25'E
26° 55'
26° 50'N
26° 55'
26° 50'
MIRIK
KURSEONG
TINDHARIA
SUKNA
N
SCALE :
0
5 Km.
INDEX :
Year of Occurrences
1899
1934
1950
1968
1980
1991
1993
1995
1997
1998
Road

Fig. 5.1

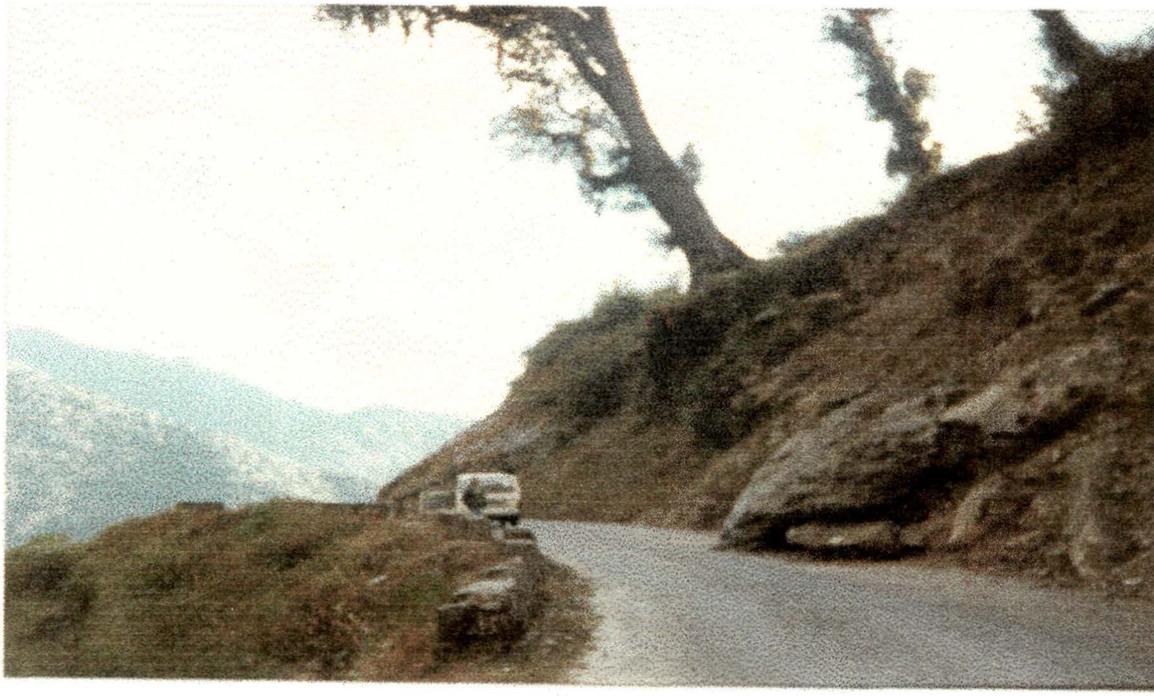


Photo.5.3a Creeps developed on bedrocks
& 5.3b Creeps developed on superficial deposits

rocks) and Damudas (sandstones, shales) are more susceptible to landslides (Fig. 5.1). Table 5.1 shows cases of major landslides, and their topographical, geological and land-use set-up in the study area:

5.3 MAJOR TYPES OF LANDSLIDES

The Kurseong Sub-Division of lower Darjeeling Himalaya is characterised by various types of slope failures. It has been observed that each landslide has its own peculiarities, therefore, for the rational solution to the problem, it is imperative that the mechanism and the causes responsible for slope failure should be apprehended properly. The following are the important types of slope failures that have been recognised by the investigator in the study area:

5.3.1 CREEPS

The slow downslope movement of slope materials is called creep. This is usually imperceptible except to observations for long duration. The study area possesses many types of field evidences which have been held to demonstrate the existence of creep including outcrop curvature, tree curvature, tilting of structures and cracks (Photo. 5.3a & 5.3b). Creeping has often been found, above the T.N.Road near Mahanadi, Tung, near Sourini, south face of Dow Hills, Castleton T.G. below Sonada, Nagri, etc.

5.3.2 SLUMPS

Slumps generally have curved failure planes, and involve rotational movements of soil and rock materials. Slumping along many roads within the study area may be either due to the removal of basal support by water action or by overloading. Another potent cause of such slumping in the urban centre is due to human carelessness i.e., leakage of water pipe lines etc. Perhaps, the best example of slumping has been found near Paglajhora (Photo. 5.4).

Photo. 5.5 Subsidence of T. N. Road near Dilaram in1998

Photo. 5.6 Debris Slide near Mirik

Apparent subsidence of the T.N. Road near lower Paglajhora (23rd. milepost) stretching for a length of about 500 meter was first recorded by Dutta in 1966. Evidences show that during 1950's disastrous landslides, a huge amount of debris was deposited below the T.N. Road, along the main Paglajhora. Subsequently, the river followed an underground channel draining through joints of the existing bedrock. Due to the enlargement of the underground passage through continuous erosion and corrosion, the basal support of the road is lost inducing the subsidence (Photo. 5.5). The rate of such movement has been estimated to be about 2.9 meters in between 1982-1986 (Basu & Sarkar, 1987).

5.3.3 SOIL SLIPS

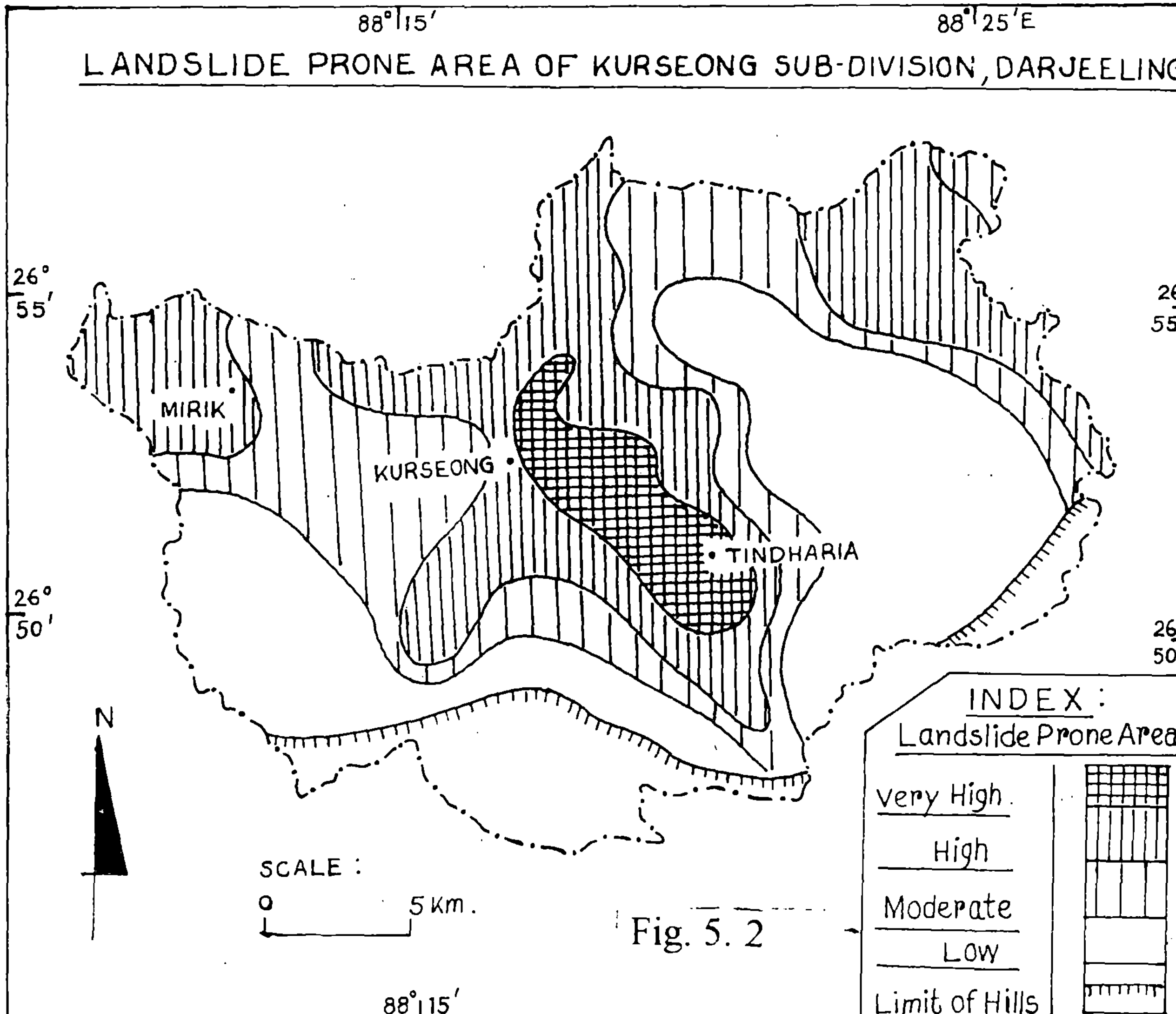
Soil slips are generally of small magnitude regarding their length and affected area. Such slips are very common and in fact found almost everywhere within the study area, particularly in between Rangtong and Mahanadi.

5.3.4 DEBRIS SLIDE

Debris slides are generally of greater magnitude and are common and devastating too. Debris slide is caused along the weak plane even when they have gentler inclination than the "angle of sliding frictions" by the reduction of cohesion due to weathering and the rise of piezometric head. Debris slides are very common in and around Tindharia, Chunabhati, Mahanadi (Photo. 5.6).

5.3.5 MUD-ROCK FLOW

Most slips found in the study area are confined to the slope formed of talus material and where the slope angle is slightly more than 40^0, due to seepage pressure of percolating water as a result of heavy rainstorm. After a slip starts, the saturated material rushes down transporting big blocks of rock eroding the channel of its own. These are known as mud-



88° 15′
88° 25′E
LANDSLIDE PRONE AREA OF KURSEONG SUB-DIVISION, DARJEELING.
26° 55′
26° 55′
26° 50′
26° 50′
MIRIK
KURSEONG
TINDHARIA
N
SCALE :
0
5 Km.
INDEX :
Landslide Prone Area
Very High
High
Moderate
Low
Limit of Hills
88° 15′

Fig. 5. 2

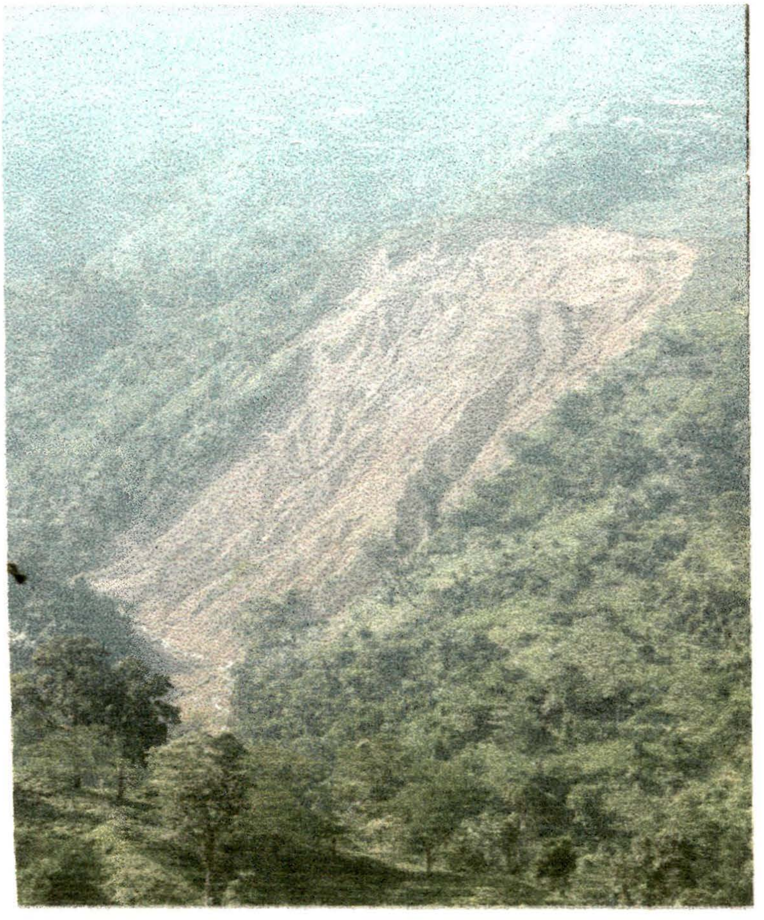


Photo. 5.8 Debris Flow near Tindharia

Photo. 5.7 Mud-Rock Flow along T. N. Road

rock flows. This type of landslide is very common in and around the lower Darjeeling Hills, particularly along the natural and artificial waterways (Photo. 5.7).

5.3.6 DEBRIS FLOW

This is another very common form of landslide found in the Kurseong Sub- Division. Here, over saturated slope material slide down at very high speed (Photo. 5.8).

5.4 LANDSLIDE PRONE AREAS

Identification of landslide prone areas has been done with the help of "check list" where each separate and discrete slope unit has been classified according to their stability rating. Rating has been done according to a scale from stable through the degrees of potential instability to those slopes, which have already failed. Special attention has been paid to the old slides, which could become reactivated. The excavation position and depth, drainage diversion across the hills, loading of the upper slopes and valleys, cutting up of basal support, unscientific construction and land-use, deforestation, legacies from the past slope movements, relief, drainage slope materials, etc. have been accounted for in the check list (Appendix 5.1). Data for such investigation have been collected from the direct field observation (150 sample sites) as well as from other secondary sources. A landslide-prone zone map has been prepared and is shown in Fig 5.2.

The map as represented in Fig. 5.2 shows some striking features, such as some tracts of the study area, especially along the Tindharia-Mahanadi, Pankhabari, Chunabhati, Ambutia, Selim hills, etc. areas posses very high susceptibility while, ridges, eastern part of Mahananda valley, Mirik Domes and some parts of forest covered lower hill exhibit moderate to moderately low susceptibility. However, for a better understanding of the geographical distribution of major landslide prone areas, the following classes have been put forward:

Class I: Exceptionally High Slide Prone Areas: These are the areas where landslides are very common, and almost every year, during monsoon, some of the tracts experience slips. Three such pockets have been identified with the help of the checklist; (i) in and around Tindharia-Chunabhati, (ii) around Paglajhora and (iii) in and around Ambutia tea garden. Slide occurrence in these areas are of great concern because they not only cause heavy damage to land, property and human life, but also disrupt the vital communication link through the T.N. Road, the life line of the Darjeeling hills

Class II: Very High Landslide-Prone Areas: Many settled areas and tea gardens of Kurseong Sub-Division may be treated as very high slide prone areas, due to steepness of slope coupled with excessive human interference. Occurrence of slide is common in these areas and this often causes heavy damage to tea gardens, settlements and arable lands.

Class III: High Slide-Prone Areas: Most of the hill slopes, valleys with moderate forest cover may be categorised as the high slide prone areas. A number of landslides have been registered during the field investigation, but due to their location in uninhabited areas they seldom invite human attention.

Class IV: Moderate Landslide-Prone Areas: Most of the eastern and southern parts of the study area fall under this category.

Class V: Low Slide-Prone Areas: Few pockets of low to very low slide-prone areas have been identified in the study area. The following are the areas, which may be treated as stable and/or safe zones; (i) along the southern flank of the study area, (ii) ridge tops of Mahaldiram, Mirik, Okaiti, Tingling and (iii) some upland terraces scattered all over the study area.

5.5 PREVENTIVE MEASURES

The stabilisation of landslide and landslide-prone areas must be executed according to a well thought plan, which lists individual measures according to their urgency. The following points should be considered before initiating difficult and expensive stabilisation work:

- The effects of a particular preventive measure changes with the engineering and geological conditions of the site.
- The choice of the techniques that are to be applied for prevention of the slope movement is also influenced by several aspects of economic character/condition.
- The local conditions of the site play a dominating role in assessing potential slide-prone areas.
- The importance of the project also influences the measure to be taken to tackle this problem.

It is important to distinguish between those physical characteristics of a site which make landslide possible and the actual cause i.e., the trigger mechanism. In the study are, it has been found that the increase in pore water pressure or rise in "piezometric head", constitute the trigger mechanism for most cases. Potentially most stable hill slopes are also sensitive either to an increase in the load, which they bear at the top or a decrease in the amount of support, which they have at the toe. To recognise which of these causative factors is in operation can in itself suggest the cure. Thus, the principles to be observed in suggesting preventive measures would naturally depend upon the causes that lead to the failure of a slope. The investigator has suggested the following preventive measures in the study area:

5.5.1 TREATMENT OF SLOPE CONFORMATION

The slope of the ground surfaces plays an important role in causing slides in soil and talus materials. Stability of a slope is thus, possible to be maintained by the reduction of the angle of slope. However, this method can be used in only some restricted parts of the study area.

5.5.2 THE DRAINAGE OF LANDSLIDES

Drainage plays the most crucial role in producing slope instability in the study area. The surface drainage of an area affected by landslide is generally uneven, hummocky and traversed by deep fissures. In the depressions and fissures, water accumulates and creates wet ground. To offer stability to such slope, all streams and temporary water sources are to be diverted from the threatened area. Moreover, all springs issuing within the affected area, especially those at its head, must be contained and diverted away from the slipped area. For an immediate provisional diversion of flowing water, any available pipe may be used. After partial stabilisation, open ditches of adequate dimension and gradient are to be constructed for discharging the rainwater. The ground surface is to be levelled and the depression to be filled up along with the filling up of all cracks, so that a continuous run-off of surface water is ensured. During such operation, the grass cover must not be disturbed unnecessarily, as it not only protects the soil from splash erosion but also prevents percolation. Prevention of percolation should be ensured at the slide areas by covering up the portion of the slope by a layer of impervious materials like clay. It has been observed that turfed slopes remain stable upto a great height than bare slopes (Sinha,Verma & Paul,1975). Turfing should therefore, be encouraged on every bare slope. Rocky slopes with open joints can be made impervious by grouting, although it is an expensive method, yet to protect T.N. Road near Tindharia, Paglajhora, Gayabari, it may be recommended.

5.5.3 RETAINING WALLS AND SIMILAR STRUCTURES

Retaining walls are erected to bring greater stability to the unstable slopes and to check the existing landslides. Construction of retaining walls become necessary especially in slopes formed on clayey soils where it is difficult to ensure drainage due to the impermeability of the materials. In Kurseong Sub-Division, most of the houses, road sections are protected by retaining walls. They are mostly built of dry rubble masonry. Some of these walls which are built of reinforced concrete have failed due to lack of adequate design. The retaining walls are found to be very weak along the T.N. Road and in the congested busty areas of Kurseong, Sonada, Tung, and Tindharia, where landslips are common and these walls are not based on proper foundation. Such structures instead of affording any protection actually contribute to the failure of the slope due to the addition of extra weight caused by seepage pressure. The retaining structures thus, should have proper weep holes for proper draining of the accumulated water without interruption. Proper and periodic maintenance should be made, so that such an outlet can never get clogged.

5.5.4 STABILISATION BY AFFORESTATION

Slope movements generally disturbs vegetation including grass cover. Afforestation of the disturbed slopes is an important part of any corrective treatment and it should be carried out during the later stages of the work, invariably after at least some degree of stabilisation of the slip has been achieved. The plantation should be proceeded by drainage along with the filling up of cracks of the affected area. Contour watling is an effective method of stabilising slip areas. It should be followed by planting of grasses like *Arundodonax* and *Saccharum* species, shrubs like *Viburnum* species, *Vitex negundo*, *Thysanolaena maxima* and tree species *like Erythrina suberosa*, *Alnus nepalensis*, *Macaranga* species and locally available bamboos.

5.5.5 RESTRICTION OF SETTLEMENTS

For a successful management of the susceptible tracts under study, it will be very useful to restrict the existing population to the geologically and topographically more stable part (granite and gneissic areas and areas having slopes less than 30^0) in the hills, setting apart the unstable areas (Dalings. Damuda and Siwalik rocks and areas having slope more than 30^0) which have to be carefully demarcated for afforestation by quick growing trees and grasses.

5.5.6 STABILISATION OF TEA GARDENS LANDSLIDES

In the tea gardens, prevention of landslides is not the only problem. It is also necessary to prevent widening up of the slip channels and fill them up and bring the area back into cultivation, if possible. For this, it would be necessary to reduce the gradient of the channels

CONTOUR PLAN AND ROCK ELEMENTS OF THE ST. MARY'S LANDSLIDE
KURSEONG

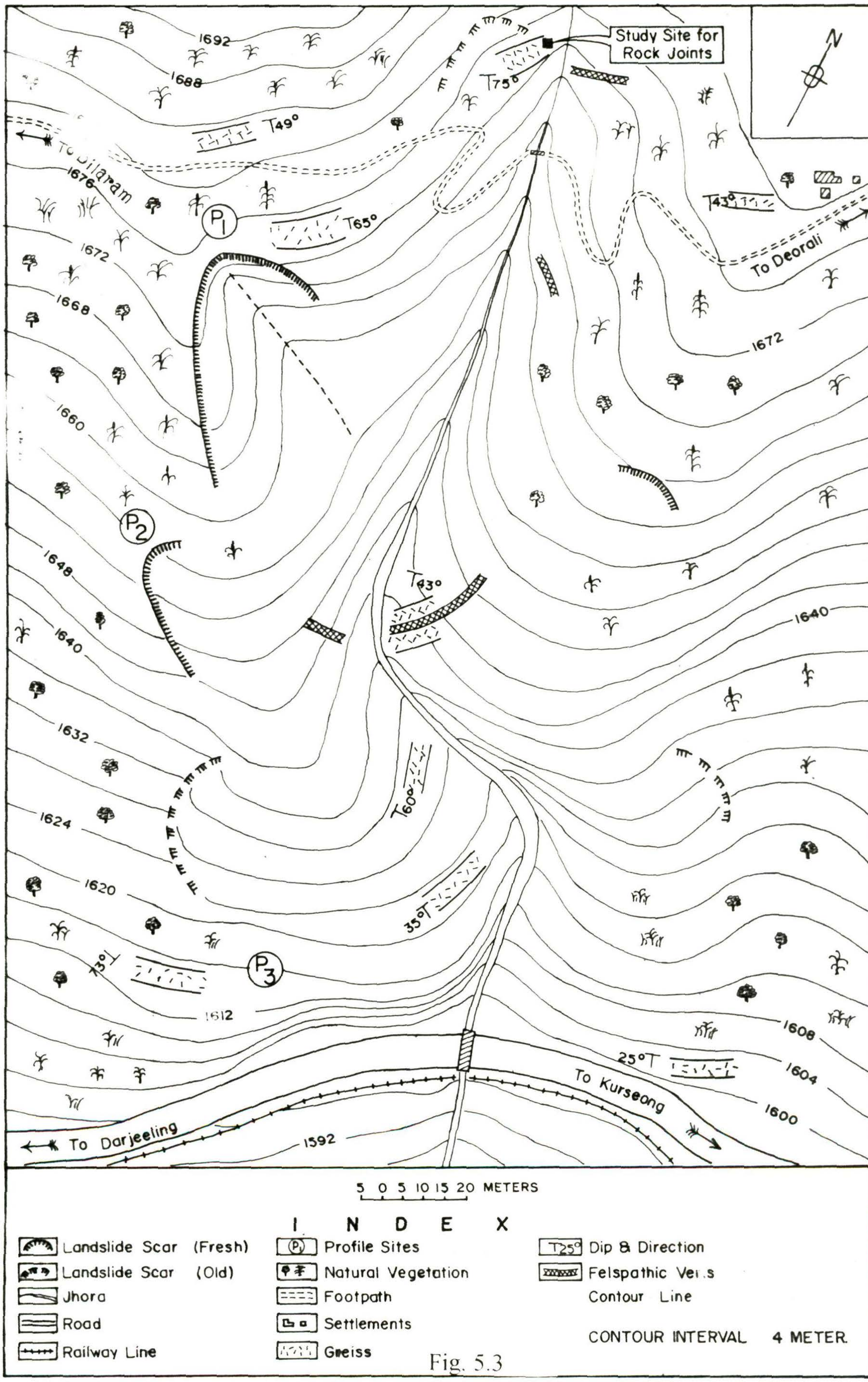


Fig. 5.3

GEOMORPHOLOGICAL MAP OF THE St. MARY'S HILL LANDSLIDE KURSEONG

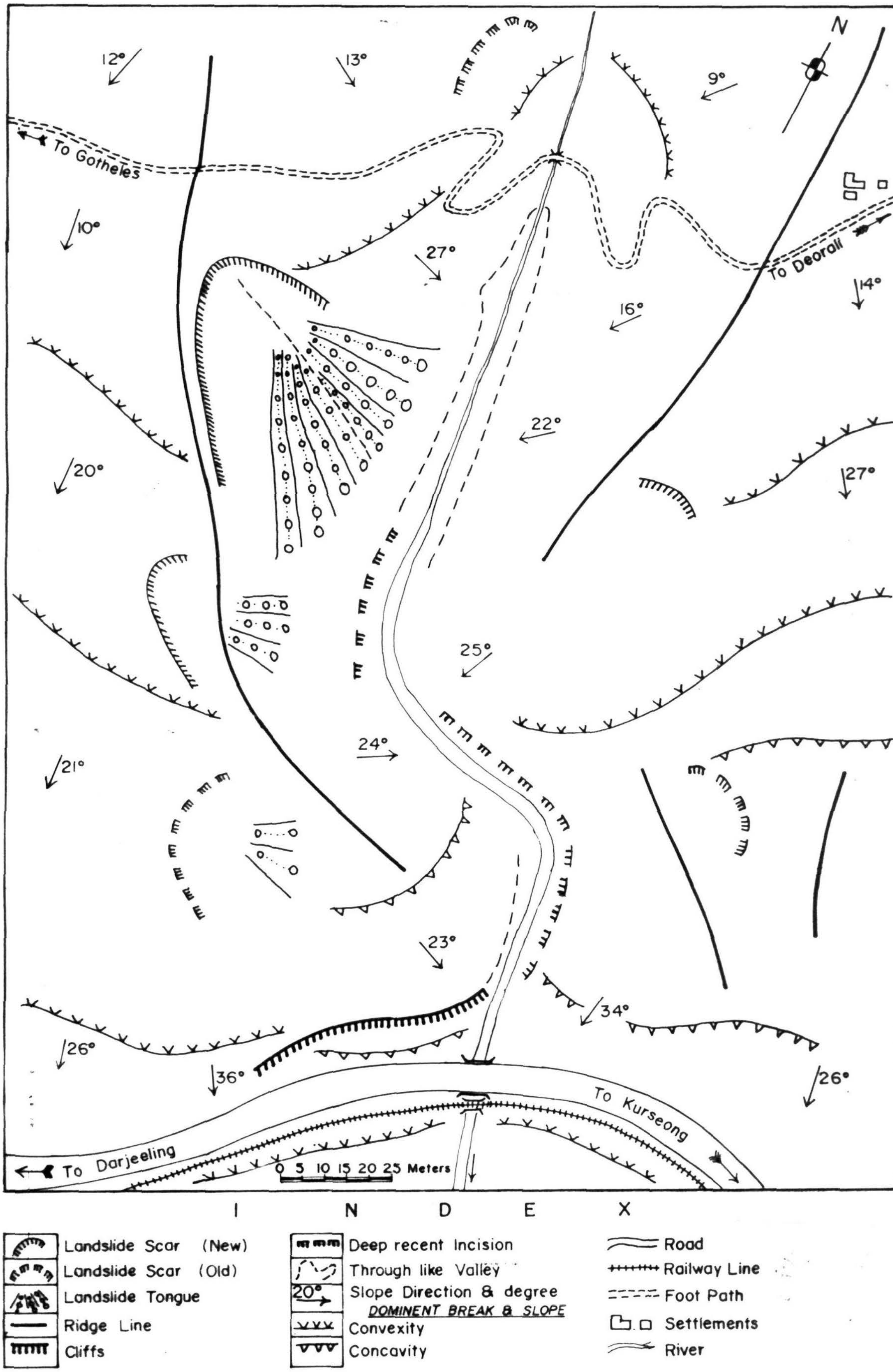
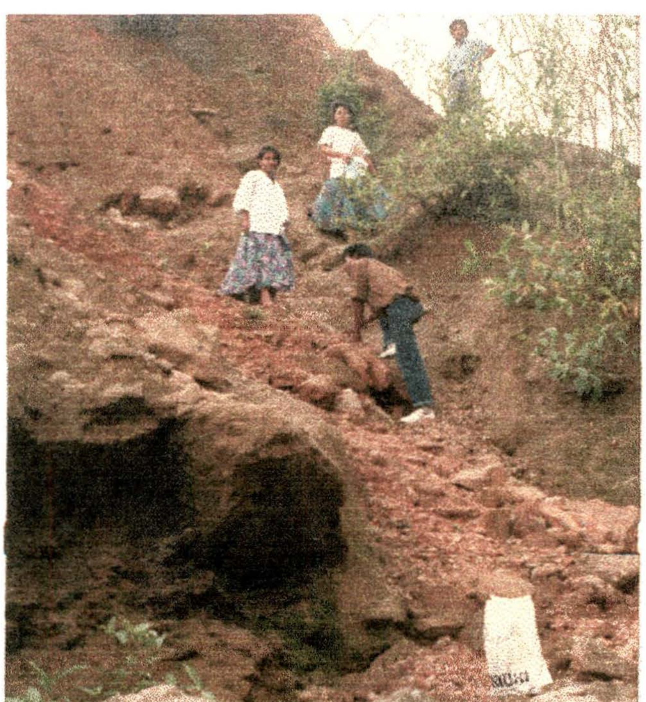
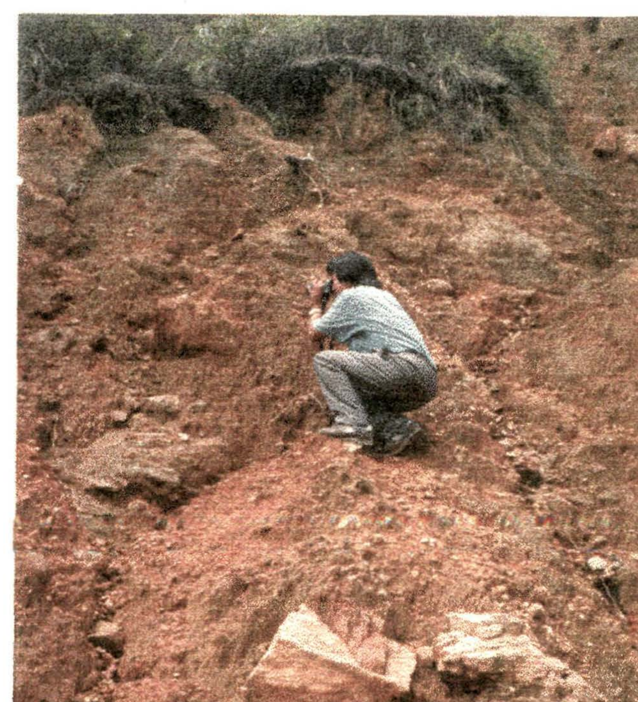


Fig. 5.4

Photo. 5.9 Landslide at St. Mary's Hill





by building check dams across them. Such dams may help in filling up the channels and thus assist in reclamation. The dams should be rock fill type and should use slip debris as fill material. In the lower portions of the dam, the rock boulders should be covered by turfing of shrubby vegetation to prevent further erosion.

5.6 CASE STUDIES OF SELECTED LANDSLIDES

From the foregoing analysis, it is apparent that many parts of the lower Darjeeling Hills (Kurseong Sub-Division) have been experiencing devastating landslides. To apprehend the exact nature of this menace and to understand the mechanism of such failures, the investigator has tried to undertake three case studies, selected from different environmental set-up. The study, though having a few unique features, may yet seem to be representative of the landslide of the study area, nearly everywhere, as human need and greed accelerated slope failures.

5.6.1 ST. MARY'S HILL LANDSLIDE

On the August 26, 1994, following heavy shower amounting 56.3 millimetres within a period of 1 hour and 35 minutes, with a maximum intensity of $55 mm/h^{-1}$, recorded at Dilaram, the hill slopes at 4.2 kilometres from Kurseong to Darjeeling, on the right hand side of the Tenzing Norgay Road, experienced a devastating landslide (Photo. 5.9). disrupting the traffic flow from Kurseong to Darjeeling (Fig. 5.3 & 5.4).

5.6.1.1 Factors of Slope Instability

To recognise the causes of failure and the factor that trigger the downhill movement of the slope materials, is of extreme importance, because only a precise and correct diagnosis can serve as a basis for effective remedial measures. A comprehensive analysis of such factors have been outlined in the following paragraphs:

Geological Factors :

The region under study is composed of slightly altered rocks belonging to the Darjeeling gneiss, of which coarse granite foliated gneiss and mica- schists are common. The rocks are dipping at angle of 25^0 to 75^0 towards SSE, SSW and WWN. The rocks are also traversed at places by quartz and quartzo-feldspathic veins of both post and pre-tectonic periods. These are well jointed (40^0 - 70^0 E-W) and highly foliated (28-55^0 SSE-NNW) rocks (Fig. 5.3). The St. Mary's hill landslide has been identified precisely by the investigator on foliated coarse-grained gneiss, characterised by cataclastic deformation. Weathering affects the rock conspicuously. Both diurnal and seasonal ranges of temperature characterised by alternate expansion and contraction has given rise to vertical cracks within the rock especially along zones of weaknesses. As a result, solid masses of rock beds disintegrate into blocks. Moreover rain water seeps through the joints and cracks, helps in decomposing feldspar to form kaolin which often acts as lubricant for sliding of slope material (Fig. 5.5).

Effects of Jointing:

The rocks in and around the slide area are found highly jointed. These are bold and intersected at many nodal points. To apprehend the nature of such joint system and its impact on slope instability, the investigator has made a detail survey. The nature and geographical distribution of the joint has been shown in Fig. 5.6. The density of joint has been estimated to be 6.71 meter/square meter of which 41% is bold, 32% is minor and remaining 27% has been identified to be incipient in nature. These closely spaced vertical or inclined joints have acted as pathways for rainwater to percolate and induce chemical and physical weathering and thereby reduce the shearing resistance of the gneissic parent rocks.

Pedological Factors:

In order to comprehend the nature and role of soil as a factor of slope instability of the slide area, a number of sample pits have been dug at the edge of the scar, to collect samples from

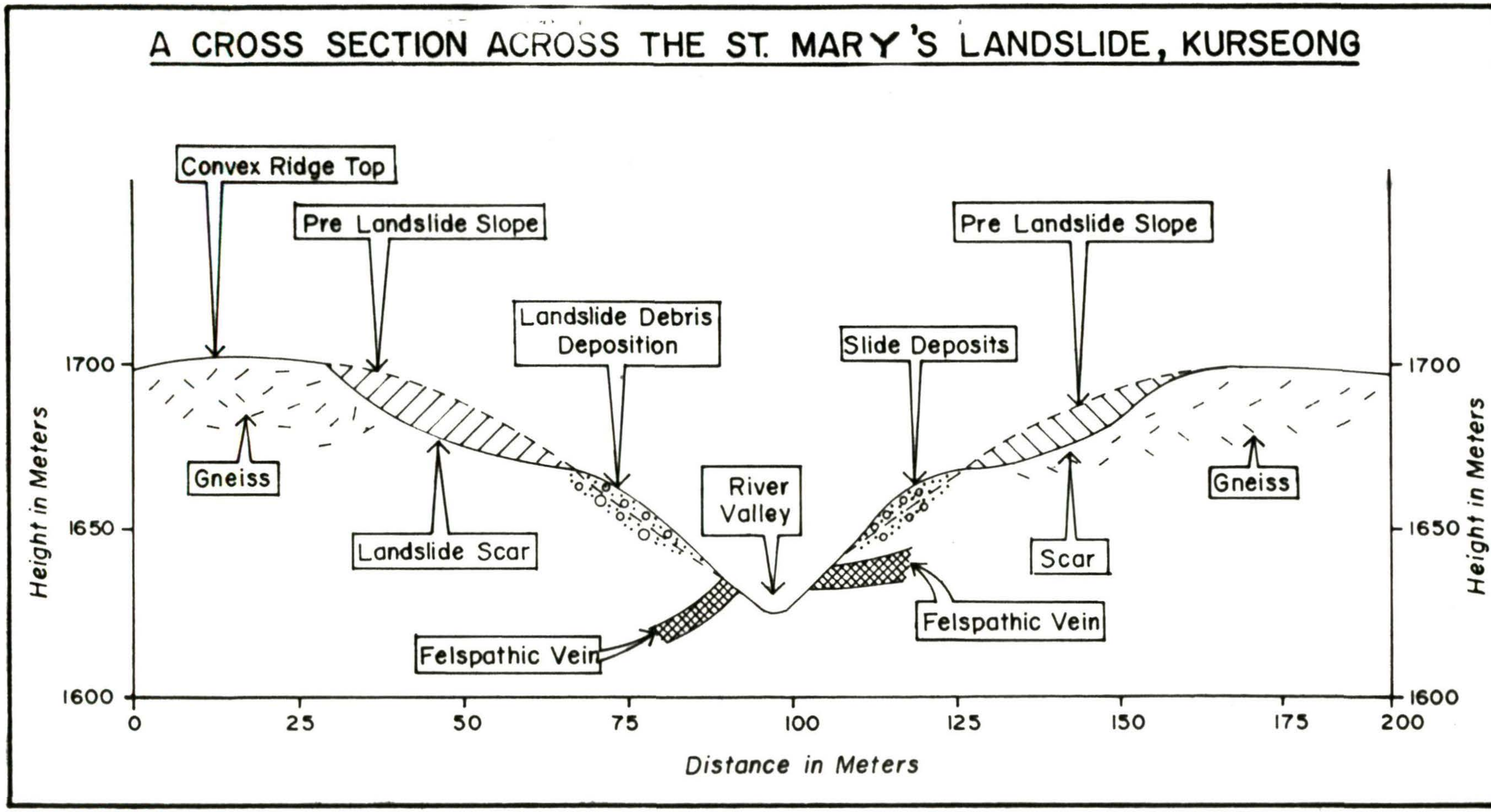
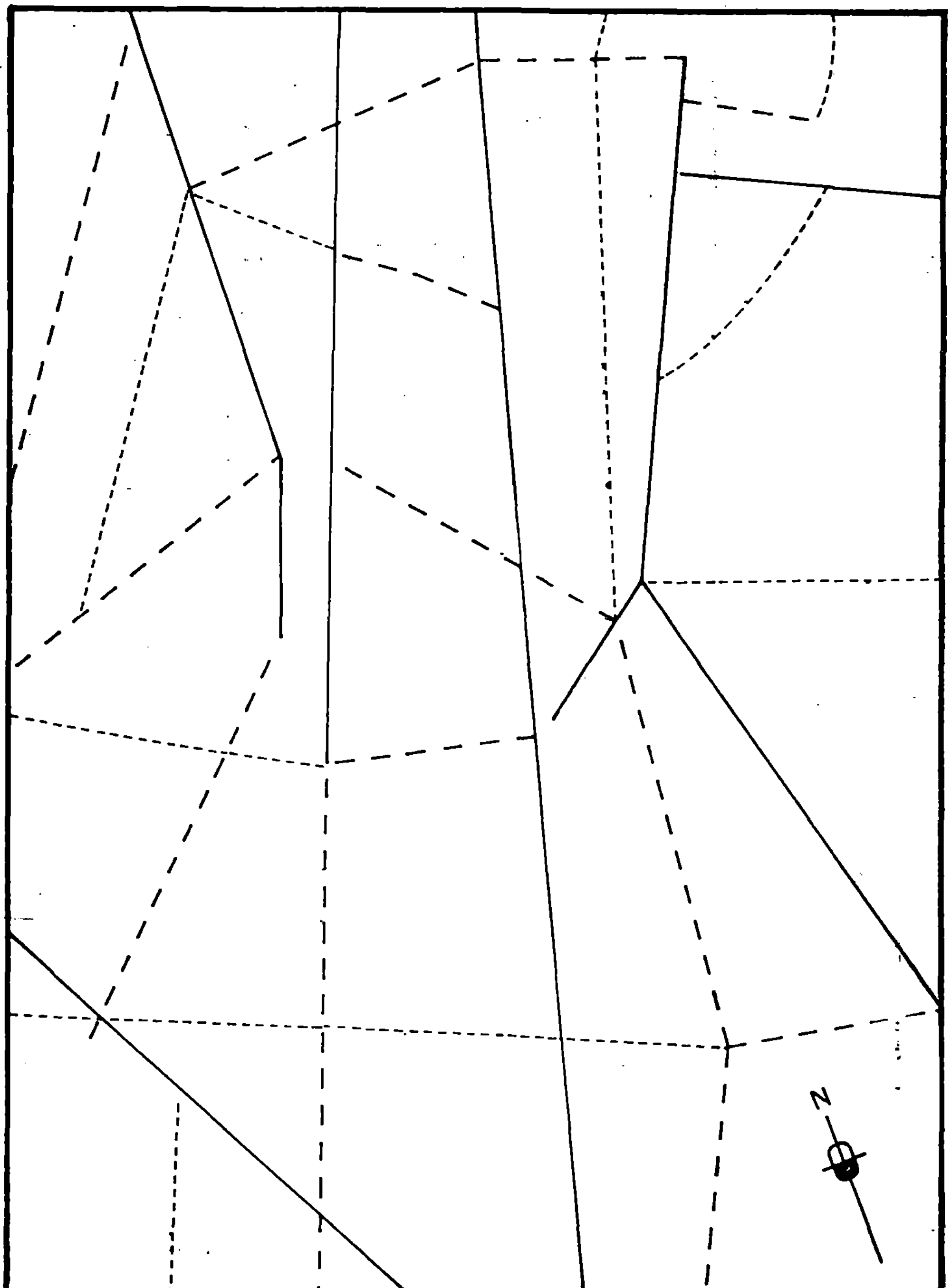

A CROSS SECTION ACROSS THE ST. MARY'S LANDSLIDE, KURSEONG
Convex Ridge Top
Pre Landslide Slope
Landslide Debris Deposition
Slide Deposits
Pre Landslide Slope
Gneiss
Landslide Scar
River Valley
Scar
Gneiss
Felspathic Vein
Felspathic Vein
Height in Meters
Height in Meters
1700
1650
1600
0
25
50
75
100
125
150
175
200
Distance in Meters

Fig. 5.5

THE NATURE OF JOINTS DEVELOPED ON GNEISS NEAR ST. MARY'S LANDSLIDE, KURSEONG



INDEX

——— Bold Joints

— — — Minor Joints

------ Incipient Joints

Fig. 5.6

SCALE

10 0 10 CM.

undisturbed areas. The samples have been analysed for the determination of water holding capacity, pore-spaces, volume expansion, hygroscopic moisture, organic carbon, plasticity, mechanical composition and infiltration rate. The analytical results have been tabulated in Table 5.2a and 5.2b. The analytical results reveal that the physical characteristics of the soil of the slide area are very interesting in the sense that at the apex, vulnerable conditions have been naturally developed at a depth of 30 to 40 cm below the surface, where clay predominates with a good amount of organic matter, high water holding capacity, volume expansion and plasticity limit.

Table 5.2a

Rate of infiltration of 3 sites at St. Mary's Landslide*

Sample sites	0-15m	15-30m	30-60m	60-120m	120-180m	Total upto 3 hrs
P1	385	209	169	75	43	881
P2	290	130	159	209	84	872
P3	312	135	123	93	62	725

* Rate of infiltration in millimetre/minutes has been measured with the help of a galvanised steel tube with a diameter of 20cm, which has been inserted into the soil maintaining a head of about 6millimetres above the ground during field investigation.

Changes in the Vegetational Cover :

The apex of the slide under study has been deforested and turned into cultivated terraces by local inhabitant. Such unscientific terraces are seldom laid along the contours with proper protective wall and thereby disturb the cohesiveness of the soil and make it vulnerable to erosion. Thus, slope under study being devoid of proper vegetative mat, remain fully exposed to heavy and concentrated monsoon shower and are susceptible to both sheet and gully erosion.

Table 5.2b

Soil Properties of The St. Mary's Landslide

Depth in Cm	Water Holding Capacity %	Pore Spaces %	Hygroscopic Moisture %	Organic Carbon %	Sand %	Silt %	Clay %	pH	Nitrogen %
0-10	37.42	69.07	4.51	3.01	33.5	10.51	55.99	5.30	0.19
10-20	21.53	51.73	3.81	1.92	34.01	9.01	56.98	5.60	0.12
20-40	41.14	47.46	2.42	0.81	44.79	6.50	48.71	5.80	0.08
40-80	18.73	43.91	1.19	0.50	58.4	4.00	37.60	5.70	0.02
Profile No.1									
0-10	30.43	65.81	2.02	2.73	45.71	10.71	43.58	5.50	0.15
10-20	25.01	45.79	3.51	1.81	50.43	8.42	41.15	5.70	0.08
20-40	35.45	49.81	2.91	1.05	40.76	4.51	54.73	5.90	0.04
40-80	24.13	36.51	1.93	0.75	65.01	4.00	30.99	5.10	0.04
80-120	19.95	34.00	1.80	0.61	69.05	3.05	27.90	5.40	0.02
Profile No.2									
0-10	32.73	70.41	3.43	2.71	39.51	12.41	48.08	5.60	0.16
10-20	26.61	64.81	2.91	2.01	38.42	10.75	50.83	5.90	0.10
20-40	34.75	43.15	2.10	1.75	32.75	4.73	62.52	6.10	0.08
40-80	24.80	40.15	1.81	0.65	61.51	4.60	33.89	6.20	0.04
Profile No.3									

Effects of Rainfall, Run-off and Infiltration :

The amount and intensity of rainfall often play a significant role in causing slope failure in Darjeeling Himalaya. In most cases, high intensity rainstorm acts as so called "trigger mechanism" for landslide to initiate. This water percolates through the cracks, joints and pore spaces of the slope material and thereby, increases the pore-water pressure and changes the consistency as well as the shear resistance of the soil ultimately loosen its cohesion. Under such suitable circumstances, with the onset of monsoon, rill cutting as well as gully erosion start and the slope become further denuded as the surface water flows through these channels.

Effects of Human Interference:

Deforestation, expansion of settlements, unscientific terracing and slope cutting are some of the noticeable issues of human interference in and around the study area. Oversteepening of slope by road cutting is the most important human induced process that removes the basal support and thereby, makes the slope vulnerable for further degradation. Field investigation reveals that the rain water, infiltrates into the rock through joints and cracks, disturbs the internal homogeneity of coarse textured foliated micaceous gneiss criss-crossed by felspathic and quartzo-felspathic veins. This causes hydrolysis, followed by the production of kaolin, which often acts as lubricating agent for sliding of slope materials.

5.6.1.2 Morphology of the Landslide

Morphological account of the pre and post-slide conditions of study area is given in Table 5.3 to follow the exact sequence of the disaster and to arrive at a logical working out of remedial measures.

5.6.1.3 Prevention and Control of the St. Mary's Landslide

The investigation therefore reveals the various factors like the geological setup, soil and hydro-geomorphological history, process of slope evolution, precipitation, deforestation and human interference have all, combined to result in the occurrence of the landslide. Prevention and control of such a landslide is a difficult task and requires good mechanical

Table 5.3

Morphological Features of St. Mary's Landslide

Pre-Slided Conditions	Post-Slided Conditions	Remarks
1. Rocks: Moderate to highly decomposed jointed, foliated, micaceous gneiss, interbedded with 1-2cm felspathic and quartzo-felspathic veins. The rocks are highly jointed 31^0 - 69^0 towards N-S, NE, SE and NNW-SSE. The rocks are dipping at an angle of 25^0 - 75^0 towards SSE, SSW and WWN. 2. Altidude : 1620 - 1684m 3. Slopes : Convex, 30^0 - 47^0 towards SSE. 4. Rainfall: Intensity $55mm/hr^{-1}$. 5. Natural Vegetation : Scattered bushes and shrubs. 6. Land-use: Degraded forests and grasslands, few cultivated terraces are also noticed around the apex to the affected area. 7. Soil Colour : top : 7.5 YR 4/2 mid : 7.5 YR 6/6 bot : 7.5 YR 4/3 8. Soil saturated during the survey.	1. Length of the Scar: Variable, average 25 meter. 2. Width : max : 15 meter min : 2 meter ave : 8-15 meter 3. Depth : max : 3 meter min : 0.5 meter ave : 1.75 meter 4. Shape : Triangular. 5. Total area affected : 720.5 square meter (total of 4 slides). 6. Total volume displaced : 1261 cubic meter. 7. Processes responsible for the landslide: Removal of basal support, stream incision and solifluction. 8. Modified slope : Concave: 20^0 to 67^0 towards SSE. 9. Type of slide: Debris slide. 10. Special features: A number of channels have developed on the slope being aided by the dip direction of the country rocks.	Displaced materials temporarily blocked the water movement through the stream. It also disrupted the road and railway communication between Kurseong and Darjeeling. Immediate construction of protective structures with adequate drainage facilities is recommended. Afforestation along the upper part may help in providing long term remedial measures for such slope degradation.

Compiled by the Author during field investigation on August 30, 1994.

Photo **5.10** Landslide at Bhanjan

and biological measures. The measures of prevention and control should include the following:

- Easing of the slope by slope re-gradation,
- Safe disposal of water through surface and sub-surface drainage using concrete slabs
- Construction of good retaining walls with proper weep holes
- Afforestation with soil binding grasses and quick growing shrubs and trees
- Jhora training works by construction of guide walls and drop structures

The basal support of the steep slopes due to construction of roads have to be strengthened by construction of proper retaining walls which should be regularly maintained. The steep slopes caused by the landslide have to be re-graded to gentle slopes over which grasses and quick growing shrubs and trees can be grown along the contours. The flow of jhoras has to be controlled by carefully designed guide walls and drop structures so as to minimise the scouring effect of water and toe erosion. Terrace cultivation near the landslide area and along the jhora banks should be discouraged. Cultivation near the household areas should be practised along contour terraces.

5.6.2 THE BHANJAN LANDSLIDE

During 2nd July, 1995, the hill slope and crest at 48 kilometres on the Siliguri-Mirik Road (Latitude 26^0 58' N and Longitude 88^0 10' E), experienced a devastating landslide, disrupting the road communication for a couple of days (Photo 5.10). To comprehend the exact nature of this menace and to understand the mechanism behind such failure, the investigator has initiated an intensive survey and field investigation during August 13th 1995.

5.6.2.1 Factors of Instability

Geological set-up:

CONTOUR PLAN FOR THE BHANJAN LANDSLIDE AND ITS ENVIRONS

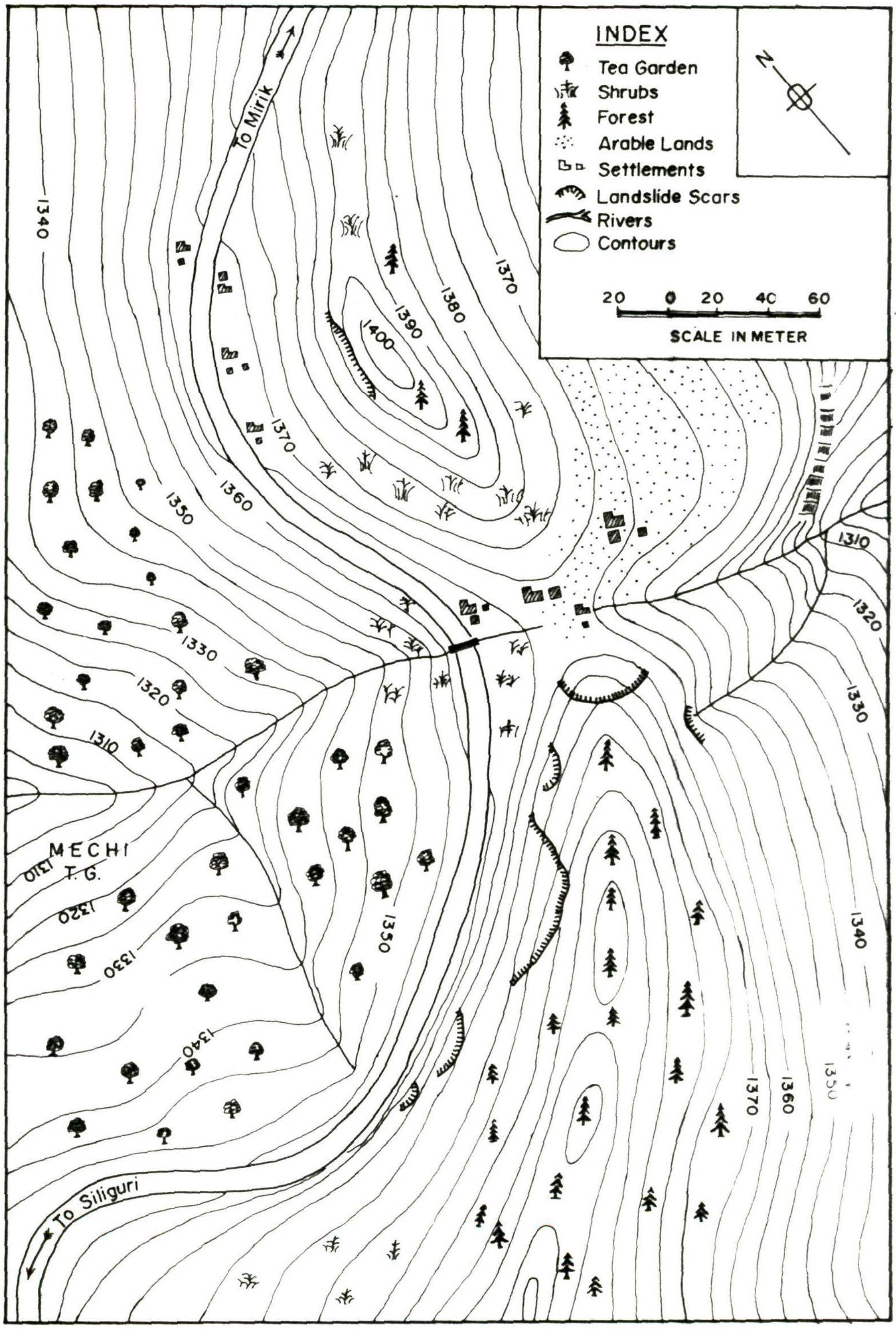


Fig. 5.7

GEOMORPHOLOGICAL MAP OF THE BHANJAN LANDSLIPS AND ITS ENVIRONS

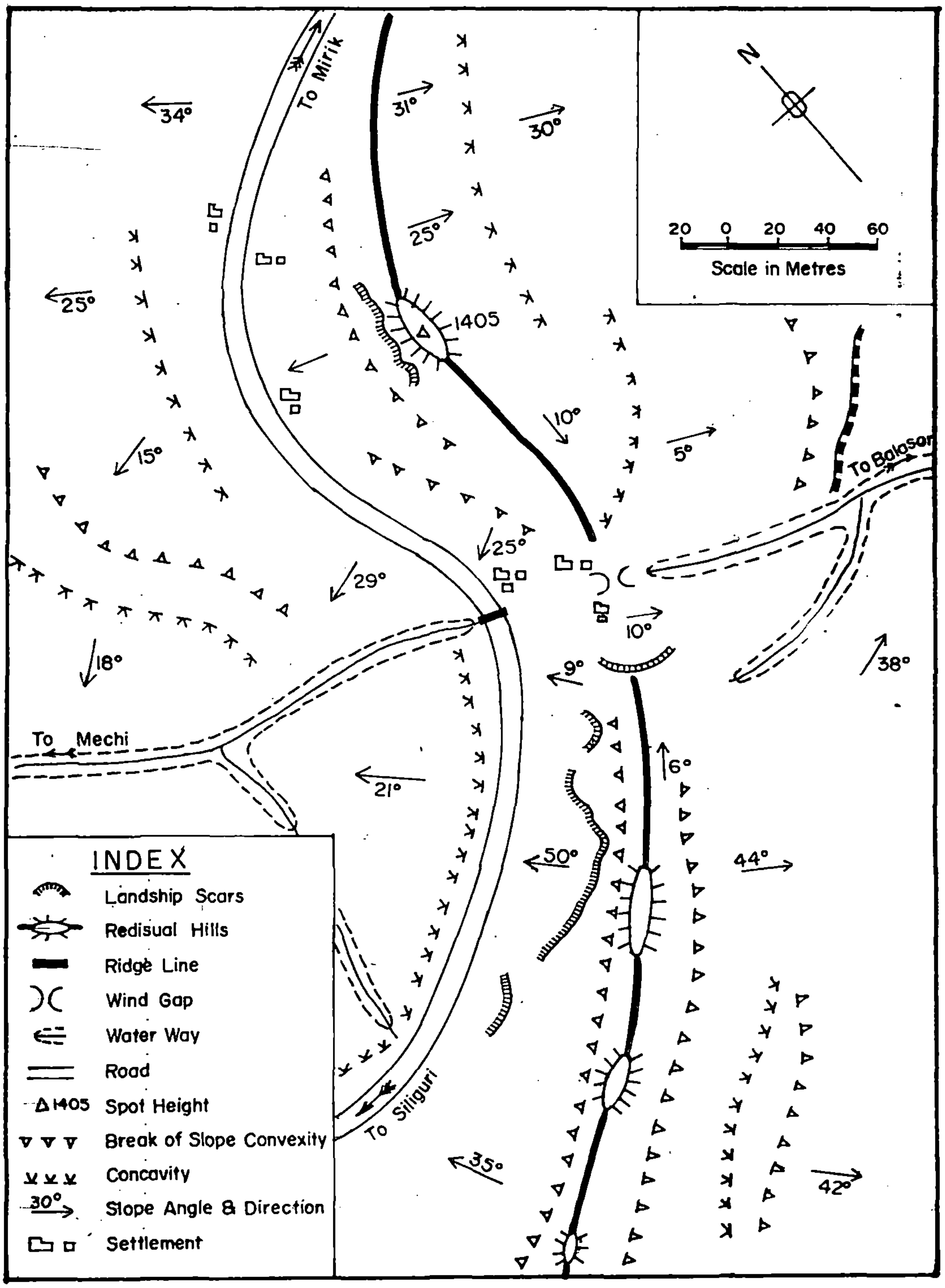


Fig. 5.8

The region under study is composed of rocks belonging to Daling Series, consisting of metamorphosed argillaceous rocks represented by purple and steel gray slates, green quartzite, phyllite and schist. These rocks are traversed by quartz and felspathic veins of variable dimensions. The rocks are mostly dipping at an angle of 29^0 to 51^0 towards NE-SW, NNE-SSW, and EES to WWN. The rocks are jointed, foliated and found to be highly weathered. The Bhanjan landslide has precisely been identified to be on the phyllitic rocks with occasional bands of quartzite. A number of quartzo-felspathic veins have been identified with a thickness of 5 centimetres and a length of over 10 metres (Fig. 5.7 & 5.8).

<u>Pedological Set-up</u>:

The analysis revealed that the physico-chemical properties of soil around the affected slope show natural vulnerability with large volume expansion, less cohesiveness, high water holding capacity and higher rate of infiltration.

<u>Land-use Pattern</u>:

The hill slope around Banjan have long been deforested and turned into cultivated terrace, tea garden and settlement. Such conversions are mostly unscientific and are seldom laid along the contours, with proper protective structures. Such terraces are often cultivated with crops like potato, ginger, maize and cardamom which are often uprooted during harvesting. This very practice often disturbs the cohesiveness of soil and makes it vulnerable to erosion. Thus, slope under study being devoid of proper vegetative mat (except the ridge top), remain fully exposed to heavy and concentrated rainfall (>3000 millimetres) and becomes an easy prey to catastrophic erosion (Fig. 5.9).

<u>Effects of Rainfall, Run-off and Infiltration</u>:

In the affected area, rain water percolates through the joints, cracks and fissures of bedrock and pore-spaces of soil and regolith. This increases the pore-water pressure and changes the

MAN INDUCED LANDSLIDES AT BHANJAN

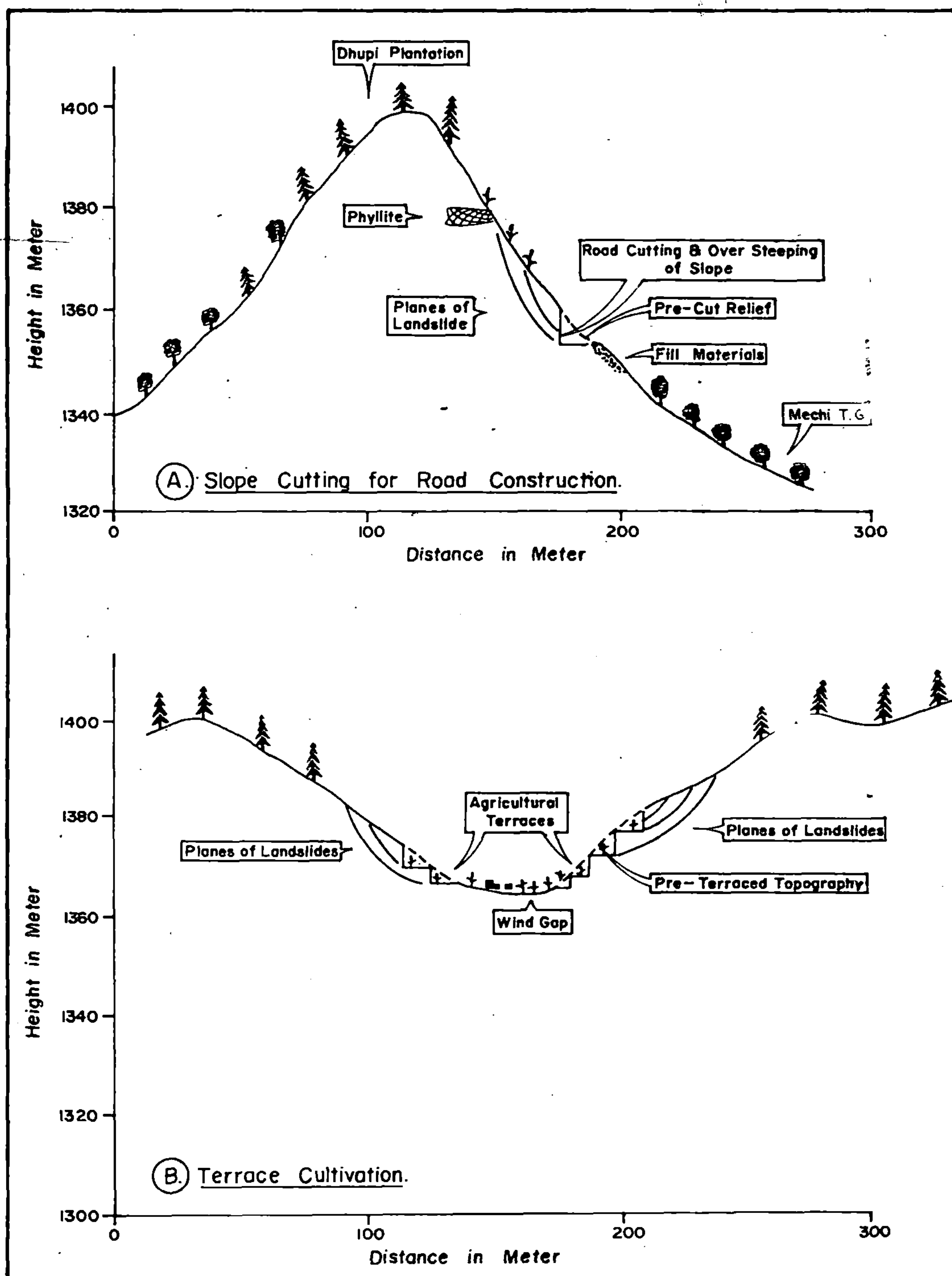


Fig. 5.9

consistency and shear resistance of the slope materials. Thus, under suitable circumstances, with the on-set of the monsoon rill cutting as well as gully erosion starts and the slope becomes further denuded as the surface water flows through such channels.

Effects of Human Interference:

Heedless deforestation took place during the close of the last century in this area for making room for tea plantation, settlement and growing arable farming to meet the demand of ever increasing human and animal population. By the mid of this century, a new metalled road between Panighata and Mirik became necessary. Large-scale slope cutting during the construction further steepened the slope. The cutting of basal support for the construction of road, settlements and arable terrace, without proper drainage may be treated as causative factors for the Bhanjan landslide (Fig. 5.9). The area under study, is thus, over steepened by both natural and human forces, reducing its natural stability significantly. During heavy rainfall, with more and more pore water pressure caused an upward movement of piezometric head and this ultimately leads to the occurrence of the slide.

5.6.2.2 Morphology of the Landslide

The morphology of the Bhanjan Landslide has been shown in Table 5.4

5.6.2.3 Prevention and Control of the Bhanjan Landslide

The study area with a high potential for landslide hazard was recognised by examining geological set-up, processes of slope evolution, precipitation, slope cover and land-use, soil and hydro-geomorphological history. Prevention of such a landslide could prove nearly impossible, however, good engineering practice can do much to minimise the hazard.

Table 5.4

Morphological Features of the Bhanjan Landslide

Pre-Slided Conditions	Post-Slided Conditions	Remarks
Rocks: Moderate to highly jointed phyllites, green quarzites, interbedded with very thin felspathic veins. The rocks are dipping at an angle of 29^0 to 51^0 towards NE-SW, NNE-SSW and EES-WWN. A number of joints have been identified. 2. Altitude: 1385 to 1390 meter. 3. Slope: Convex and reclinear, 30^0 to 35^0. 4. Natural vegetation : Scattered bushes, shrubs and bamboos. Dhupi plantation has been found around the ridge top. 5. Land-use: Mechi Tea Garden is situated below the road and upper parts have been terraced for arable crops. 6. Soil colour : top : 5YR 3/2 mid : 5YR 5/5 low : 5YR 5/6 7. Soil was saturated during the survey.	1. Length of the scar : 70 meter 2. Width of the scar : max : 21 meter min : 1 meter ave : 11 meter 3. Depth of the scar : max : 2.3 meter min : 0.2 meter ave : 1.25 meter 4. Shape: Triangular to rectangular. 5. Total area affected: 770 square meter. 6. Total volume of materials displaced :962 cubic meter. 7. Processes: Removal of the basal support by toe cutting makes the stage ready for slide. Spontaneous liquefaction due to heavy rainfall has actually provided the so-called "trigger mechanism". 8. Modified slope: Concave and irregular, 20^0 to 55^0. 9. Type of the slide: Debris slide. 10. Special features: A number of small channels have developed, being aided by the dip direction of the country rocks.	Displaced materials disrupted the road link between Siliguri and Mirik. It has also endangered the settlement and farmland near the slided area. Huge materials were deposited along the jhora in the Mechi T.G. Immediate construction of protective wall with adequate drainage outlet are recommended.

Compiled by the Author during field investigation on 1995

Methods of prevention and control should include:

i) Slope regradation and removal of unstable slope materials,

ii) Excavation followed by surface and sub-surface drainage,

iii) Construction of retaining wall and filling,

iv) Jhora management and

v) Afforestation.

A few closely spaced excavations may be carried out at the foot of thick overburden situated above the road, to rotate the entire mass of regolith towards the jhora and hence, minimise load. This slide is also closely related to the existing hydrological conditions, where an increase in hydrostatic pressure often initiates the downhill movement. The proper drainage help to increase the resisting force of the slope materials and hence, hill-slope stability be maintained. A number of temporary drains may be constructed over the affected area, to cut off all sources of surface water. The collected water may be conveyed through the natural way into the jhora down to the river Mechi. Afforestation is also an important remedial measure for a long-term control against check wall collapse and soil movement. Fast growing species may be planted all along the affected area.

5.6.3 THE KALIMATI LANDSLIDE, TINDHARIA

On September 9, 1984, the hill slope at 26.5 kilometres from Siliguri on the left hand side of the T.N. Road experienced a devastating landslide (Basu & Sarkar,1985). The slide was apparently stabilised in the following years. The slide was reactivated again on the August 10, 1993, following 115 millimetres of rainfall within a period of 48 hours (recorded at Tindharia), disrupting the Darjeeling Himalaya Railway line and the T.N. Road communication for a couple of days (Fig. 5.10).

<u>Slope Instability Factors</u>:

The region under study is mainly composed of slightly altered sedimentary rocks of

THE KALIMATI LANDSLIDE; TINDHARIA

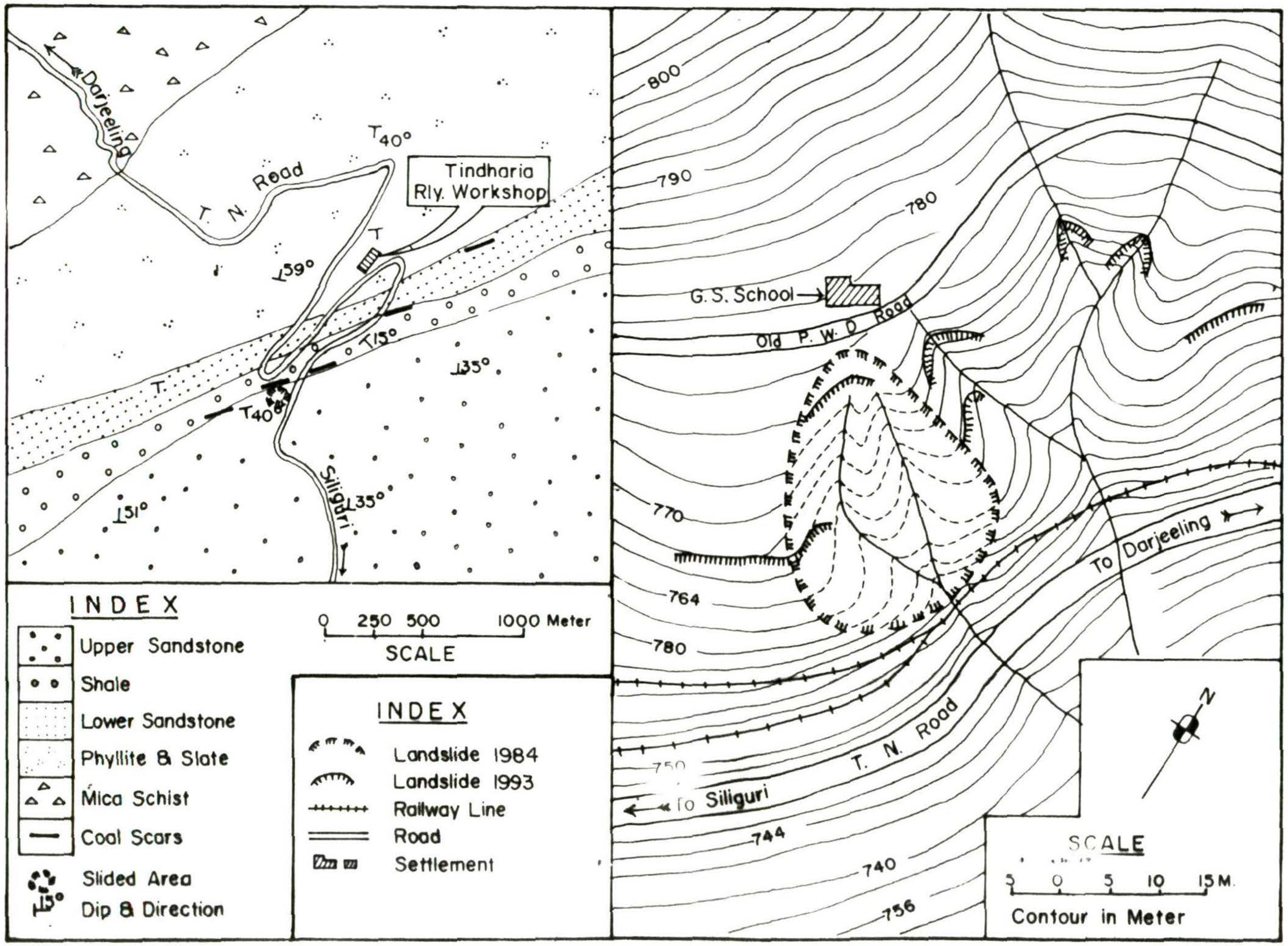


Fig. 5.10

Gondwana formation (Damuda Series) of which sandstone and shale are noteworthy. Small and thin coal seams are found occasionally in sandstone. The sandstone is characterised by cataclastic deformation, which destroyed the clastic texture with intense granulation along ramifying narrow zones of fracture. The inclination of this rock is generally steep (30^0-45^0) towards the road.

The pedological investigation reveals that the physical characteristics of the soil are very interesting in the sense that at the apex of the slided zone, vulnerable conditions have developed at a depth of 30-40 centimetres below the surface, where clay predominate with a good amount of organic matter, high water holding capacity and volume expansion.

The apex of the slided area has long been deforested and turned into cultivated terrace by local inhabitant, which have been commonly cultivated by root crops. The slope under study thus, being devoid of proper vegetation mat, remains fully exposed to heavy and concentrated monsoon rainfall and are susceptible to both sheet and gully erosion. The coal seams are hitherto unexposed, have sometimes been unearthed after the removal of the surface layer of the soils. The local people, suffering immensely due to lack of fuel, naturally get delighted at the sight of a new source of energy and have a tendency to collect fragmentary pieces of coal, creating large hollows at the base of highly inclined terraced slope. Such human interference readily ruptures the slope stability to a large extent by removing the basal support and sets the stage ready for further erosion havoc.

After 1984 landslide, the local government imposed restriction on such illegal mining in and around Tindharia. Subsequently, the slope became apparently stabilised and the so-called administrative restriction became nullified. By 1990, some local people in collusion with some unscrupulous traders started to collect coal from the same area. As a result, the slide reactivated by 1993. The problem that is unique in this case, will, however, be not so easily solved for local inhabitant (mostly below the poverty line) having once had an access to exposed coal seams, will continue to dig for coal, even surreptitiously. If this source of fuel is not sealed up immediately, the trigger action inducing landslide shall ever remain dormant in this area.

5.7 CONCLUSIONS

In view of the ever-increasing problem of landslides in the study area, man must be made aware of the possible dangers that he is inviting, due to his careless dealing with the nature. It is true that one has to make room for the growing population and in this pursuit he has to utilise every piece of land available. But, the precautions that have to be adopted should not be neglected.

The analysis of the landslide carried out in the foregoing paragraphs has indicated that each of the landslides under study has its own peculiarities, and is not due to a single factor. Of the various factors, water has the most deleterious effect. Some of the slides have admittedly been caused by toe erosion of the drainage elements. Again, some of the slope failures are due to the effect of unscientific and unplanned human interference disrupting the delicate hill eco-system. Therefore, the choice of remedial measures to prevent landslide and similar slope movement should be made after careful analysis of the causative factors. The design of the preventive structures should depend on the geomorphological and geological framework of the region and strength of the materials involved in the landslide.

Although, prevention or controlling of landslides are not always an economically viable propositions, but where such control is necessary it is of fundamental importance that the nature of slope instability should be fully understood. It is our sacred duty to educate the local inhabitant about the perils of degradation and the methods of checking them and to develop mass awareness among both the local people and the tourists, so that they are aware of the possible dangers that they are inviting by interfering with the natural laws.

REFERENCE

Basu, A.R. 1969-79; A geo-technical note on investigation of certain stretches of border roads under project Swastik in Sikkim and Darjeeling districts, West Bengal, unpublished G.S.I report.

Basu, S.R. & Sarkar, S. 1985; Some considerations on the recent landslides at Tindharia and their control; Indian Journal of Power and River Valley Development, 188-194.

Basu, S.R. & Sarkar, S. 1987; Eco-System vis-à-vis landslides: A case study in Darjeeling Himalayas, Impact of Development on Environment, 2; 45-53.

Dutta, K.K. 1966; Landslips in Darjeeling and neighbouring hillslopes in June 1950, Bulletin G.S.I. B 15 (1), 7-30.

Froehlich, W, Kasza, I and Starkel, L. 1990; Ambootia Landslide Valley in the Darjeeling (Himalaya) active since 1968; Earth Science, 39(2); 111-128.

Ghosh, A.M.N. 1950; Observation of the landslide of the 11th and 12th June 1950, in the Darjeeling Himalayas, unpublished G.S.I.report.

Griesbach, G.L. 1899-1900; General Report, G.S.I.

Nautiyal, S.P. 1951; A geological report on the hill slopes stability in and around Darjeeling, W.B., unpublished G.S.I. report.

Nautiyal, S.P. 1966; On the Stability of certain hill slopes in and around Darjeeling, W.B. Bulletin G.S.I. B15 (1), 31-48.

Paul, D.K. 1973; Report on geo-technical investigation of hillslope stability and alignment of border road under the project Swastik in Darjeeling district , W.B. and Sikkim, unpublished G.S.I. report.

Roy, S & Sensharma, S.B. 1967; Geological report on the stability of hill slopes in and around Darjeeling town, Darjeeling district, W.B. unpublished G.S.I. report.

Sarkar, S. 1996; Landslips in the Mahanda basin, Darjeeling Himalaya and their control, Resource Management in Developing Countries, Concept, 10.

Sinha, B.N., Verma, R.S. & Paul, D.K. 1975; Landslides in Darjeeling (West Bengal) and adjacent areas, Bulletin G.S.I. Series B, 36; 1-45.

Sondhi, V.P. et al, 1996; Landslides and hillside stability in the eastern Himalaya, Bulletin, G.S.I. B 15(1) 1-117.

Verma, R.S. 1972; A note on the geo-technical investigation of the stability of hill slope along stretches of border roads in Sikkim and Darjeeling district, W.B., unpublished G.S.I. report.