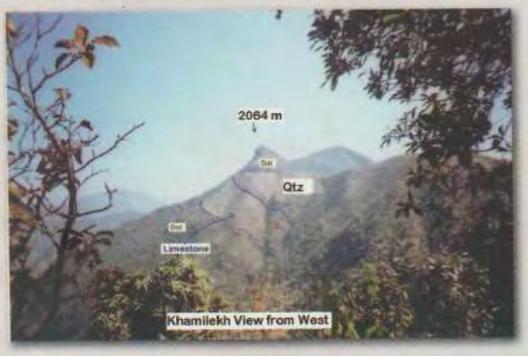

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Annual Report No. 7, DMG

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Foreword

This Annual Report No. 7 of the Department of Mines and Geology (DMG) is annual series of publication. This report includes information on the geo-scientific study and mineral exploration work conducted by the Department in the fiscal year 2066/67 and thus it can be considered as a book including the technical activities undertaken by the Department. The main objective of this publication is to disseminate the technical information to the relevant stakeholders. The information in the report will be an asset to the Department and also will be helpful for the planners, geoscientists, geosciences students, entrepreneurs and others in the field of geoscientific study and mineral based industries.

I am of the opinion that this report with scientific papers on various topics will be an useful not only for the Department and the Government, but also to the individual/ institutions related to mineral and geosciences.

I would like to express my sincere thanks to all professionals, contributors, service providers who help to bring this report in this shape. I would also like to express my gratitude to the members of the Editorial Board who had made valuable contribution with patience to bring this report in this form in stipulated time.

SPMahato

Sarbjit Prasad Mahato
Director General

Editorial

This "Annual Report No. 7" is the continuation of publication of Departmental activities as per its annual program for the fiscal year 2009/10. An 'Editorial Board' was formed on 15 April 2010 to publish this 'Annual Report'. This issue focuses on mineral exploration, geological mapping, engineering and environmental geology, petroleum exploration etc.

The 'Editorial Board' is delighted to publish this 'Annual Report' and hope that this issue will be able to furnish the information regarding the different geo-scientific activities of the Department and also hope that it will be useful for concerned people, engineers, planners and different government and non-governmental agencies.

This 'Editorial Board' is thankful to all the authors and staff of the Department for their efforts and contribution in the publication of this Report.

Hifzur Rahman
Chief Editor

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A Synopsis of Exploration of Dhanpure Limestone Deposit, Syangja District, Lesser Himalaya, Western Nepal

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ABSTRACT

Dhanpure Limestone Deposit is a part of Dhanpure Limestone of Sirkot Group. It has parallel laminated argillaceous limestone. The limestone is gray to dark gray, platy to medium bedded and homogenous along the strike. The upper part of the limestone consists of mm to cm scale laminations and argillaceous beds intercalation. The limestone at middle part consists of parallel laminations of mm scale whereas lower part consists of mm to cm scale laminations and argillaceous beds intercalation. The surface and subsurface exploration was carried out in various phases of the work like preliminary, follow-up, detailed follow-up and exploratory drilling. The surface exploration of the limestone deposit shows that the weighted average value of CaO- 49.68% and MgO-2.56%. The subsurface exploration of the limestone deposit shows the weighted average value of CaO-45.47% and MgO-2.3%. Based on the conventional cross sectional method, the deposit has a total of 10.21 Million Tons reserve in which 6.57 Million Tons is the proven and 3.64 Million Tons is the probable deposit.

INTRODUCTION

According to the annual field program of Department of Mines and Geology(DMG) under the Mineral Exploration Project for the FY 2005/06, 06/07, 07/08, 08/09, an exploration of cement grade limestone at Dhanpure of Sorek VDC, Syangja district has been undertaken.

The prospect lies within the Toposheet no.2883 16C, 1:25000 scale. It is about 4.5 km NW of Waling. The prospect lies within the investigated area with latitude 27^0 58' 56 to 28^0 01' 16" and longitude 83^0 46' 30" to 83^0 48' 04". The Topo-geological survey area covers 50 hectors.

The geology of the area was studied by Hirayama et al (1988). Jnawali et al (1999) and Shrestha et al (2000) did geological investigation of the area. The stratigraphy and structure of the region has been established by Dhital et al (2002). A reconnaissance geological investigation for cement grade limestone was carried out by Madhikarmi (2000) in the same area.

Exploration of the Dhanpure limestone prospect has been carried out with preliminary follow-up, follow-up, detailed follow-up and exploratory Diamond Core Drilling in the successive years (Khadka, 2005/06, 06/07, 07/08, 08/09). Based on the field and laboratory results, the grade and tonnage for the suitability of cement grade limestone has been assessed.

OBJECTIVE

The main objective of the exploration is to determine suitability of cement grade limestone in terms of quality and quantity.

METHODOLOGY

a) **Desk study**: The existing reports, data and personal queries were made available before departing for the field study. The field data were analyzed as soon as the availability of chemical laboratory results. The survey map and sections were drawn. The proposed drill-hole locations were plotted. Drilling program was analyzed. The drill-hole logs were drawn. Based on the drill locations, chemical assays and geological sections, the reserve have been estimated according to the conventional cross sectional method.

b) **Field study**: The surface exploration begins with the geological mapping during preliminary follow-up exploration. The continuous chipping of the outcrops has been conducted simultaneously. The follow-up exploration was based on continuous channel sampling whereas the detailed follow-up exploration was conducted to cover the remaining area with channel sampling. The area was also covered with topo-geological surveying and explored with Diamond Core Drilling in order to ascertain the quality and quantity of the subsurface.

REGIONAL GEOLOGICAL SETTING

The present prospect area is a part of the preliminary exploration area within the Lesser Himalaya of western Nepal. Geologically, it consists of Sirkot Group of rocks which are represented by Dhanpure Limestone and Sorek Formation. The Nawakot Complex of rocks is represented by Benighat Slates and Dhading Dolomite in the study area (Fig.1).

Nawakot Complex

The name Nawakot Complex was introduced by Stocklin and Bhattarai (1977, 1980) in the central sector of the Nepal Himalaya. Here, it is represented by the Benighat slates of Upper Nawakot Group and the Dhading Dolomite of Lower Nawakot Group.

Dhading Dolomite (Lower Nawakot Group)

It is found in the Surkaudi area (Fig.1). It consists of gray crystalline, fine to medium grained and thick to massive bedded dolomite. It shows splintery nature and intercalated with thin strips of black carbonaceous slates. The lower part consists of medium to thick bedded dolomite where as middle part has domal stromatolites of thick to massive beds. The beds are shattered and cross cut by calcite veins at places. The chemical result of a chip sample taken from Surkaudi area shows CaO-15.07% and MgO- 18.14%. All beds are dipping due south. This is considered to be the youngest unit of the Lower Nawakot Group and of Middle Proterozoic in age.

Benighat Slates (Upper Nawakot Group)

The Benighat Slates are exposed around Waling and Sorek Kot areas overlying the Dhading Dolomite (Fig.1). It has black slates. The slates contain thin black carbonaceous matter. The Benighat Slates transitionally passes into the overlying Sorek Formation. The age of the formation is considered to be of Late Protetrozoic.

Sirkot Group

The Group was introduced by Dhital et al 2002. It consists of Sorek Formation and the Dhanpure Limestone in the exploration area.

Sorek Formation

This Formation is cropping out around the Devisthan, Triyasi and Chyangdi Khola (Fig.1). Thinly interbedded red-purple and greenish gray slates and quartzites are exposed at the Archale road section. It consists of green gray laminated slate and fine grained quartzite at the lower part. It is followed by inter-beddings of red purple, greenish gray and pale yellow quartzite. The age of the formation is considered to be of Late Proterozoic.

Dhanpure Limestone

The Dhanpure Limestone is exposed in Devisthan, Dhanpure, Mankhu, Khahare Khola within the exploration area (Fig.1). It consists of gray to greenish gray parallel laminated argillaceous limestone. Basal part consists of 1cm to 10 cm thick light gray to dark gray limestone occasionally with mm scale cross cutting calcite veins. It grades up to the medium bedded limestone at the middle part of the deposit. The upper part consists of thin to wavy laminations. Sometimes, it shows ribs and furrow structures due to differential weathering at the surface. The weathered surface shows brown to maroon discoloration

Structurally, it has a syncline passing through the upper middle part of the deposit. The exposure is in the dip slope (Fig.2). It has a series of chevron folds. The overall dipping is due south. The basal part is overridden by slates of Sorek Formation along the thrust (Fig.1, 3). The measured thickness is 70m from TR-1, TR-2 and TR-3 at Archale (Fig.3). The age of the formation is considered to be of Late Proterozoic.

GEOLOGY OF THE PROSPECT AREA

The Dhanpure Limestone Deposit lies within the Dhanpure Limestone, the youngest formation, of Sirkot Group in the Lesser Himalaya of Western Nepal. The prospect area has also outcrops of slates of Sorek Formation at the middle and basal part (Fig.1, 3). The limestone, in the prospect area, has a dip slope exposition dipping due south. It has a unique feature at the dip slope. The kinking of the strata has given rise to Chevron folding. The surface outcrops are fresh and greenish gray in colour with thin to medium bed scale. The subsurface exposures at the Archale Khola cliffs are dirty and weathered. The cheveron folding and its effect manifests at the surface level by giving rise to gentle to vertical beds within a short interval (Fig.3).

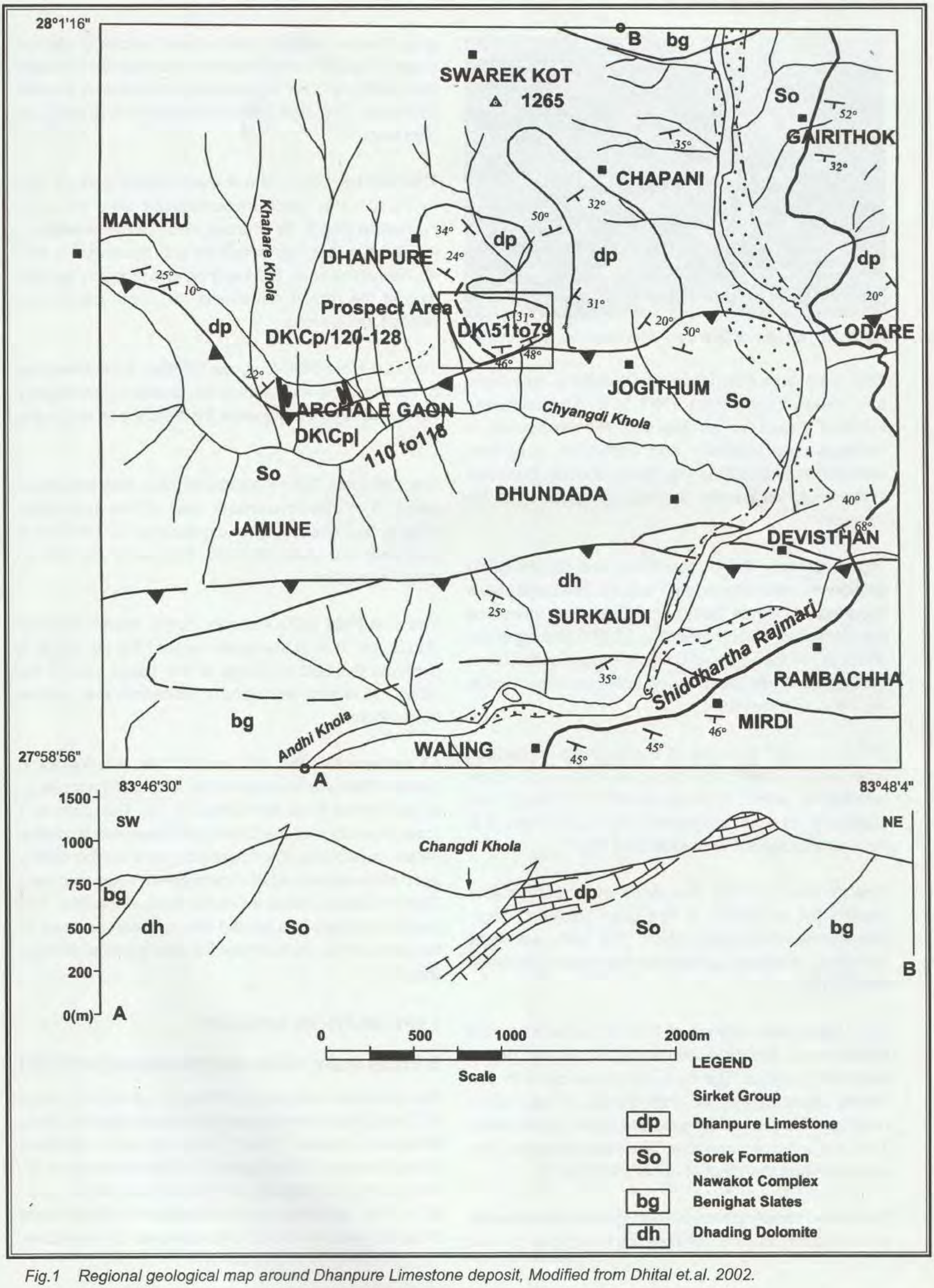


Fig.1 Regional geological map around Dhanpure Limestone deposit, Modified from Dhital et.al. 2002.

Fig.2 An overview of Dhanpure limestone deposit

The main characteristics of Dhanpure limestone has been studied from TR-1 to 3. The complete surface exposure shows that the limestone is homogenous laterally and vertically in colour, laminations and weathering nature of beds. However, it does not rule out the chemical composition of the limestone.

Topographically, the Archale Khola and Gajane Khola sections have been eroded (Fig.2, 4). The confirmable sequence of Sorek Slates and Dhanpure limestone are distinct at Gajane area (Fig.3). The kinking of the strata at the topographic break is unique at the basal part where it has steep topography, probably due to the effect of thrust front.

The lower part consists of thin to medium bedded limestone. It has gray colour at fresh and yellow weathering colour. It shows parallel laminae of mm scale and cm scale argillaceous beds up to 5cm. It is more argillaceous than middle part (Fig.5).

The middle part has thin beds of limestone and weathered at places. It has gray colour at fresh and yellow weathering colour. The beds are thinly laminated. It is less argillaceous than lower and upper part (Fig.6).

The upper part consists of thin to medium bedded limestone. It has gray coulour at fresh and yellow weathering colour. The beds are cross cut with thin calcite veins at places. Sometimes, it has calcite coatings. The parallel laminae are of mm to cm scale. The argillaceous limestone has more frequent mm scale laminae than that of upper part (Fig.7).

16 channel sampling sections during surface exploration show that the surface samples are fresh, gray to dark gray, thin to medium bedded and calcite coated places (Fig.3). The sections are homogenous latera and vertically. The argillaceous limestone is paral laminated. The argillaceous laminae have reaction acid test.

The Drill Hole DDH-1 shows that the depth from 43.75 to 55.30m has black carbonaceous slate of Sor Formation (Fig.3, 8). Further down, it has limestor It indicates that the limestone bed thickness is or 43.75m at this hole. The lower band is probably anoth limb of the fold. It represents the upper part of t deposit in dip slope.

The Drill Hole DDH-2 shows 60.65m thick limesto band (Fig.3, 8). The beds at this location show sligh north dipping. It represents the middle part of the c slope.

The Drill Hole DDH-3 shows 65.75m thick limesto band. It is the lowermost part of the dip slo (Fig.3, 9). The surface exposures at TR-1 to correlate the same horizon. The beds are thin medium bedded.

The Drill Hole DDH-4 shows 29.6m limestone ba (Fig.3, 10). It is at the upper level of the dip slope. confirms the bed thickness of the upper part of t slope. And also is helpful to ascertain the volun calculations.

All sections AA', BB', CC' and DD' has a topograph break at the lower level due to the folding of the strata a result of the thrust front (Fig.8, 9, 10). The upper a lower boundary of the Dhanpure limestone is clea shown in sections. The lower boundary can be clea seen at the Archale Khola upstream at motor road ne Gajane village where the water tank is located. T upper boundary is a faulted one and can be seen the base of the slope where flat land starts at Archa (Fig.1, 3).

EXPLORATION HISTORY

1. Preliminary follow-up exploration (2005/0

The geological mapping of 150sq. km. area in the sca of 1:25000 has been carried out to locate cement gra limestone prospect. The 5 prospects were identifi during the study. Total number of chip samples was 7 The geological mapping of 10 sq km area in the sca of 1:10000 scale has been undertaken in the prese prospect area to locate chip samples of limeston

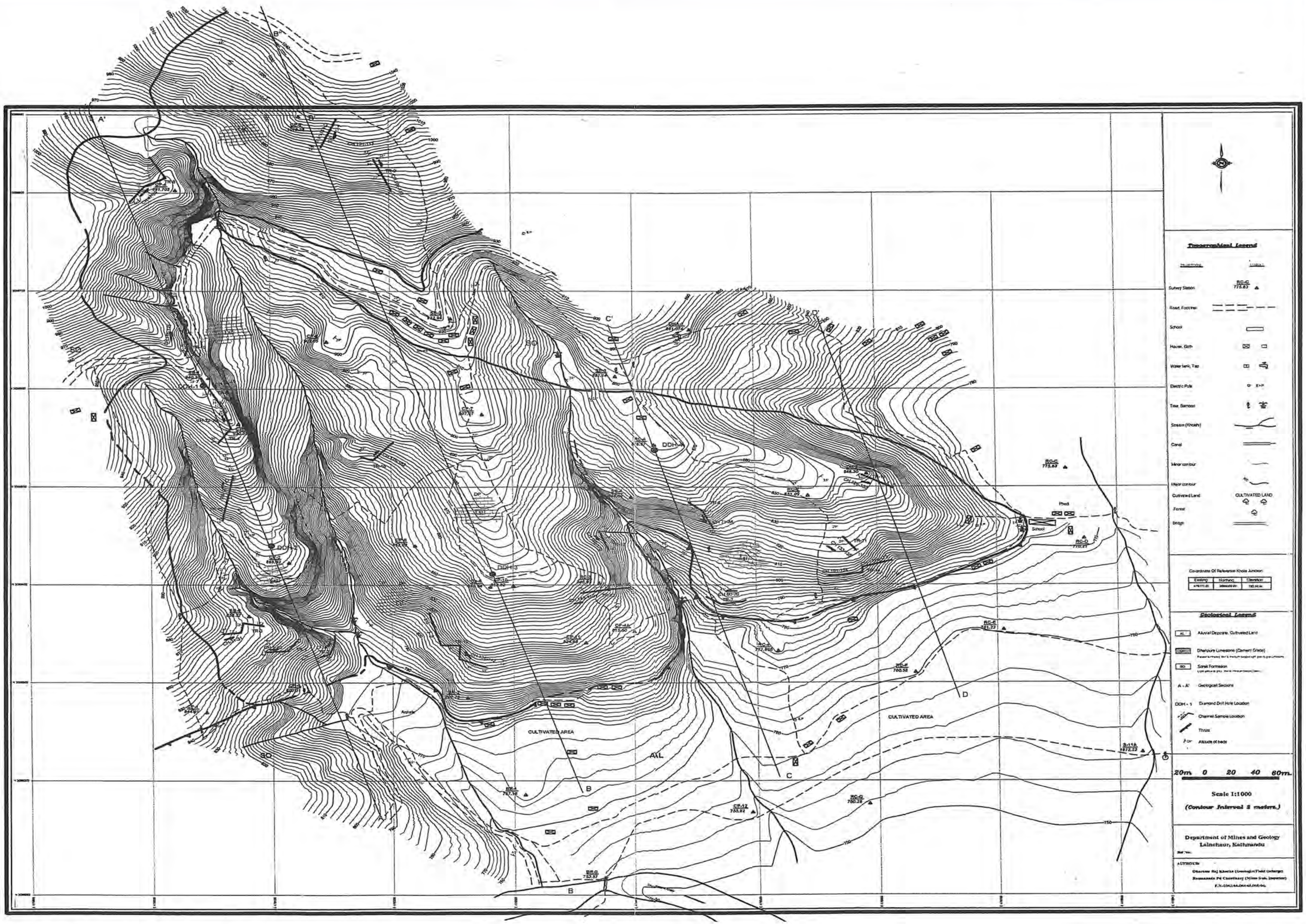


Fig. 3 Topo-Geological map of the Dhanpure Limestone deposit

Fig.4 Gajane Khola section of Dhanpure Limestone Deposit

Fig.5 Core of DDH-1, lower part, Dhanpure Limestone Deposit

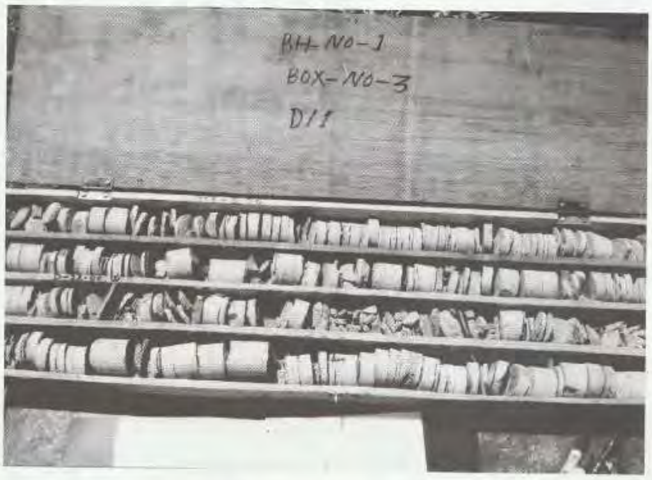


Fig.6 Core of DDH-1, middle part, Dhanpure Limestone Deposit

The samples DK-51 to DK-79 represent the present prospect of Dhanpure Limestone. The total no of samples were 29 from 139m sampling length with an interval of 4 to 5m (Fig.1)

Fig.7 Core of DDH-1, upper part, Dhanpure Limestone Deposit

2. Follow-up exploration (2006/07)

During follow up exploration, the geological mapping was done with Channel sampling in the present prospect. The total channel sampling line length was 184.8m. The 86 samples were taken with an interval of 2 to 3 m from TR1 to TR 8(Fig.3). The total chip samples were 9 from the Khahare Khola with sampling length of 31m (Fig.1). Simailarly, a total of 9 chip samples were taken from the Archale gaon section with sampling length of 20m (Fig.1).

3. Detailed follow-up exploration (2007/08)

During detailed follow up exploration, the Topo-geological mapping of the 50 hector area was covered in the scale of 1:1000. A total channel sampling line length of 200m from TR9 to TR-16 was taken and 80 samples were collected (Fig.3).

4. Exploratory Drilling (2008/09)

Altogether 4 holes with total length of 279.5m have been drilled in which 106 samples were taken to get assay returns of the subsurface beds.

QUALITY OF THE DEPOSIT

a) Surface exploration

A total of 29 countinuous chip samples during preliminary follow-up (2005/06) were taken from the Dhanpure limestone prospect to confirm the grade of the deposit. The assay values of these samples are under the cement grade limestone with maximum and minimum CaO 52.05% and CaO 37.85% respectively. Similarly, the maximum and minimum MgO content is 5.21% and 0.76% respectively. Similarly, a total of

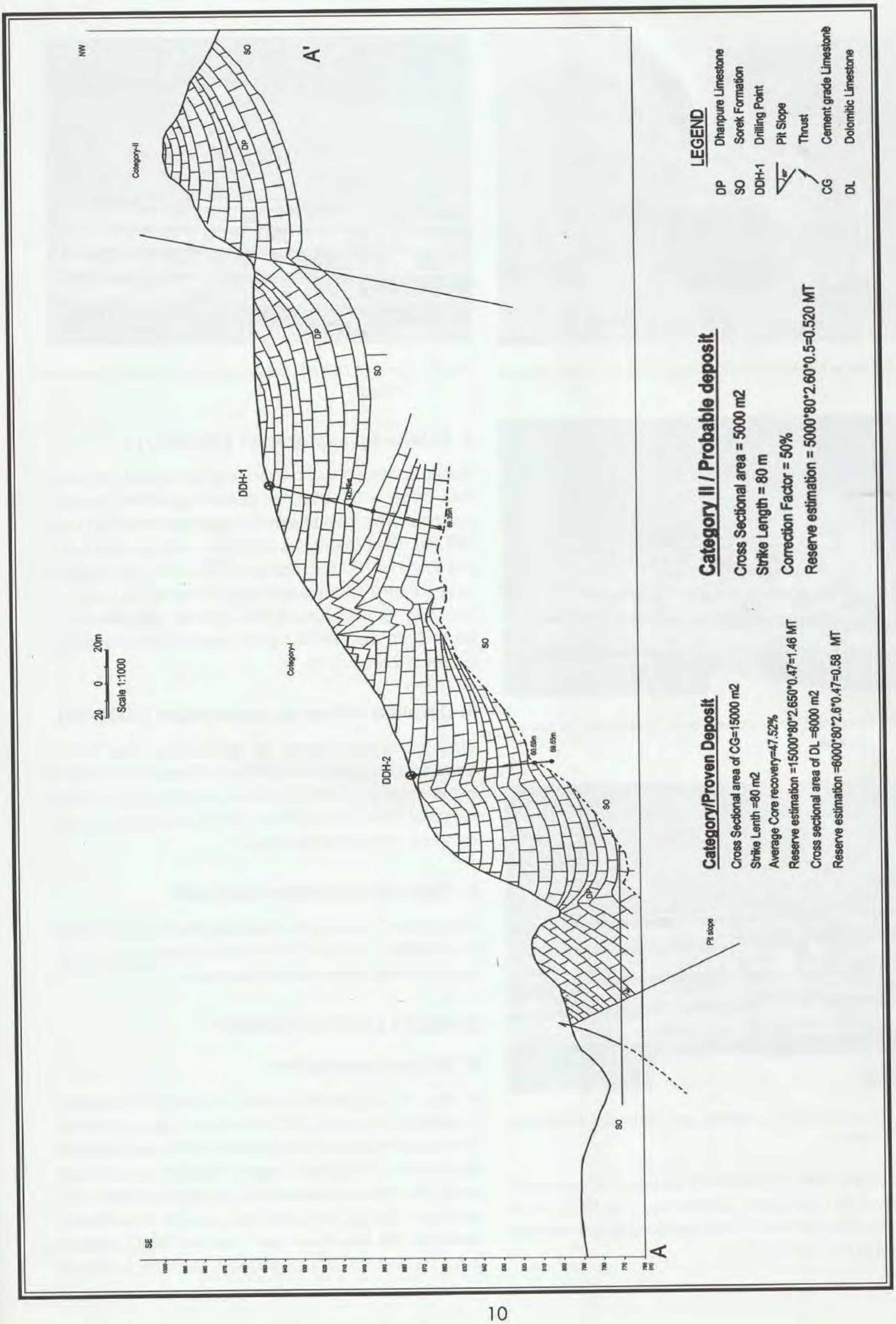
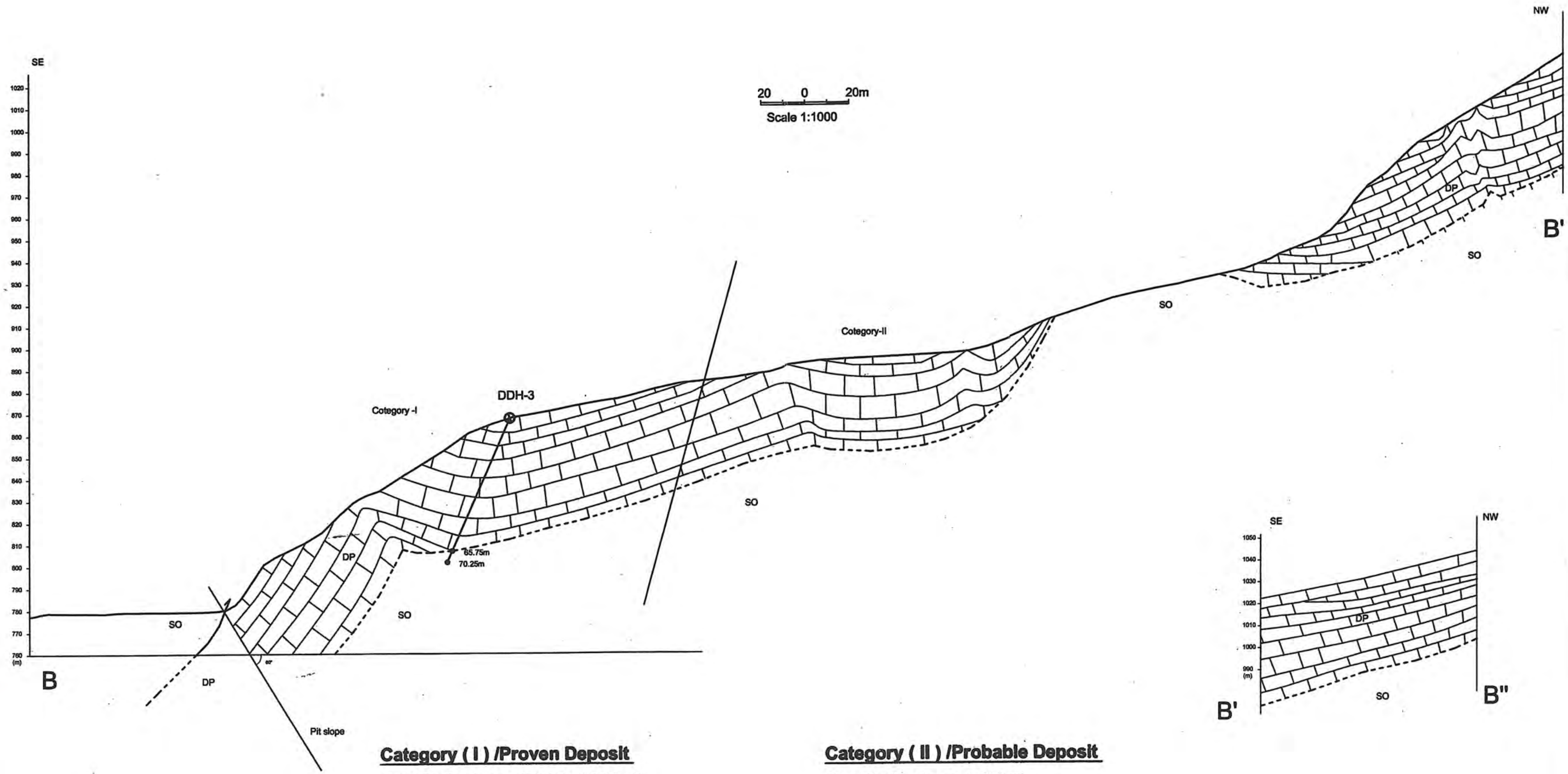


Fig.8 Geological section AA', Dhanpure Limestone Deposit



Category (I) /Proven Deposit

Cross Sectional area =100*100 =10000 m2
Influence Lenth = 165 m
Core recovery=43.11%
Reserve estimation =10000*165*2.60*0.43 =1.8447 MT

Category (II) /Probable Deposit

Cross Sectional area =15000 m2
Strike Lenth = 166 m
Correction Factor = 50%
Reserve estimation =15000*160*2.60*0.50 =3.12 MT

Fig.9 Geological section BB', Dhanpure Limestone Deposit

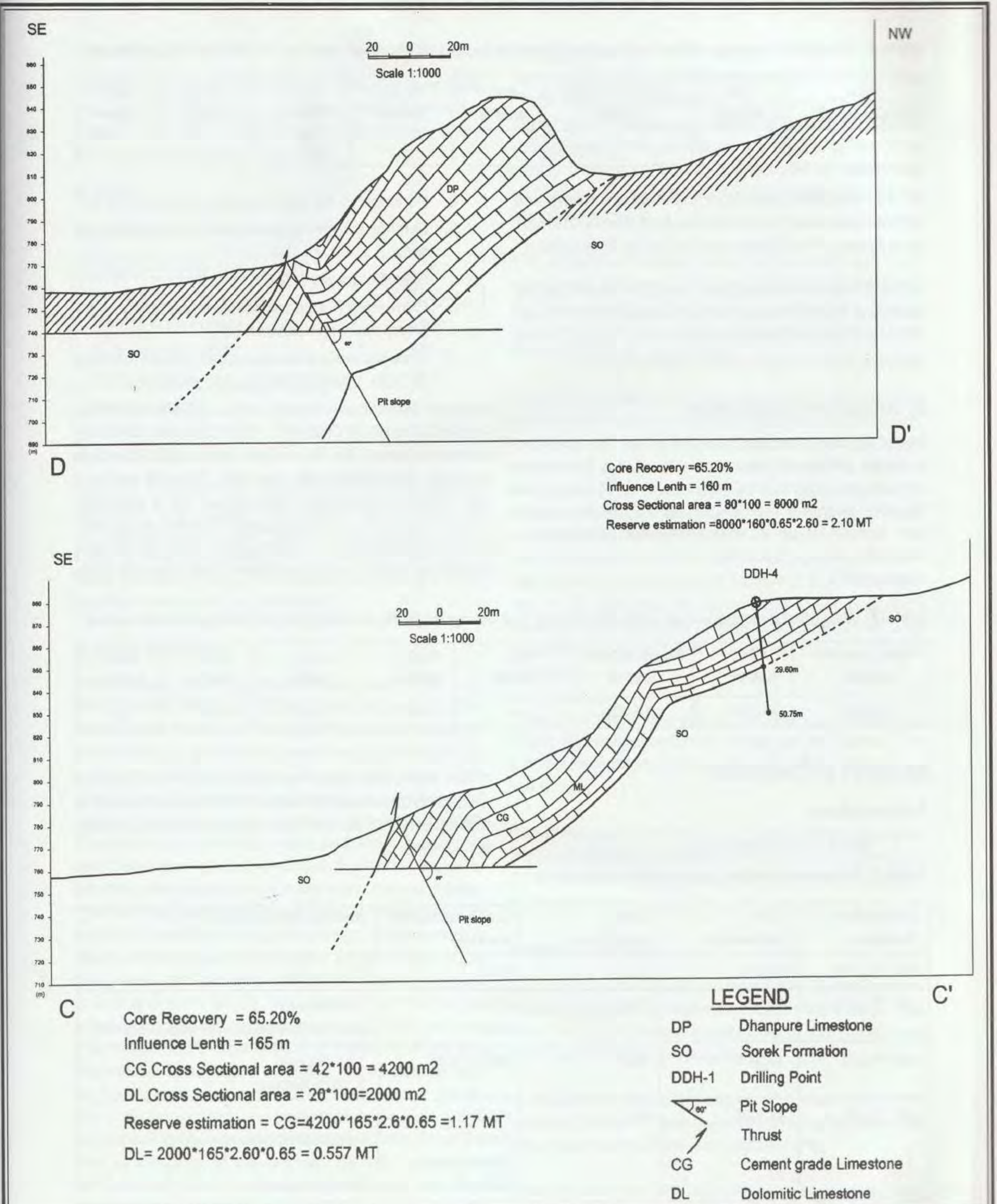


Fig.10 Geological section CC' and DD', Dhanpure Limestone Deposit

Table-1: Weighted average values calculated from the assays of channel samples of Dhanpure Limestone

Total sample length	LOI %W/W	Acid Insoluble %W/W	SiO_2 %W/W	Fe_2O_3 %W/W	Al_2O_3 %W/W	CaO %W/W	MgO %W/W

18 chip samples taken from the Khahare Khola and Archale Gaon sections during the field season 2006/07 have assay values under cement grade limestone.

A total of 166 channel samples taken from the Dhanpure *limestone deposit during the field season 2006/07 and* 2007/08 have weighted average assay returns of the samples under cement grade limestone (Table-1).

b) Subsurface exploration

Based on core sampling of 4 drill holes, the weighted average values of assay results of the Dhanpure Limestone Deposit has been calculated based on 85 core samples (Table-2). The 21 core samples with sample length 42.95m have been excluded for weighted average calculation since the results are not encouraging.

Table-2: Weighted average values calculated from the assays of Drill core samples of Dhanpure Limestone

Total sample length	LOI %W/W	AcidInsoluble %W/W	SiO_2 %W/W	Fe_2O_3 %W/W	Al_2O_3 %W/W	CaO %W/W	MgO %W/W
179.45m	36.53	13.05	-	0.49	0.95	45.47	2.3

RESERVE ESTIMATION

Assumptions

1. Beds are homogenous
2. Pit slope of the terrain is considered to be 60^0
3. Quality is homogenous along the influence area
4. Specific gravity is 2.6
5. *Correction Factor for possible grade/Category* II has been considered 0.5
6. Core recovery % has been taken as an average of DDH-1 and DDH-2 for AA' section

Reserve estimation is based on the conventional cross sectional method (Table-3). The channel sampling pattern is based on the surface exposures. The core samples were taken with due care. The drill sections are almost homogenous throughout the 4 sections. The lower, middle and upper part of the drill sections is almost homogenous in nature, colour and argillaceous limestone present. The average core recovery from 4 drill holes has been calculated and the result is 48.52% for the limestone band since the total limestone thickness is 233.8m and total limestone core recovery is 113.45m.

Table-3: Parameterization and reserve estimation

Geological Sections	Core recovery%	Strike length (m)	Cross sectional area(m^2)	Reserve (Million Ton, MT)
DD' (Fig.10)	65.2%	160	8000	2.1(Proven)
CC' (Fig.10)	65.2%	165	4200 2000	1.17(Proven) 0.557(Dolomitic limestone/Overburden)
BB' (Fig.9)	43.11%	165	1000015000	1.84(Proven) 3.12(Probable)
AA' (Fig.8)	47.52%	80	15000 6000 Overburden) 5000	1.46(Proven) 0.58(Dolomitic limestone)/ 0.52(Probable)

Total Proven/ Category I deposit= 6.57MT
Total Probable/Category II deposit=3.64MT

INFRASTRUCTURE

The approach to the deposit area from the road head and the nearest market place has been described in Table-4. The electricity and the socio-economy of the area have been briefly discussed.

a) Road

Table-4: Road connectivity

Waling to Deposit area	4.5km
Waling to Syangja	27.6km
Syangja to Pokhara	37km
Waling to Kathmandu	198km
Waling to Tansen	62.4km
Waling to Butwal	92.4km

b) Electricity

A 132KV Transmission line is nearby the deposit area along the Andhi Khola. The nearest sub stations are at Pokhara, Butwal and Tansen. The nearest power stations are Kaligandaki "A" (144MW) and Andhi Khola (5100KW)/BPC. The deposit area and its nearby localities have rural electrification.

c) Socio-economy

Rice, wheat, maize, cerals, millate, orange etc. are the main agricultural products. Three parallel irrigation canals are at the base of the deposit to irrigate Chyangdi Khola terrace. The deposit area has no forest and no soil conservation practices. The area has about 75% private land. The deposit is crossed by the village dirt roads at the base and also at the middle of the deposit. The nearest airport is at Pokhara and Bharatpur. Mobile communication is possible. CDMA and Andhi Khola FM are the communication and information means. A seller mill is located at Archale Khola. Paragliding is possible from the Sorek top. Waling is the major market which is nearly at the midway from Butwal and Pokhara. Local manpowers are available since few of them are going to Gulf and India for job. The economy of the people is based on agriculture, remittance and public service. The village has a High School at Silmle, Primary and Secondary Schools are available from public as well as private sectors. There is a health centre at Sorek. About 50 households are residing nearby and within the deposit area. Chyangdi Khola catchment has flat land at the base of the deposit. Skilled, semiskilled and unskilled labors are scarcely available. The area has gentle topography so that it has no environmental threats at present like landslide, mass erosion etc.

DISCUSSION

The core recovery of the drill holes is low. The core loss of the holes is controlled by the structurally complex terrain since the area consists of series of chevron folding with voids parallel to the strata. In the other hand the kinking of the strata and cavity formation and weathering in drill hole DDH-2 are responsible for the low core recovery.

The weighted average value of channel and core samples is different. It is probably due to the fresh surface samples. The surface samples are mostly of upper level of the limestone band which is less argillaceous than lower level.

Dolomite appearance in DDH-2 is high comparing the rest of all drill holes. It could be due to the effect of cavity formation and replacement of calcium due to solution which may be at the time of deposition. The effect of the solution has been localized and probably has no effect on significant distance as verified from drill hole sections DDH-1 and DDH-3.

The limestone thickness of DDH-4 is low. The hole has been designed to control the lower boundary characteristics of the Dhanpure Limestone. The limestone is transitional with black slates of Sorek Formation.

The upper and lower part of the Dhanpure limestone is little bit argillaceous than middle part limestone. The parallel laminated nature is homogenous throughout the terrain.

The limestone resource is within the inhabitant areas. However, some of the terrain is barren and is away from 50 to 100m. Due care should be given to the utilization of the resource.

CONCLUSIONS

Geologically, the Dhanpure Limestone Deposit is a part of the Dhanpure Limestone of the Sirkot Group. The stratigraphic thickness is only 70m in the study area. It has gentle dip slope exposure.

A total of 166 channel samples of limestone from 16 sections (384.8m) have given rise to weighted average values of CaO-49.68% and MgO-2.56%.

Analysis of a total of 85 core samples of limestone from 4 Drill holes (179.45m) with average core recovery of 48.52% have given rise to weighted average values of

CaO-45.47%, MgO-2.3%, Al_2O_3-0.95%, Fe_2O_3-0.49%, LOI-36.53% and Acid Insoluble-13.05%.

Based on conventional cross sectional method, the tonnage of the cement grade limestone deposit has been assessed. The I[st] category /proven deposit, which is calculated in this study, is 6.57 Million Tons, whereas, II[nd] category/ probable deposit is 3.64 Million Tons.

A total of 1.13 Million Tons dolomitic limestone has been assessed and considered as an overburden.

RECOMMENDATION

The average grade attributes of limestone including silica, alumina, calcium oxide, magnesium oxide and ferrous oxide can be improved using standard geo-statistical methods of capturing spatial variation of the deposit.

It is desirable to have bulk testing of limestone to justify grade attributes.

The quantity of the deposit could be increased as we explore the unexplored areas in the adjacent part of the deposit within the same formation westward.

Feasibility study for the establishment of the cement plant is warranted.

ACKNOWLEDGEMENT

I am very much indebted to former Director General Dr. R.B. Shrestha, present Director General Mr. S.P. Mahato for the encouragement and facilities provided during the field work and various phases of the assessment of data. I would also like to extend my gratitude to Mr. S.R. Maharjan, Deputy Director General and Mr. H.R. Khan, Deputy Director General for valuable suggestions during the various phases of the project. I thank Mr. K.D. Jha, Planning Chief, and Mrs. Rita Shrestha, Senior Divisional Chemist, for the support. Equally acknowledged are Chemical Section, Draughting Section, Drilling Section, Petroghaphy Section personnel and Mr. Ramananda Chaudhary for surveying the area.

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Annual Report of Department of Mines and Geology, 2011, No. 7, pp 19-22

Preliminary Exploration for Coal Deposits in Dhauwadi-Durlung area, Western Nawalparasi, Western Nepal

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Abstract

Dhauwadi-Durlung area mainly consists of the rocks of Lakharpata and Surkhet Groups. The rocks of these Groups are folded into a syncline and are thrust over the rocks of the Siwalik Group along the Main Boundary Thrust towards the south. No distinct coal seam is identified in the area, however some carbonaceous-shale lenses were observed within Melpani Formation of the Surkhet Group. The result of chemical analysis of the collected carbonaceous-shale samples shows very low calorific values. The area, instead of coal, shows positive indications for iron (hematite) deposit.

Introduction

Department of Mines and Geology (DMG) carried out a 'Preliminary Exploration of Coal Deposit in parts of Nawalparasi District, western Nepal' according to the annual field program for the year 2010. The area is included in the topographical maps of 1: 25,000 scales of sheet no. 100 09 and 100 10 published by the Government of Nepal, Survey Department. It covers about 125 km^2 within the longitudes of 84°00'00" and 84°10'00"E and the latitudes of 27°42'30" and 27°47'30"N. The area is about 16 km in length along E-W and 8 km in breadth along N-S directions, respectively.

The study area is easily accessible by road. Daldale and Chormara are two important market places along the East-west Highway which connects eastern and western parts of the study area respectively by gravelled road (Fig. 1).

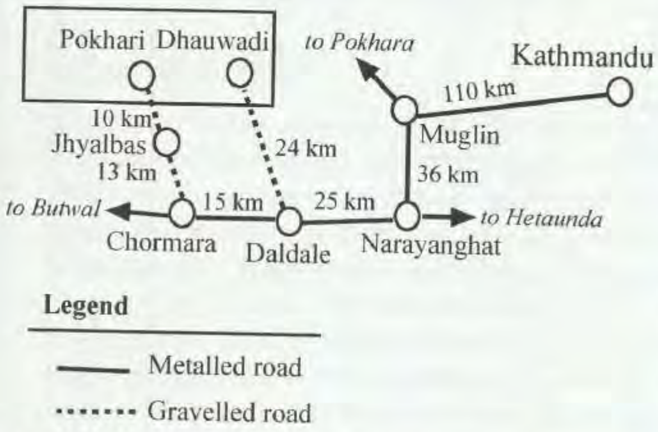


Fig. 1: Route map to access the study area

The geological map - Petroleum Exploration Block-5, Chitwan (scale- 1:250,000) - prepared by Petroleum Exploration and Promotion Project (PEPP) includes the entire present study area. But, there has never been any previous study for coal exploration.

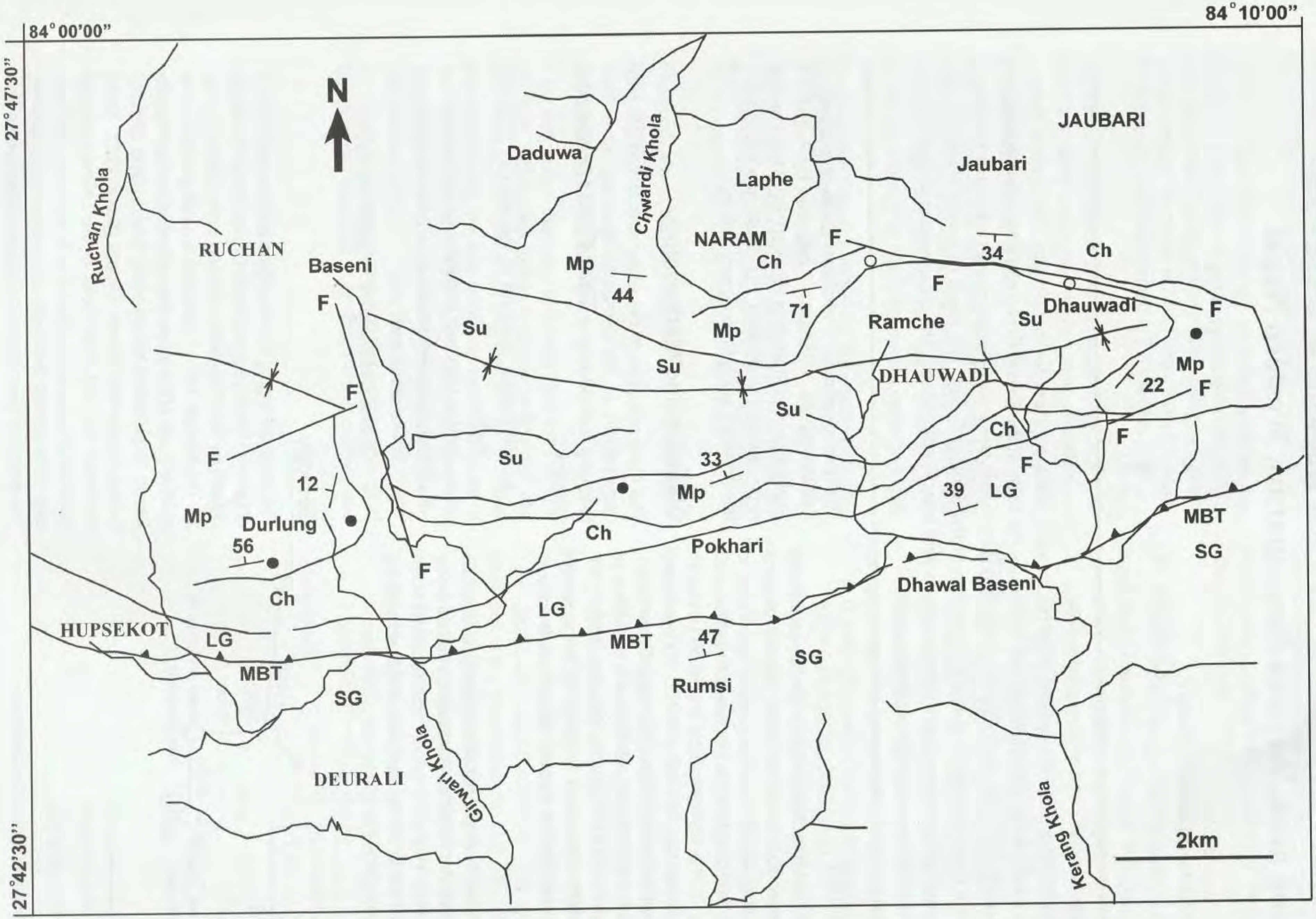
Objective and Methodology

The main objective of the study was to find out coal occurrences in the Dhauwadi-Durlung area. The following methodologies were adopted to achieve the objective:

- Geological mapping of the area in 1:25,000 scale,
- Find out the coal occurrences in the area,
- Determine the thickness and the extension of coal seams, and
- Collect coal samples for quality analysis.

Geology

The rocks belonging to Lakharpata and Surkhet Groups of Lesser Himalaya and Siwalik Group of Sub-Himalaya constitute the Dhauwadi-Durlung area (Table 1, Fig. 2). The Siwalik Group occupies a small portion in the southern part of the study area whereas the Lakharpata Group (equivalent Kaligandaki Group) and Surkhet Group (equivalent Tansen Group) (Sakai 1983, 1984) constitute the rest. The rocks of the Lakharpata and Surkhet Groups are folded into a syncline. The fold axis runs almost E-W with an eastern fold closure. The area has been highly disturbed by transverse and



LEGEND SW: Siwalik Group; Surkhet Group (Su: Suntar Formation, Mp: Melpani Formation, Ch: Charchare Formation), LG: Lakharpata Group, F-F: Fault, ●: Hematite Sample; ○: Coaliferous shale sample, MBT: Main Boundary Thrust longitudinal faults. The effect can be attributed to the MBT.

The rocks in Dhauwadi-Durlung area strike E-W and have low to very high dip amounts. The dip amounts range from as low as nearly horizontal to as high as nearly vertical. They dip towards north and south respectively in southern and northern limbs.

Table 1: Lithostratigraphy of the Dhauwadi- Durlung area (adopted after Kayastha, 1992)

Tectonic Unit	Group	Formation	Lithology	Age
Sub-Himalaya	Siwalik	Middle Siwalik	Sandstone, mudstone, conglomerate	Middle Miocene-Pleistocene
---Main Boundary Thrust---				
Lesser Himalaya	Surkhet	Suntar Formation	Metasandstone, Slate/shale	Oligocene - Early Miocene
		Melpani Formation	Quartzite, slate/ shale	Late Cretaceous - Paleocene
		Charchare Formation	Diamictite, slate, conglomerate	Permian - Early Cretaceous
	---*Unconformity/fault*---			
	Lakharpata	Lakharpata (undifferentiated)	Quartzite, slates, Dolomite, limestone	Late Precambrian - Early Paleozoic

Coal Occurrences and quality

Coaliferous-shale seams have been found in two locations namely, Dhauwadi and Ramche, all in the Melpani Formation (Fig. 3). The coaliferous-shale is friable and dull with some mixed contents of highly carbonaceous slate fragments and carbonaceous mud. Three samples were collected and analysed in the chemical laboratory of the DMG for Moisture content, Total Ash, Volatile Matter, Fixed Carbon and Calorific Value. But the analysis result showed the calorific value to be very low that is less than 1000Kcal/kg. It indicated the seams are not coal but coaliferous-shale.

Other Minerals

It is found that the area consist of a hematite deposit. Thin-bedded to massive, fine-to medium- grained (? siliceous), brownish red hematite beds exist mainly within the southern limb of the Melpani Formation (Figs. 4 and 5). The hematite band ranges in thickness from 7 m up to 25m. The hematite band is observed to be about 10 km in extension and runs throughout the length of the area. It is exposed at Dhauwadi in the east, at Pokhari in the central part and at Durlung in the west. Twenty-two random hematite samples were collected and analyzed in the DMG laboratory to find out the Iron (Fe) content. The chemical results showed the samples contain up to 53% Fe.

Fig. 3: A coaliferous-shale lens exposed near Ramche

Fig. 4: Hematite beds exposed at Durlung area

Fig. 5: A hand-specimen of hematite collected from Durlung area

Conclusion and Recommendation

- No coal seam exists in Dhaubadi-Durlung area, except some coaliferous shale zones.
- Instead of coal deposit, the area shows high potential for hematite deposit. Therefore, an exploration for hematite deposit is highly recommended in the area.

Acknowledgement

We express our gratitude to Mr. Sarbjit Prasad Mahato, officiating director of the DMG for providing all the necessities to carryout this research. We thank the DMG laboratory for analyzing the samples and Mr. Y. P. Parajuli, assistant sampler, for accompanying in the fieldwork.

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Annual Report of Department of Mines and Geology, 2011, No. 7, pp 23-26

Limestone Exploration (Follow-up) Khamilekn, Kuvinde Daha, Salyan

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ABSTRACT:

Department of Mines and Geology has been exploring non-metallic mineral, especially the cement grade limestone, in the country. The follow-up exploration of Linestone at Kuvindedaha, Sallyan was a part of the departmental program of FS 2065/66. Field program was carried out from 4th Falgun to 10th Chaitra 2065. During field period, ten square kilometer area was prospected preliminarily and five square kilometer was prospected in detail for limestone. Khamilekh hill ridge was found having limestone of good grade and medium sized deposit. This area was explored by 200 meter channel sampling, 100m chip sampling. Geology of the area is complex having series of faults and tight folding. The result of chemical analysis shows that the lime contents more than fifty percent and magnesium oxide less than two percent. Moreover, content of colorings elements are also very less. Thus the limestone is considered for the production of white cement.

INTRODUCTION:

The follow-up exploration work for the limestone aiming to find out the suitability for cement production was carries out as per the departmental programme of the fiscal year 2065/2066. The field work was conducted from 2065/11/04 to 2065/12/10 totaling 37 days.

Nepal is experiencing growing demand of construction materials day by days specially that of cement materials. Domestic production supply only 35-40% of the national demand. Remaining demand is supply by the clinker grinding industries and foreign supply. Cement production in the country would produce value added product of limestone available in the country. Keeping in view of this fact Department of Mines and Geology (DMG) has been conducting exploration of cement grade limestone and associated rock of dolomite.

As per the departmental program, field work has been conducted around Khamilekh and Kuvinde Daha areas of Salyan district. The area of exploration lies in HMG survey department's toposheet number 2882 09B and 2881 12B, scale 1: 25000 (figure-1).

Exploration site can be reach via Tulsipur. Schematically accessibility can be shown as follows:

Kathamandu --------370km pitch road------Lamahi -------42 km pitch road--------Tulsipur ---------70 km graveled road -------Salyan Khalandga ----------10 km rough road----------Jaitpani---------4 km trail---------Khamilekh (exploration site).

During field work, geological mapping of carbonate rocks occurrences found in the area, systematic channel and chip sampling have been done. As a result 5 square kilometers area has been mapped in detail, prospecting work in 10 square kilometers area was done. In total 100 channel samples and 10 chip samples have been collected.

OBJECTIVES:

The main objective of the exploration work was to identify and explore in detail the cement grade limestone and industrial grade dolomite deposit. Analysis of mineability based on the topography, exposure and accessibility.

TARGET:

- Detail geological mapping of 5 square kilometers area in Khamilekh range.
- Geological mapping of 10 square kilometers area in Kuvindedaha area.
- 400 m length channel sampling.
- 100 m chip sampling.

PREVIOUS WORK DONE:

Senior Geologist Mr. Tekraj Panta carried out the preliminary exploration work in the area in fiscal year 2064/065. He had covered 150 square kilometers area during preliminary work. Samples collected during field work were analysed in the chemical laboratory of DMG. Analysis has shown that explored area is potential for cement grade limestone and industrial grade of dolomite. The analysis report has been attached as annexure-1.

JOB CARRIED OUT:

The following job have been done during field work

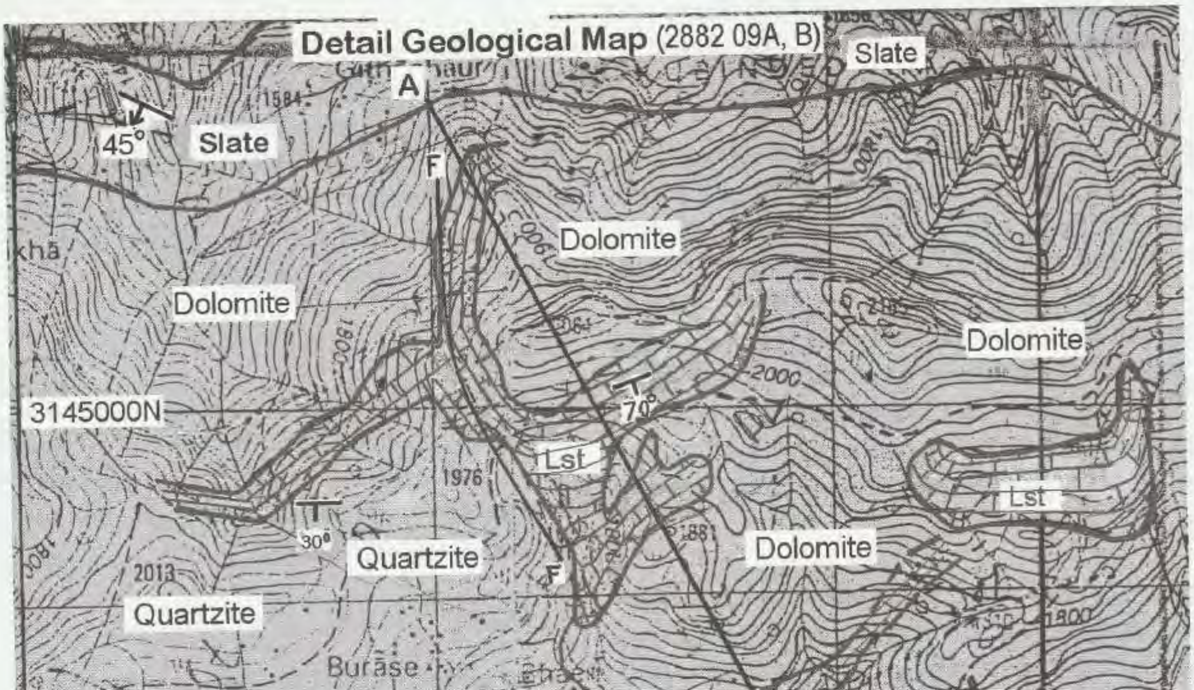
- Detail geological mapping within 5 square kilometers area (scale; 1: 10000),
- Geological mapping of 10 square kilometers area adjacent to the above area (scale; 1: 10000),
- 100 channel samples collected covering 200m channel length,
- 10 chip samples collected covering 100 m section length.

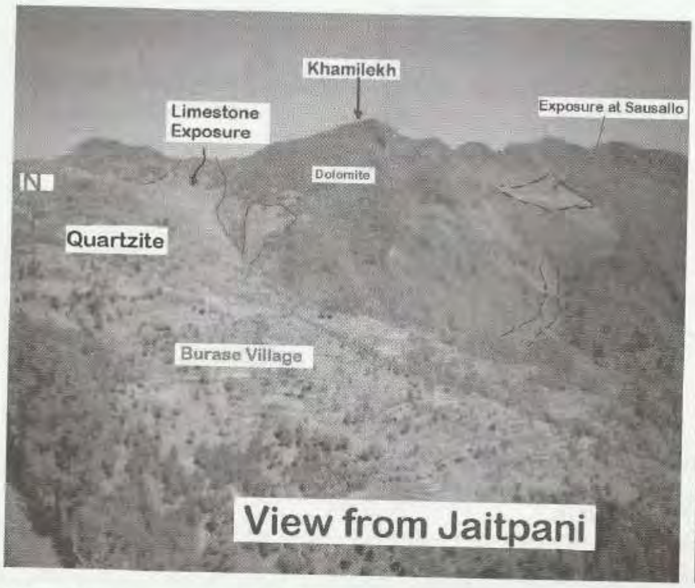
GEOLOGY:

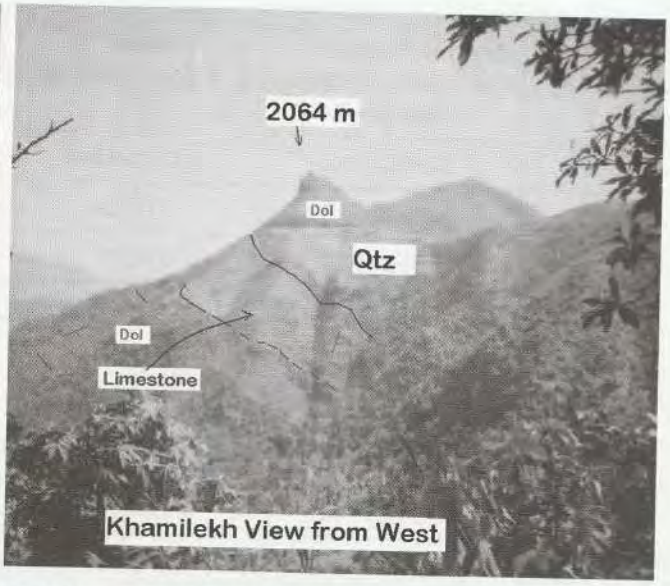
Stratigraphically the Khamilekh, Kuvindedaha area of Salyan district has been placed in Nawakot Group. The limestone band is in Kumak Formation of Kumak Nappe (Kansakar 1983).

Two distinct limestone bands (top-38 m and bottom-20 m) can be seen separated by a 10m dolomite band in between. The dolomite band looks thins at places. Upper contact is with quartzite and the bottom is with dolomite. The top band of limestone is of grey color on surface but when broken it looks white friable. The bottom band is bluish grey, dirty and siliceous. Thickness of limestone bands is more, about 100m, on eastern side and become thinner towards west. The trend of the limestone is striking east to west dipping towards south with varying dip amount 30^0 to 70^0. Striking trend is found changing at higher exposure of Khamilekh area. The bottom contact appears as concave curve towards south. This may be due to squeezing of the band along the strike. Faults are assumed at places created by squeezing of the bands.

Limestone bands of Khamilekh area had been explored and channel, chip samples were collected. The geological of the explored area specially showing the contact of limestone exposure, trends of the band, sample location has been given in the map below.



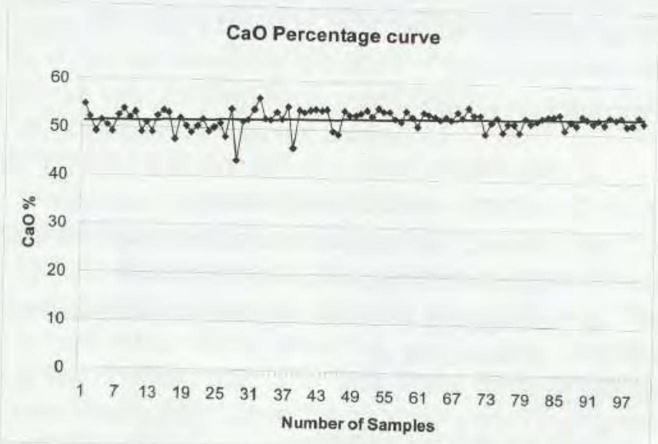


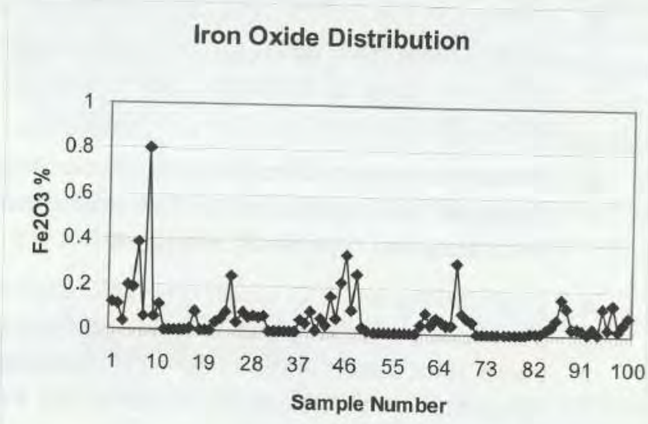


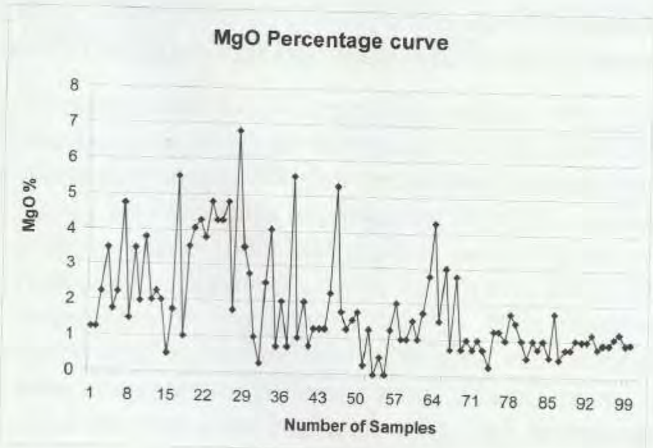
Chemical analysis of samples has been done in DMG laboratory. The chemical analyses average values are as follows:

Average Value, %	LOI Insoluble	Acid	CaO %	MgO %	$R2O_3$ %	Fe_2O_3 %	Al_2O_3 %
Channel Samples (100 Nos)	41.14	2.42	52.32	1.87	1.09	0.06	0.94
Chip Samples (10 Nos)	41.70	2.49	52.01	2.72	1.24	0.24	0.99

Element distribution seen in the graph as below:







The constituent elements which cause the coloring of Ordinary Portland Cement (OPC) have also been analyzed randomly. The chemical analysis result

FINDINGS:

- In Khamilekh area a limestone bed of thickness about 50-80 m has been traced and mapped in detail within five square kilometers area.
- The same band has been followed up to Kuvinde daha area and demarcated in the topo map. This shows the continuity of the limestone bed.

SL. No.	Sample number	Cr (% w/w)	Mn (% w/w)	Ni (% w/w)	Fe_2O_3 (%w/w
1	SLN-CH-2	0.02	0.0125	0.0075	
2	SLN-CH-12	not detected	0.025	0.0075	
3	SLN-CH-22	0.0025	0.0075	0.0075	
4	SLN-CH-32	0.0025	0.0125	0.0075	
5	SLN-CH-48	not detected	0.0225	0.0075	
6	SLN-CH-52	not detected	0.0125	0.005	
7	SLN-CH-60	0.005	0.01	0.0075	
8	SLN-CH-75	0.02	0.02	0.0075	
9	SLN-CH-85	not detected	0.035	0.0075	
10	SLN-CH-95	0.02	0.045	0.0075	
11	SLN-CP-5	0.0175	0.015	0.0075	
	Average Value	**0.007954545**	**0.019773**	**0.007273**	**0.06**
	Limit for White Cement (wikipedia)	**0.003**	**0.03**	**Not specified**	**0.3**

- Channel in five section and chip samples in a section have been taken across the thickness of the samples of limestone bed shows the possibility of workable deposit of limestone.
- Strike extension is disturbed by the Squeezing (faults) in the Khamilekh area. Extension is not continuous but repeatedly appeared.
- Limestone is white to bluish grey soft, friable, thick bedded. Striking east to west and dipping south at moderate angle of 30 – 70^0. Overlain by quartzitic schist/slate and underlain by the dolomite.
- Khamilekh portion area is found having mineable limestone band.
- Chemical analysis shows the limestone is of high calcium carbonate with low iron content. The coloring matters are also very low.

CONCLUSION:

- Khamilekh area is having complex type of high calcium Limestone deposit.
- Deposit can support a medium scale cement manufacturing plant (400–1000 tpd).
- Limestone seemed suitable for white cement manufacturing

RECOMMENDATION:

Detail exploration and proving be carried out from the suitability for white cement manufacturing point of view.

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Landslide Hazard Zonation Mapping in parts of Myagdi, Baglung and Gulmi Districts, Central West Nepal (Toposheet No.2883)

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ABSTRACT

A Landslide Hazard Zonation map of parts of Myagdi, Baglung and Gulmi district is prepared using bivariate statistical method. Geology, landuse, slope and slope aspect were considered to be the main causative factors for landsliding in the area. The study area is classified into high, moderate and low hazard zones indicating likely hood of occurrence of landslides as high, moderate and low respectively. Out of 650 sq.km of the study area 233 sq.km is covered by highly unstable zone forming 34.4% of the total area. About 61% of the area falls on moderate and 4.93% is on low hazard zone. The hazard zonation map is expected to be useful for planning of infrastructure development activities in the region.

INTRODUCTION

Landslide mapping and inventory was carried out to prepare Hazard Zonation map of parts of Myagdi, Baglung and Gulmi districts in Western Development Region. The survey covered 650 sq. km area of toposheet no. 2883 (62P/7) during a field period of 32 days from 13th Falgun to 14th Chaitra 2065. The study is a part of the annual program of the Department of Mines and Geology, fiscal year 2065/66 to collect data on landslides at regional scale.

The area is located between latitudes 28° 15' 00" to 28° 30' 00" N and longitudes 83° 15' 00" to 83° 30' 00"E. Myagdi, Bhitriban, Tara, Aije, Bhedikhor, Bhim Kholas and their tributaries are draining the study area. The Myagdi Khola flows almost in west to east direction in the northern part. The Tara Khola flows in almost north-south direction in the southern part. The highest altitude in the area is 3633m above msl in the northwest corner and the lowest elevation is 934m above msl at Pakhar along the Myagdi Khola valley.

Traverses were taken along river valleys, main trails and along the ridges for verification of erosion features interpreted on aerial photos and satellite images. Field survey was focussed on collecting data for landslide inventory and their distribution using 'Inventory Forms' and mapping of various factors that are mostly responsible for triggering landslides. Data collected during field verification and desk level interpretation were integrated for the preparation of factor maps. All collected data were analyzed using GIS techniques to prepare landslide hazard zonation map at 1:50,000 scales.

OBJECTIVES

Landslide related disaster destroy life and property in the hilly region of Nepal. Thousands of people are left homeless every year in spite of the governments efforts to minimize the risk. Hazard mitigation works and planning of future development activities are done without the information on areas that are prone to such disasters. In this regard, present study is planned for the following objectives:

- to record the landslides of the study area using 'Landslide Inventory Form'.
- to integrate landslide distribution and geologic data with slope morphology and existing landuse for the preparation of landslide hazard zonation map at 1:50,000 scale by optimum utilization of Remote Sensing and GIS techniques.
- to prepare the regional database of landslides.

BACKGROUND

Geological Studies have been carried out by a number of researchers in the Myagdi Khola area. Among others, Jnawali and Tuladhar 2058, Vaidya 2057 and Joshi 2026 have done the geological mapping covering parts of the target area. A compiled geological map by J.N. Shrestha et al. is published by DMG in 2003

A.D. This map will be used as a base for the geological data. Reviews of existing geological maps suggest that the area is represented by metasedimentary rock sequences of Pre-Cambrian age belonging to Upper and Lower Nuwakot Group. Several thrusts, faults and folds of regional scales are also mapped indicating weak tectonic belts.

Land capability, land utilization and land systems maps prepared by Land Resources Mapping Project (LRMP) in 1984 at 1:50,000 scales are the other information available in hand.

Information on probability of occurrence of natural disasters such as landslides is not available for this area. In this context present study program has been planned to provide geo-scientific information especially on landslide hazards beneficial for planning of infrastructure development activities in the region.

METHODOLOGY

Desk Study

Aerial photographs taken on 1979 at 1:50,000 scales acquired from the Survey Department were interpreted to study the landslides, erosion features, tectonic structures, existing landuse pattern and lithological units. The False Color Composite of Landsat-TM images of December 1992 was studied as supplement to the aerial photographs for comparing the landuse pattern, landslides, tectonic structures of regional significance. Land capability, land utilization and land system maps were studied. The topographic maps at 1:25,000 and 1:50,000 scales were used as a base map for the field data collection together with aerial photographs. Geological maps and reports were also reviewed. Different Thematic layers, their sources, parameters used and the method of generation are summarized in table-1.

Field Investigation

Field checking and data collection was carried out taking traverses along different routes using landslide inventory form, aerial photos and topographical maps. Emphasis was given to study the landslides and other areas prone to soil erosion by close observation. Some of the major landslides were studied in details using 'Preliminary Landslide Inventory Form' for regional inventory.

Table-1. Data overlays, Sources, Parameters and Method of generation

Data overlays	Database /sources	Parameters	Method of generation
Geology	Geological maps from DMG[1], aerial photographs / SD[2], LANDSAT -TM /BGR[3], and ADEOS-AVM/ ICIMOD[4]	Lithology and Rock type	VI[6], FC[7] and GIS
Structure	Geological maps from DMG[1], aerial photographs / SD[2], LANDSAT -TM /BGR[3], and ADEOS-AVM/ ICIMOD[4]	Lineaments, regional structures and Dip slope relationship	VI[6], FC[7], GIS and image processing
Topography	Topographical map in digital format/ SD[2]	Topographic features, slope gradient / direction	GIS based Digital Elevation Model (DEM)
Slope	Topographical map in digital format, and aerial photographs / SD[2]	Classification of slope	FC[7] and GIS
Slope aspect	Topographical map in digital format, and aerial photographs / SD[2]	Classification of slope direction	GIS based Digital Elevation Model
Land use	Topographical map in digital format, maps from LRMP[5] and aerial photographs / SD[2]	Classification of Landuse	VI[6], FC[7] , GIS and image processing
Landslide	Topographical map in digital format, aerial photographs / SD[2] and LANDSAT -TM /BGR[3], and ADEOS-AVM/ ICIMOD[4]	Landslide occurrences and gully erosion	VI[6], FC[7] , GIS and image processing

DMG[1]: Department of Mines and Geology, Kathmandu. SD[2]: Survey Department, Kathmandu
BGR[3]: Federal Institute for Geo-science and Natural Resources, Hanover, Germany
ICIMOD[4]: International Centre for Integrated Mountain Development, Kathmandu
LRMP[5]: Land Resources Mapping Project, Kathmandu. VI[6]: Visual interpretation. FC[7]: Field checking

GEOLOGY

Unconsolidated soils such as residual, alluvium and colluvium (including talus) deposits were mapped within the study area. Thick alluvium soil is developed as river terraces along Myagdi, Tara, Bhedikhor and Bhim Khola valleys. River terraces developed in these areas are often covered by colluviums deposit derived from the high hills lying on either side of the river valley. These river terraces are cultivated and have settlements near the riverbanks. However, these areas still lack proper infrastructures like road, electricity and irrigation. Hill slopes are also cultivated except in the remote areas. Improper cultivation practices have often triggered landslides damaging property worth of millions of rupees.

Meta-sedimentary rocks such as phyllites, quartzites and slates of the Kunchha Formation and Dandagaon Phyllite are observed around the northern part in the catchment area of Myagdi Khola. Slates, quartzites and dolomites of Benighat Slates, Nourpul Formation and Dhading Dolomites are developed in the southern part (Fig. 1c). These rocks are of Precambrian age. Old workings of metallic minerals like copper and iron were observed in localities of Pandavkhani and Bhedikhor. The 22 localities (Baaish Khani) for metallic minerals are known in Baglung and Myagdi districts. A new road is under construction from Baglung to Pandavkhani and it passes close to the hematite bed exposed at Bhangkhani area.

PREPARATION OF FACTOR MAPS

A landslide distribution map (Fig. 1a) was prepared by compiling various sources of information and the data from field checking. In this case, the landslide distribution map contains active and reactivated landslides. Similarly the factor maps with various parameters that are mostly responsible for land sliding were prepared using GIS system by incorporating the data obtained from desk study and field verification.

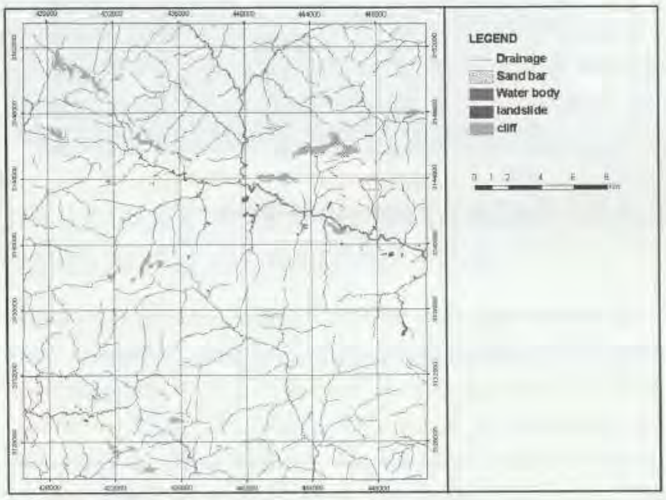


Figure 1(a): Landslide Inventory Map

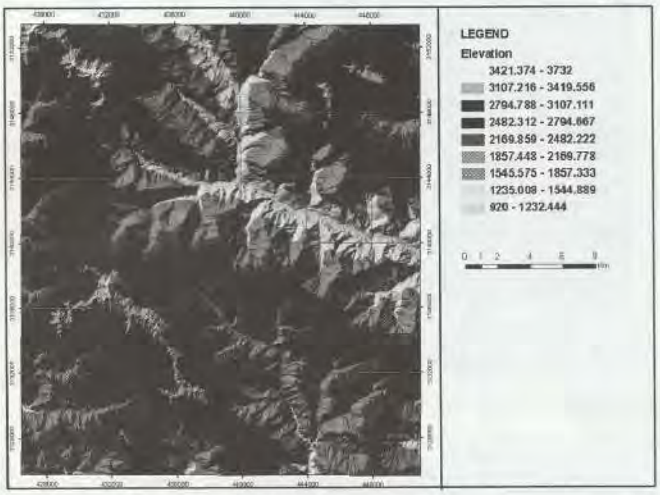


Figure 1(b): Digital elevation model

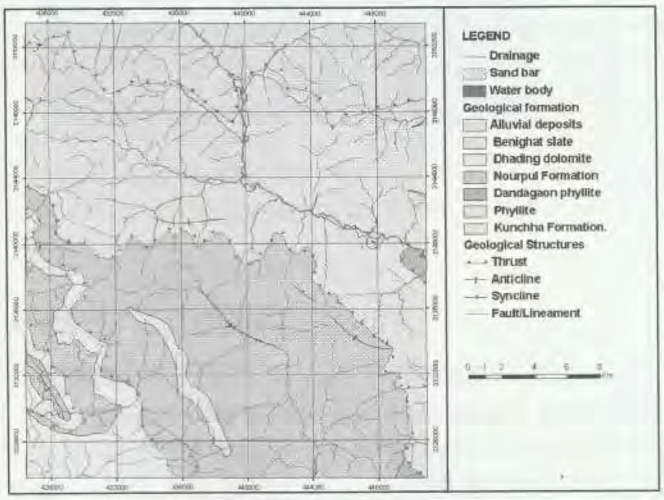


Figure 1(c): Geological Map

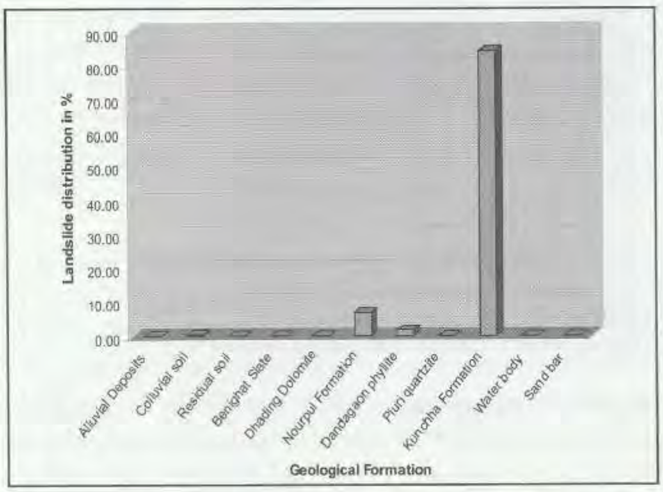


Figure 1(d): Relation between landslide and geology

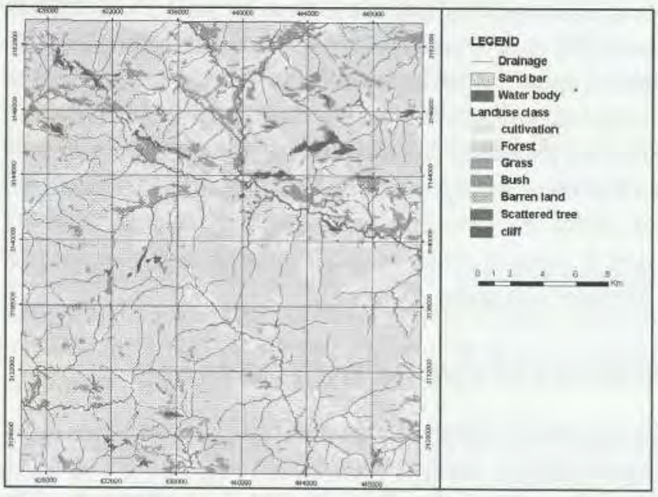


Figure 1(e): Landuse Map

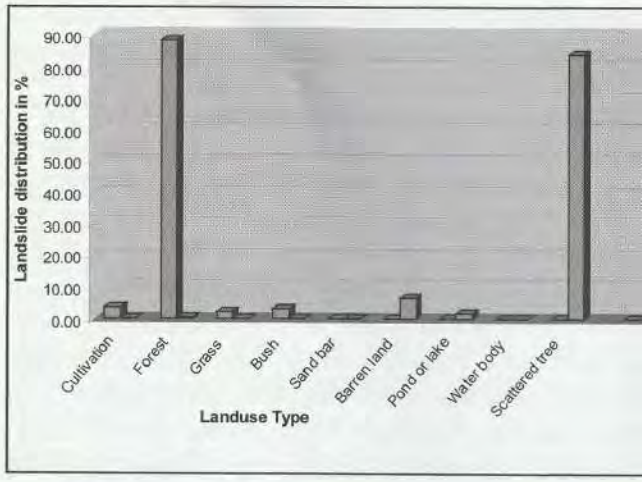


Figure 1(f): Relation between Landslide and Landuse

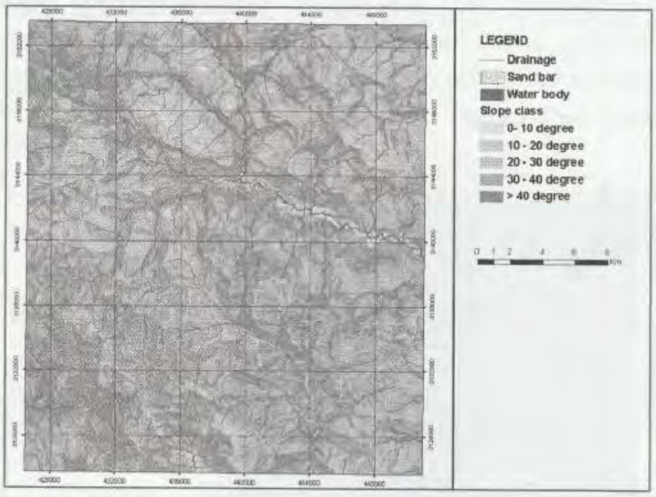


Figure 1(g): Slope Map

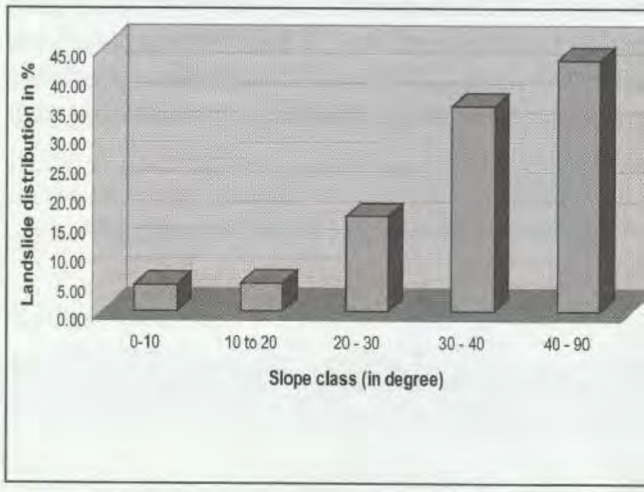


Figure 1(h): Relation between Landslide and Slope

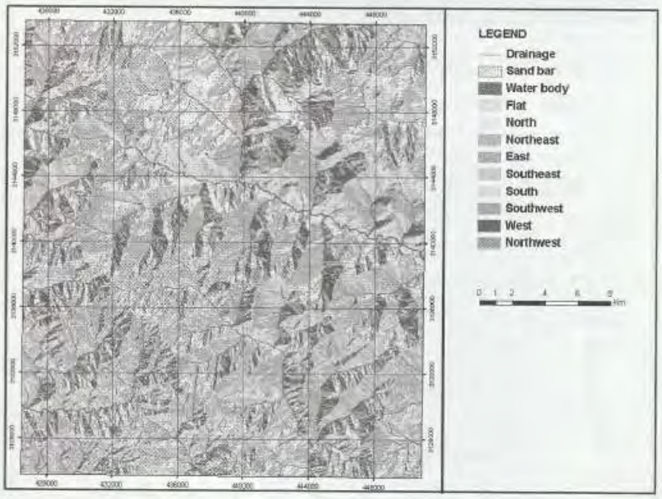


Figure 1(i): Aspect Map

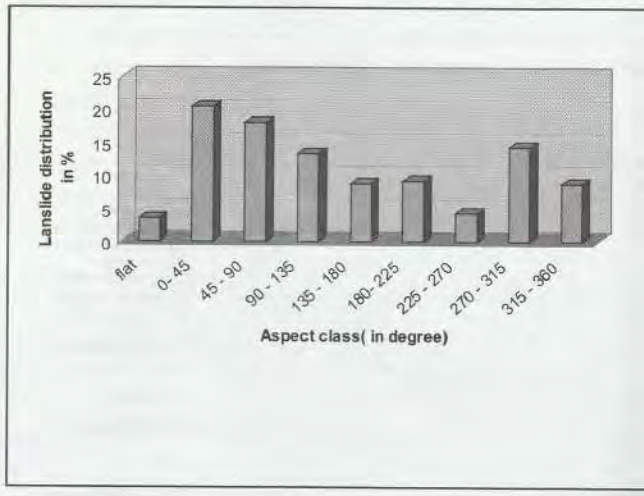


Figure 1(j): Relation between Landslide and Aspect

Figure 1: Various factor maps showing their relation with the landslide distribution

Slope Map, and Aspect Map were generated using a Digital Elevation Model (DEM, Fig. 1b). In the present study, factors such as geology (Fig. 1c), land use (Fig. 1e) slope (Fig. 1g) and aspect (Fig. 1i) were considered for the assessment of probability of landslide hazard at regional scale. The statistical relationships of landslide distribution to various causative factors are summarized in figures 1d, f, h, and j.

ROLE OF REMOTE SENSING DATA AND GIS IN LANDSLLIDE HAZARD STUDY

Data acquired by the remote sensing techniques are becoming better in resolution and user friendly to integrate in GIS system. In this context, Remote Sensing and GIS are widely used to evaluate the degree of danger from landslide in an area by considering the nature of causative factors in the surroundings. Different models are proposed and used to assess the relative likelihood of landslide occurrence by different researchers. The present study was based on bivariate statistical method and deals with one of the dependent variable like landslide density and other independent variables such as geology, landuse, slope and slope aspect. The following formula was used (after Van Westen, 1993); for the present analysis.

$$W_i = \ln \frac{\text{Densclas}}{\text{Densmap}} = \ln \frac{\dfrac{\text{Area of landslide in a certain parameter class}}{\text{Area of certain parameter class}}}{\dfrac{\text{Area of landslide in the entire map}}{\text{Area of entire map}}}$$

Where,

W_i = Weight given to a certain parameter class

Densclas = Landslide density within the parameter class

Densmap = Landslide density within the entire map.

INVESTIGATION RESULTS

Slope failure processes noted on satellite image, aerial photographs, topographical maps and geological maps were verified in the field. Areas prone to soil erosion by gully formation and land sliding were also recorded during field checking. Majority of the slides are soilslides. Rockslides are also triggered in intensely fractured rock mass. Discontinuities affecting rock mass are joints, bedding planes, foliations, thrusts or faults. Wedge and planner failure are common in rock mass. Block falls and topples are also noted at places of steep slopes especially along the Myagdi Khola valley whereas rotational and translation features were observed in the soil mass resulted mainly due to over saturation and toe scouring of the slope by the rivers.

Heavy rainfall of 12th Ashad 2065 around the Dadhe Lek between altitudes of 3400 to 3500 meters (Toposheet No. 2883 10C) washed down the logs, branches and trees along with loose boulders to the rivers that originate from the area. Such concentrated rain with loose materials rushing into the rivers accelerated the toe scouring of the riverbanks thereby adding the loose material forming debris flood. This type of debris flood heavily affected the settlements, cultivated land, infrastructures such as suspension bridges and micro-hydropower projects. People had to flee their houses suddenly in order to protect themselves from flood.

The effect of flood disaster was intense along Lukharban Khola (Khunga VDC), Bhedikhor Khola (Ransin Kiteni VDC), Bhim Khola (Ramuwa of Pandavkhani VDC), Tara Khola (Tara Khola VDC) and Khahare Khola (Rum VDC). The settlement of Ramuwa was badly affected as the river was diverted towards the village when the large tree trunks in the debris created a dam in the flow direction near the intake of the micro- hydropower plant. Seven suspension bridges of different locations in the Bhedikhor Khola were washed away. A house with General Store (shop) located at Dovan was completely washed away. Many hectares of cultivated land were destroyed in Tara Khola area. Four suspension bridges were washed away along the Kahare Khola. People are expecting support from the government for mitigation works and construction of damaged structures as soon as possible.

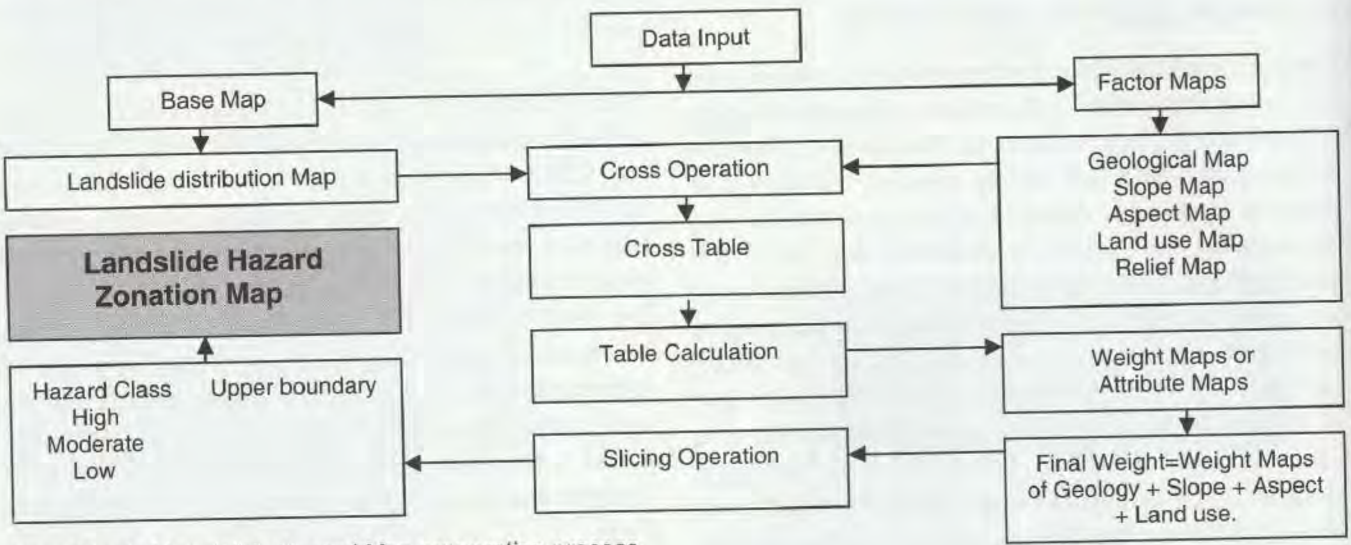
Road to Darbang from Beni is affected by rockslides and soilslides at different locations. The rockslide occurring near Simalchaur is a large-scale slope failure resulted in the highly fractured rock mass which obstructs traffic during rainy season. Landslides along Khahare Khola of Rum VDC are affecting the settlement of Seglun and Aribhara area.

Based on the field verification, aerial photo interpretation and satellite image interpretation soil type distribution map and landslide distribution map were prepared. Various parameters mapped on Soil type map, geological map, slope class map and aspect map were used as causative factors for causing the landslide. Landslide inventory map was taken as base to calculate the rating values of causative factors to derive the Landslide Hazard Zonation Map using GIS based ArcInfo system in the computer.

Main causes for the occurrence of landslide in the area can be attributed to intense fracturing of rock mass, difference in relief forming steep slopes, improper slope cultivation practices and toe scouring of adjacent slopes of high gradient rivers or streams and high intensity of rainfall.

PREPARATION OF LANDSLIDE HAZARD ZONATION MAP

Based on the density of landslide distribution in each class/unit of the causative factors at present situation a landslide hazard zonation map (Fig. 2) was prepared and divided the entire study area into three categories predicting probability of danger from landslide. Since each unit of the factor map has different weight value derived according to the density of landslide distribution within the unit, the addition of all the weight value for a certain region was carried out during the statistical calculation. After calculation of total weight for hazard coverage the area was subjectively classified into three different zones as low, moderate and high hazard. Process of hazard zonation is summarized in the following flow chart.



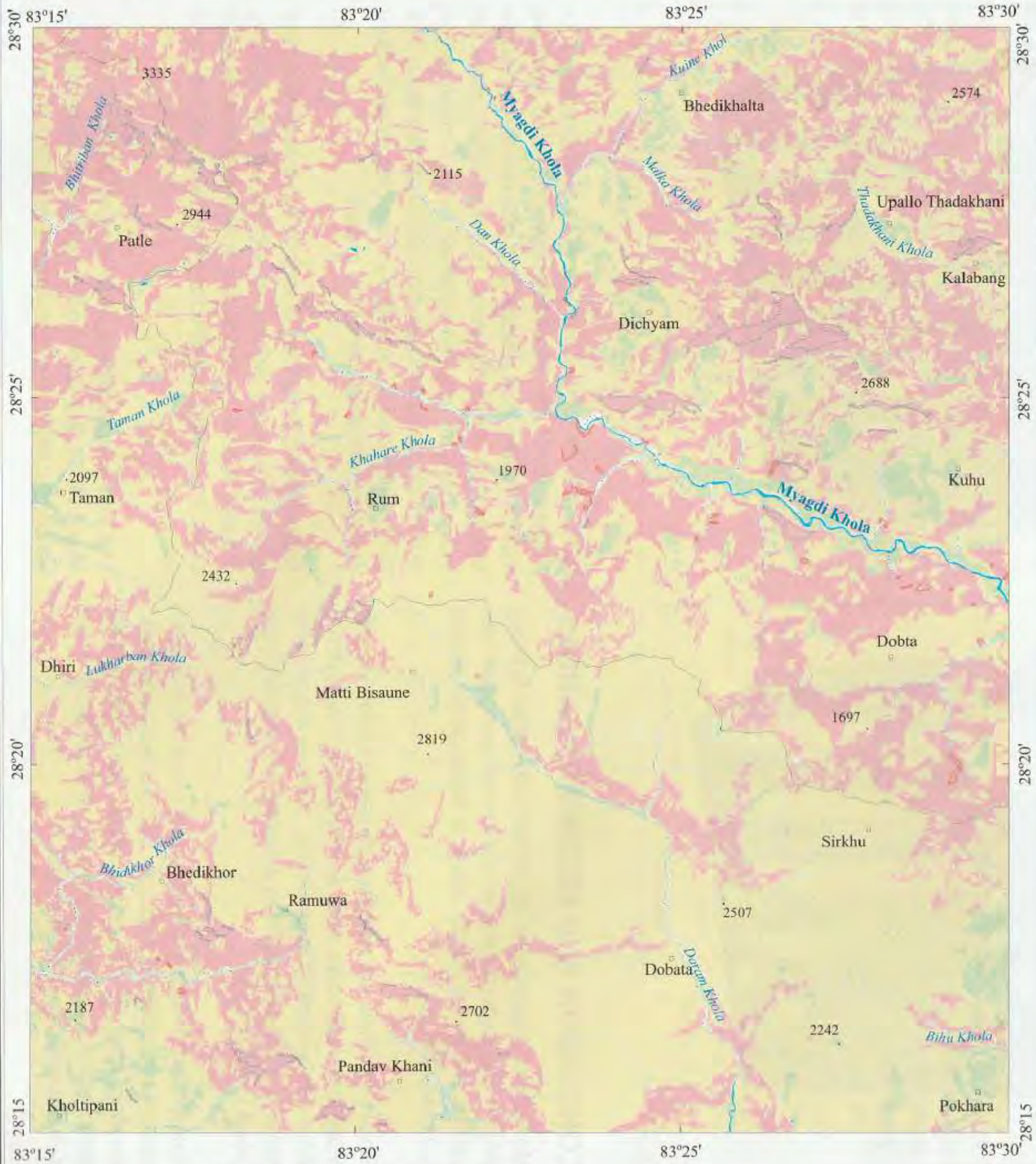
Flow Chart of Landslide Hazard Map preparation process

RESULTS OF STATISTICAL ANALYSIS

The Landslide Distribution Map (Fig. 1a) was combined with the Landslide Hazard Zonation Map (Fig. 2) using overlay option in Arcview environment. Density of landslide distribution within each hazard zone was calculated. In the present study area 95.39 % of the landslides were found to be distributed in high hazard zone; nearly 4.3 % in moderate and only 0.32 % in low hazard zone suggesting a satisfactory precision of the adopted method for probability of landslide occurrence in this area. The relation between hazard class and causative factors (Fig. 3a, b, c, and d) was also evaluated to assess the affect of various factors for estimating the range of instability in the region in terms of probability of landslide hazard.

LANDSLIDE HAZARD ZONATION MAP OF PARTS OF MYAGDI AND BAGLUNG DISTRICTS

SHEET NO. 2883 10



EXPLANATORY LEGEND

The Landslide Hazard Zonation Map was prepared by adding the weighted values of the four causative factors (Geology, Landuse, Slope, and Slope aspect). The weighted values were derived by statistical analysis based on the ratio of landslides within each class of the causative factors. The relative hazard is expressed as low, moderate and high hazard, based on weight value ranging from -6.252 to 2.521

Hazard Class	Possible Damage	Remarks and Recommendation
Low	Very few landslides and no major slopes instability at present. Toe cutting and bank collapse along the river. During the wet season, depositon of debris in low land area are likely.	Normally stable and regulated constructions suitable. Limitations may impose by soil conditions and other hazards like river bank collapse and seismic events at places.
Moderate	Less landslide density and rock falls and soil erosion presence. Possibility of reactivation of old landslides. High susceptibility of sliding above 20 deg. Possible damage towards the N E and WNW slope direction.	Urban development activities possible with appropriate safety measures. Proper irrigation needed and water should not be diverted towards slide areas. Careful selection of road alignment and heavy construction needs specific site investigation.
High	High density of landslides and rock falls. High susceptibility of sliding steeper than 30 degree. Loss of arable land and soil. High risk of life and property.	Limited stable areas for safe infrastructure development activities. High cost for preventive geotechnical works likely during detail site specific geotechnical works.

NOTE

This map is mainly based on statistical and empirical evaluation of various causative factors related to slope instability and their relationship with existing landslide distribution within the area. The map relies on the surface information obtained by ground survey of accessible areas and data from aerial photographs. Direct mapping of all individual existing landslides was not possible due to inaccessibility, concealment in densely vegetated areas and limited time. Area close to thrusts and faults are tectonically weak zones.

The map is exclusively intended for planning at a regional scale. It should not be used as the only basis of investigation for individual buildings. The map cannot replace detailed site investigations. It is time dependent and needs periodic revision. Change in any single factor by natural or human activities needs reevaluation because change of a single factor can be sufficient to exceed the threshold for slope failure.

General Symbol

Stream / River / Sandbar
Lake / pond
Contour line with height in metre (1300)
District boundary
Landslides
Cliffs
Village
•1381 Spot height in metre

1 0 1 2 3 4 Km.

Figure 2: Landslide hazard zonation map of parts of Myagdi, Baglung and Gulmi Districts

Figure 3(a): Relation between Geology and Hazard

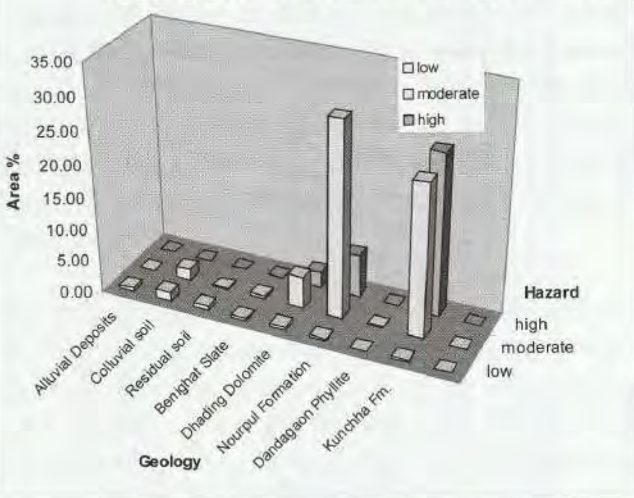


Figure 3(b): Relation between Landuse type and Hazard

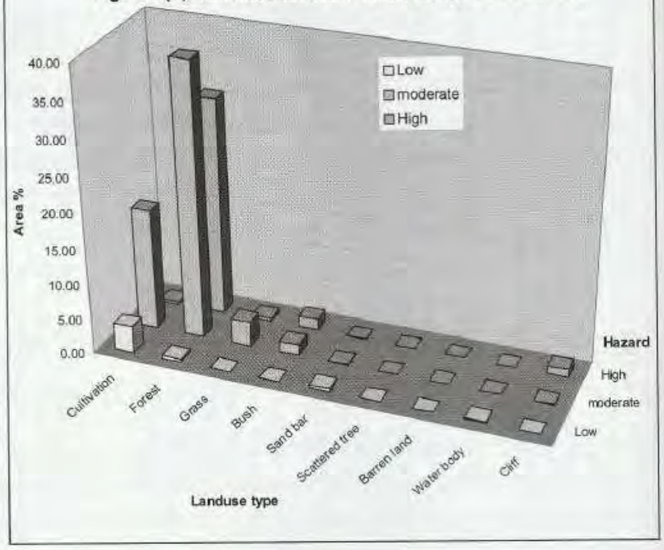


Fig. 3(c): Relation between Slope and Hazard

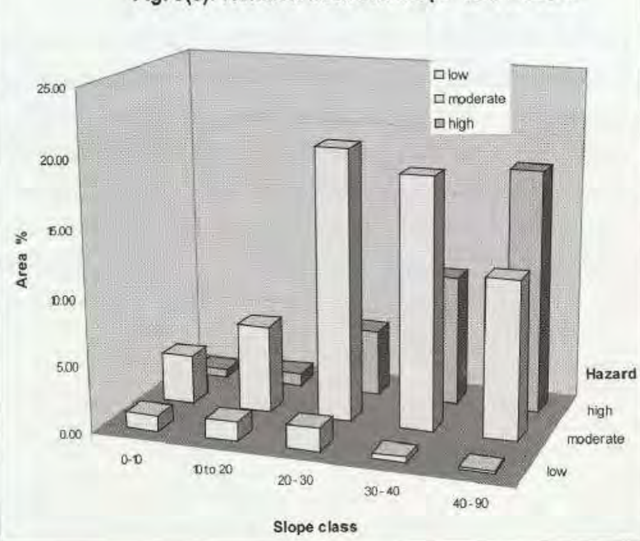
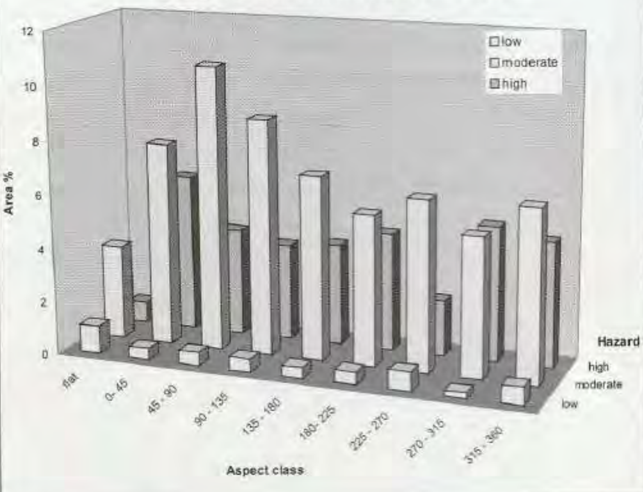


Fig. 3(d): Relation between Aspect and Hazard



CONCLUSION AND RECOMMENDATIONS

Most of the study area is hilly terrain with gentle to steep slopes. Flat to gentle slopes are formed along the river valleys and on the ridges. Areas of flat to gentle slopes are more stable.

Slopes with thick soil mass or with highly jointed, deeply weathered, soft rocks such as phyllites are found to be more susceptible to land sliding. Steeper slopes with highly jointed rocks such as dolomite and quartzite are prone to block falls.

Suspension bridges constructed close to the river banks on loose soil mass in the old river channels are damaged by the debris flood. Settlements and cultivated lands developed on the river terraces close to riverbanks are also affected.

Landslide Hazard Zonation Map was prepared by integration of the causative factors related to slope instability and their relationship with existing landslide distribution within the area. The map totally relies on the surface information obtained by ground survey of accessible areas and data from aerial photographs. The map is intended to be useful in planning infrastructure development activities of the region.

Altogether 45 landslides of various sizes were observed within the study area and almost all the existing old and active landslide fall within the high hazard zone indicating satisfactory precision of the used method.

The total weight values were from –6.2517 to 2.5212. About 95.39 % percent of the landslides are found to be located within the high hazard zone, 4.3 % percent in moderate hazard zone and only 0.32 % percent in low hazard zone.

Hazard zonation map shows that about 233.49 sq. km covered by highly unstable zone forming 34.40 % of the total study area whereas about 60.89 % area are on moderate hazard zone and the rest 4.93 % in low hazard zone.

This map is exclusively intended for planning of infrastructural development activities at a regional scale. It should not be used as the only basis of investigation for individual buildings or any major civil structure. It cannot replace detailed site-specific investigations. It is time dependent and needs periodic revision. Change in any single factor by natural or human intervention needs re-evaluation because change of a single factor can be sufficient to exceed the threshold for slope instability.

ACKNOWLEDGEMENT

We are grateful to Dr. R. B. Shrestha, former Director General and Mr. S. P. Mahato, Director General, DMG for supporting the field program and guidance. Our sincere gratitude is due to R .R. Shakya, former Superintending Geologist for his valuable suggestions. The GIS analysis was done by Mrs. Shova Singh. Her painstaking efforts should be acknowledged. Sincere thanks are extended to staff members of Remote Sensing Section as well as other sections for fruitful discussion.

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Annual Report of Department of Mines and Geology, 2011, No. 7, pp 37-45

Landslide Hazard Mapping of some parts of Myagdi, Baglung and Parbat Districts, Western Nepal

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Abstract

The mountainous terrain in the Nepal Himalayas is generally characterized by steep slopes, high relief, highly weathered and densely jointed rocks with unfavorable hydrogeological conditions with respect to slope stability. "Landslide inventory and geohazard mapping of some parts of Myagdi, Baglunf and Parbat districts" was conducted in accordance with the annual programme of DMG for the fiscal year 2065/066 in order to acquire first hand information on the landslide hazard condition of the study area. Recently utilization of new methodologies including remote sensing and Geographical Information System (GIS) are rapidly becoming popular in landslide hazard zonation mapping because of availabilities of appropriate data sets and powerful computer environment. The factors geology, slope angle, landuse all contribute to slope instability. These are analyzed in relation to landslide density and are numerically weighted. Landslide hazard map prepared using bivariate statistical method and field landslide hazard map were considered together to prepare the final Landslide hazard map. From this, the study area has been classified into three classes of low, medium and high hazard. The map of this landslide hazard zonation may serve as a base for further study.

Introduction

The landslide hazard is referred to as the probability of occurrence of a potentially damaging landslide within a specific time and area. Landslide hazard map shows the interactive and combined result of all the above activities in an area. The assessment of landslide hazard is a costly and time-consuming activity. It requires interpretation of aerial photographs, field surveys and measurements, and rock / soil property tests in laboratory etc. Recently, utilization of new methodologies including Remote Sensing and Geographical Information System (GIS) are rapidly becoming popular in landslide hazard zonation because of availabilities of appropriate data sets and powerful computer environment. Landslide Hazard Zonation mapping helps to find the ways to mitigate landslide disaster.

Nepal is famous for its rugged mountainous terrain with unstable slope. The mountainous terrain in the Nepal Himalayas is generally characterized by steep slopes, high relief, highly weathered and densely jointed rocks. In addition to that, the heavy concentrated monsoon rainfall makes these steep slopes unstable and often leads to different slope failures. Such slope failures are causing severe damage to infrastructures, loss of human life and properties worth millions of rupee every year resulting disruption to the social and economic development of the country. In this context, Department of Mines and Geology (DMG) has been conducting landslide hazard zonation mapping since last few years. Present study covers the "Landslide inventory and geo-hazard mapping of some parts of Myagdi, Baglung and Parbat districts". It was conducted in accordance with the annual program of DMG for the fiscal year 2065/066.

The study area is bounded by latitude 28^0 15' 00" N to 28^0 30' 00"N and longitude 83^0 30' 00" E to $83^0$45' 00" E covering 650 sq. km. area. It comprises inventory and distribution of landslides and other factor maps required for the preparation of Landslide Hazard Zonation map at 1:50,000 scale. The area of investigation falls in sheet No. 2883 11.

The present study of such landslide hazard mapping is carried out for the first time in this area. Therefore, it is expected that its results shall be beneficial for planning the infrastructure development in the area.

Objectives

Present investigation aimed to achieve the following main objectives:

- To study the major landslides and register them in the Preliminary Landslide Inventory Form
- To map all the landslides observed in the field in 1:25,000 scale as far as the scale permits.
- To prepare landslide distribution map
- To integrate landslide distribution with geological information, slope morphology and existing landuse for the preparation of landslide hazard zonation map at a scale of 1:50,000 by using suitable Remote Sensing and GIS techniques.
- To identify major causes of landslides and recommend applicable preventive measures if any.
- To prepare a landslide hazard zonation map of the study area.

Methodology

- Topographic maps of 1:25,000 scales from the Survey Department were used as base map for the investigation purpose.
- Images from Google are studied to evaluate overall development of the hill slope processes and manmade impact in the nature.
- Existing geological maps and relevant literatures of the study area were reviewed.
- Evaluate the hazard category of an individual slopes. Walkover survey was carried out along the valleys and/or ridges whichever was found suitable for better visibility of the slopes with or without landslide.
- Geological reasons were investigated in the area whenever an anomalous landslides occurrence was observed.

Landslide inventory forms were filled mainly for old, big and famous landslides. In statistical landslide hazard analysis, the combinations of factors that have led to landslides in the past were determined statistically and quantitative predictions were made for landslide free areas with similar conditions.

Various organizations are using different methods for landslide hazard analysis. DMG in the past was using mainly bivariate statistical method. Bivariate statistical analyses deals with one dependent variable, which in this case is the occurrence of landslides, and one independent variables, the parameter map.

For this study, landslide distribution map and all parameter maps were prepared in the scale of 1:25,000. This method is mainly based on the following formula (modified, Van Westen, 1993):

$$W_i = \ln\left\{\frac{\text{Densclas}}{\text{Densmap}}\right\} = \ln\left\{\frac{\dfrac{\text{Area of landslide in a certain parameter class}}{\text{Area of certain parameter class}}}{\dfrac{\text{Area of landslide in the entire map}}{\text{Area of entire map}}}\right\}$$

Where,
Wi = the weight given to a certain parameter class (e.g. a rock type, or a slope class)

Densclas = the landslide density within the parameter class

Densmap = the landslide density within the entire map

In Bivariate statistical analysis, crossing of parameter maps and calculation of landslide densities form the core of the analysis (Van Westen, 1993). The importance of each parameter can be analyzed individually.

Field investigation and preparation of arameter maps

The instability of a slope is mainly governed by geological conditions such as lithology and structural condition of the rocks, overlaying properties of soils; and terrain parameters such as slope gradient, vegetation, land use pattern and human activities. However, individual impacts of these causative factors can hardly be differentiated. Therefore, the overall hazard potential at any given area is a combination of subjective rating of that area against each of the above factors.

The data required for the present investigation were obtained from different sources of information together with field work of one month duration, carried out in 2066. The landslide data were collected from field survey. Toposheets at a scale of 1:25,000 were used as base maps for plotting the data.

Emphasis was given in checking big landslides, vulnerable landslide area and deep erosion. The prominent landslides that occurred in the recent past were shown in the photo below. The data overlays, sources, derivative parameters and method of generation are given in Table-1 below.

Table 1 : Data overlays, sources, parameters and method of generation

Data Overlays	Database/ Sources	Parameters	Method of generation
Geology	Geological maps from DMG[1], Aerial Photographs /SD[2]	Lithology and Rock type	VI[6], FC[7] and GIS
Topography	Topographical map in digital format/ SD[2]	Topographic features slope gradient/direction	GIS based Digital Elevation Model
Slope	Topographical map in digital format/ SD[2]	Classification of slope	FC[7] and GIS
Land Use	Topographical map in digital format, maps and aerial photographs/ SD[2]	Classification of Land use	VI[6], FC[7], GIS
Landslide	Topographical maps in digital format and aerial photographs /SD[2]	Landslide occurrences and gully erosion	VI[6], FC[7], GIS

DMG1: Department of Mines and Geology, Kathmandu
SD2 : Survey Department, Kathmandu
VI6 :Visual Interpretation. FC7 : Field Checking

The published geological map of DMG (62 P/11) was used for the purpose of geological data derivation for the preparation of landslide hazard map of this study. According to the published geological map, the study area consist mainly the rocks of Higher Himalayan, Upper and Lower Nawakot Groups. Major rock types and their probable age of the group of rocks are given in the Table 2.

Table 2: An overview of geology of the study area

Group	Formation	Rock type	Age
Superficial Deposit	Alluvial Deposit	Gravel, Boulder, sand and Silt in terraces, flood plain and stream channel	Quaternary to Recent
Upper Nawakot Group	Benighat Slates	Black and yellowish grey banded slate; dark grey to black carbonaceous slates with carbonates	Pre-Cambrian
	Dandagaon Phyllite	Greyish green to grey phyllites, phyllitic slate with thin seams of dolomite and quartzites	
Lower Nawakot Group	Fagfog Quartzite	White fine-grained quartzites with green phyllites and basic rocks	Pre-Cambrian
	Kunchha Formation	Sericitic, chloritic phyllitic quartzite interbeded with yellowish green gritty phyllite with quartzite. Garnetiferous and biotic in the northern areas	
	Kushma Quartzite	White, platy fine grained quartzites with dykes of basic rock	
	Ulleri Gneiss	Grey, light grey augen gneisses, quartzites	
Higher Himalayan Group	Formation II	Gneisses, marbles, micaceous quartzites, pegmatites	Pre-Cambrian
	Formation I	Coarse grained two mic gneisses with garnet, kyanite and/or sillimanite, migmatis, quartzites.	
	Igneous Rocks	Amphibolites (Basic rocks)	

The study area is dominant by the rocks of Kunchha Formation. The rock of Higher Himalayan is mainly covering in north east part. Terraces of Kaligandaki River and some of its tributaries are occupied by alluvial deposit. The factor maps of various parameters such as landslide distribution, Geology, Slope and Land use pattern were prepared by using GIS technique. The relationship of landslide ratio to various classes of parameter maps were summarized and found to be associated with certain classes of different parameters and presented after statistical analysis.

Photo: 1 Big landslide in Ratopani village on the Beni-Jomsome road which swept away many houses

Photo: 2 Highly disturbed hill slope on the way to Galeshwor from Beni Bazaar

Photo: 3 Huge landslide at right abutment of the Raughat Khola just downstream of Tatopani below Thirbang village

Photo: 4 Landslides on top of the Aul village threatening the people

Photo: 5 Milanchowk village resting on the flood plain of Thotneri River along Beni-Baglung road. The village is highly in danger during cloud burst flood

Photo: 6 Manmade causes of landslides in highly fractured quartzite on Gurung¯Sera-Patichaur road due to construction of road by disturbing natural slope

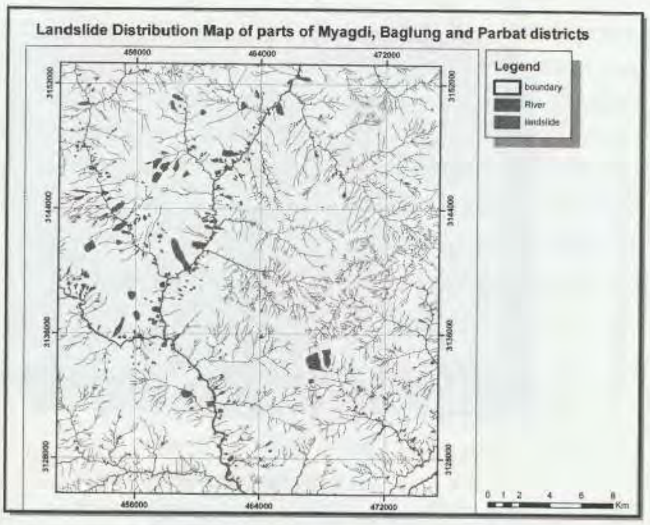

Fig. 1 (a) Landslide Distribution Map

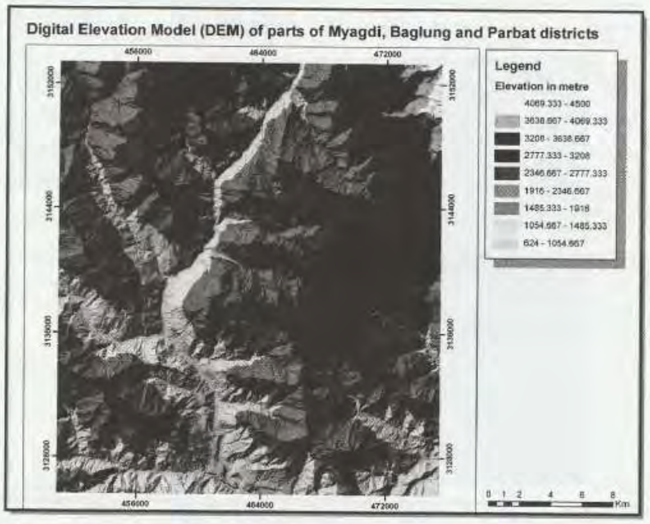

Fig. 1 (b) Digital Elevation Model

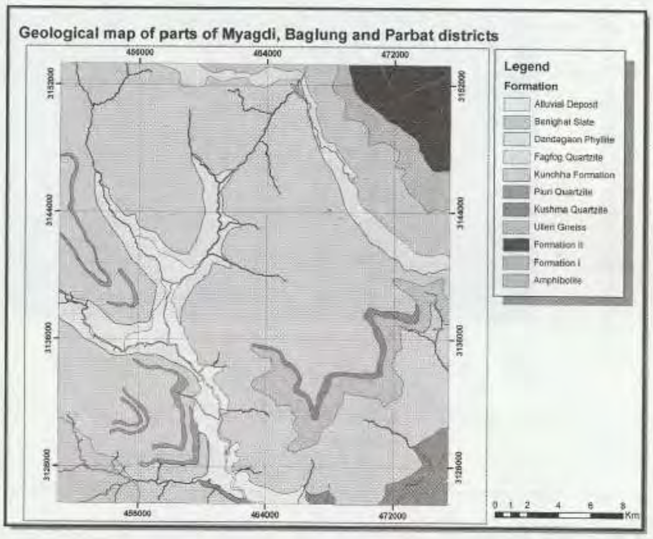

Fig. 1 (c) Geological Map

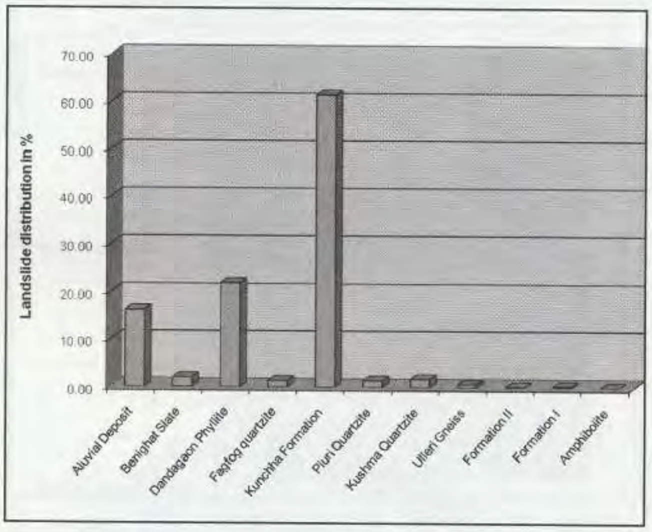

Fig. 1 (d) Relation between Geology and Landslide distribution

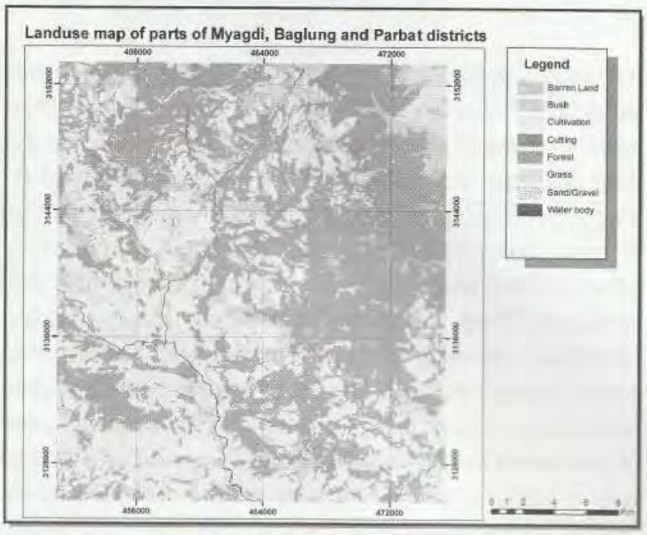

Fig. 1 (e) Landuse Map

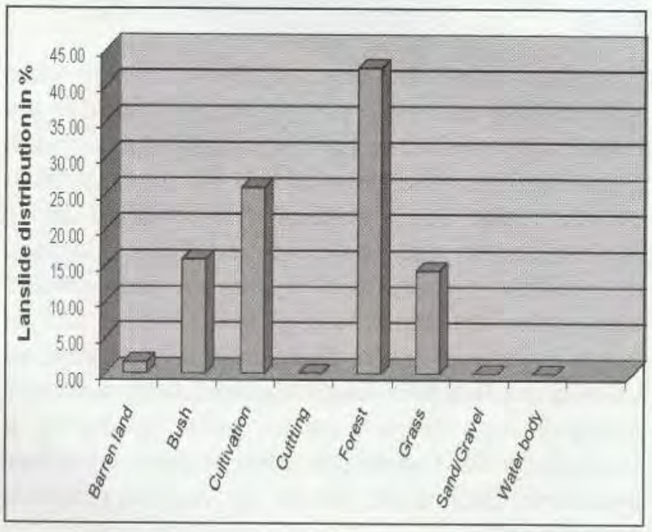

Fig. 1 (f) Relation between Landuse and Landslide distribution

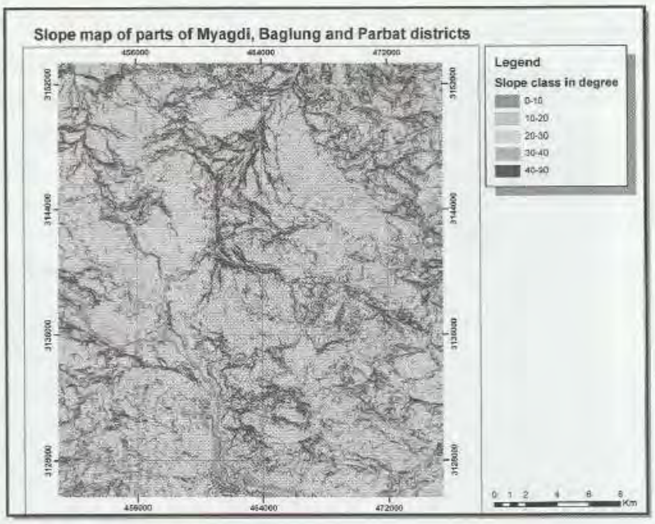

Fig. 1 (g) Slope Map

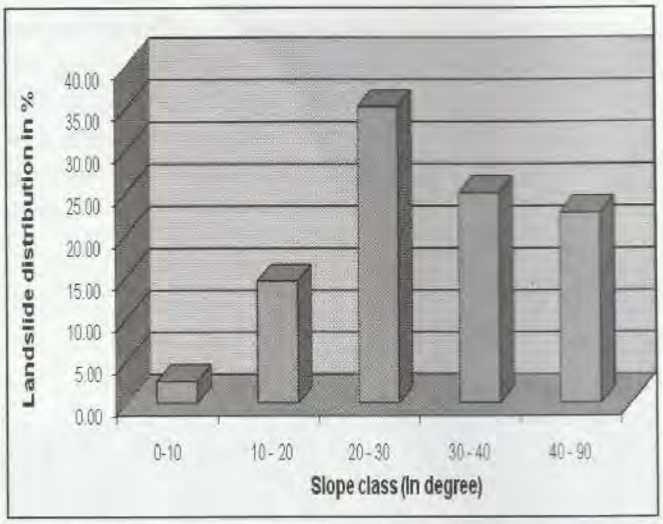

Fig. 1 (h) Relation between Slope and Landslide distribution

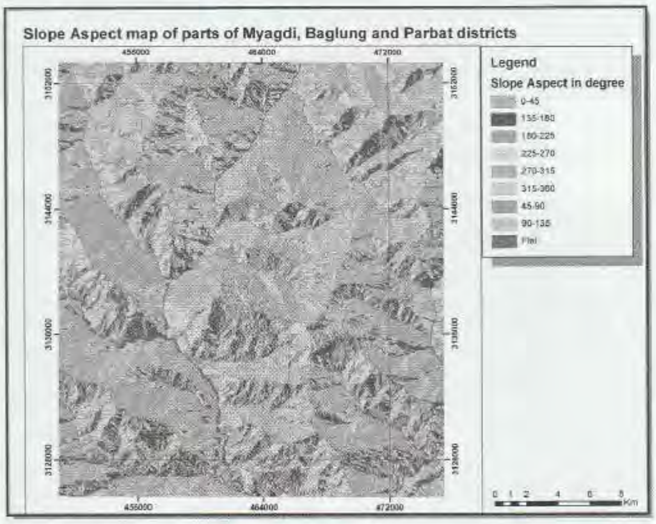

Fig. 1 (i) Slope Aspect Map

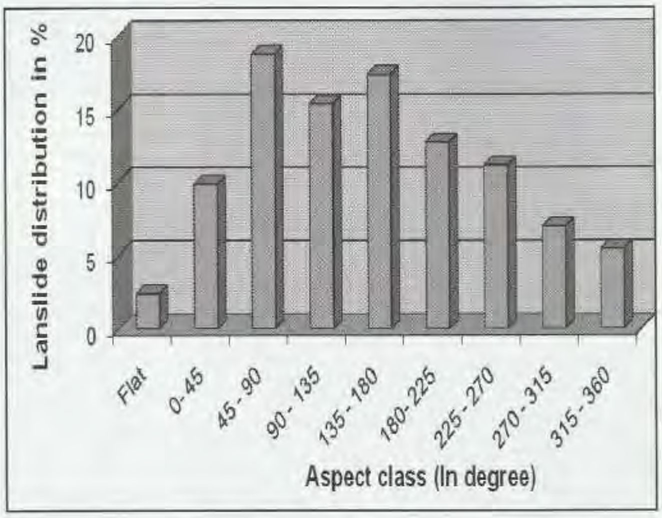

Fig. 1 (j) Relation between Slope Aspect and Landslide distribution

Preparation of Landslide Hazard Zonation Map

Landslide hazard map was prepared to identify areas with differing landslide hazard. This map divides the entire study area into sub-areas based on the degree of a potential hazard from landslides. For the calculation of hazard map, considerations of the weighed values of all parameter class were required. The preparation of landslide hazard zonation map involved several steps. After the preparation of the landslide and all factor maps in shapefile form, they were intersected utilizing the GIS techniques. Subsequently statistical analysis was carried out in order to derive a bivariate model. The results of this analysis were then transferred back to the GIS for deriving the landslide hazard zones.

While preparing the final landslide hazard map, besides intensive use of GIS techniques human intelligence was an added factor. In this respect, individual slope units were evaluated in terms of hazard class based on the field condition that depends upon the morphology of the slope, geological condition, land use, vegetation cover, human intervention and geohydrology. Immediately after the field work, a rough landslide hazard map was prepared. Then, landslide hazard map prepared using bivariate statistical method and the field hazard map were considered together to prepare the final Landslide hazard map. In most of the cases, the hazard category of individual maps from field condition and GIS based was matching. Whenever they differ from each other, field conditions are found to play a big role in it. Hence, the suitable hazard class was assigned manually after the proper judgment.

Landslide hazard zonation map (Fig. 3) was prepared by differentiating the entire study area into three hazard classes based on the degree of potential hazard from landslide. In the map, the high hazard zones correspond with high frequency of landslides. For a GIS based map each class of the parameter map had different weight. For hazard calculation, summation of such weight values of all parameters is carried out for a certain region.

Result of the statistical analysis

After assigning the hazard classes an analysis was carried out in order to check the relationship between hazard category and the each parameter maps. For this each parameter map was overlaid with the final hazard map. The following figures show the relation between hazard categories and various causative factors (Fig. 2a, 2b, 2c and 2d).

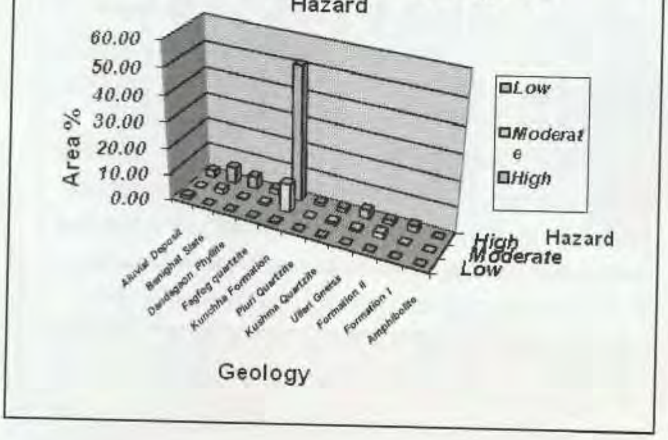

Fig. 2(a): Relation between Geology and Hazard

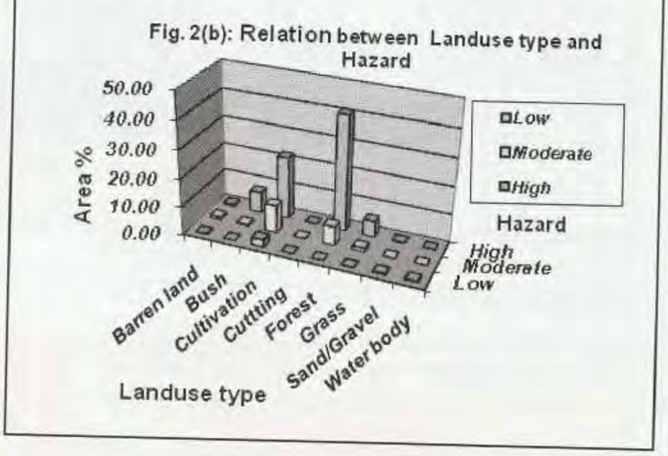

Fig. 2(b): Relation between Landuse type and Hazard

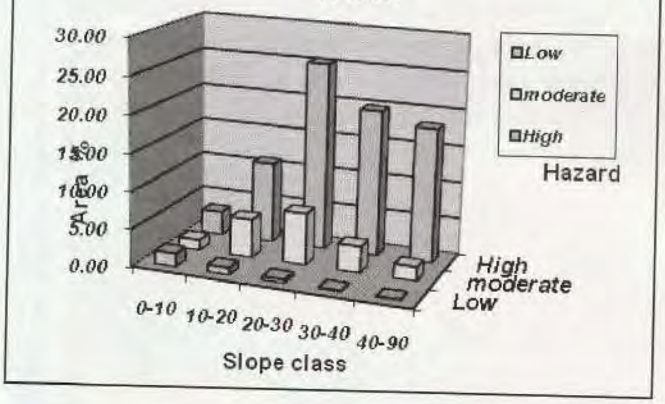

Fig. 2(c): Relation between Slope and Hazard

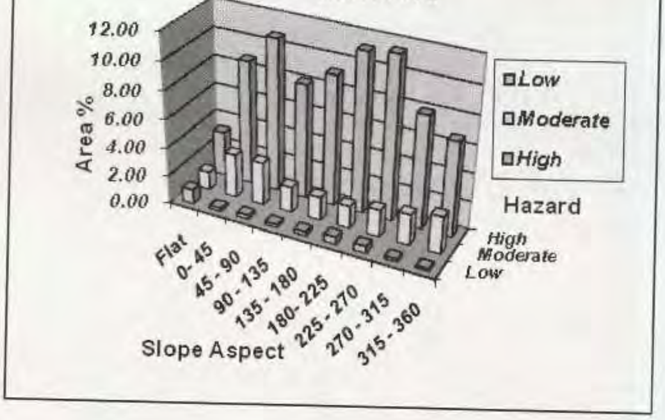

Fig. 2(d): Relation between Slope Aspect and Hazard

LANDSLIDE HAZARD ZONATION MAP OF PARTS OF MYAGDI, BAGLUNG, PARBAT AND KASKI DISTRICTS

SHEET NO. 2883 11

EXPLANATORY LEGEND

The Landslide Hazard Zonation map was prepared by the combined action of derivation and addition of the weighted values of the factor maps (Geology, Landuse, Slope and Slope Aspect) and field evaluation of individual unit slopes in terms of slope morphology, geology, geohydrology, human intervention etc. The weighted values were derived by statistical analysis based on relation of landslides within each unit of the factor maps. The relative hazard was expressed as low, medium and high hazard based on weighted value. Similarly, the field evaluation was expressed in terms of high medium and low hazard areas. The two maps were later combined and a single relative hazard map was prepared by smoothing and adjusting the boundary wherever necessary and finally showing low, medium and high hazard zonation map.

Hazard Class	Possible Damage	Remarks and Recommendation
Low	Rarely any active landslide present except at slope edges, and in wet season. Presently no major slope instability. River bank collapse and deposition of debris in low land area possible during wet season.	Usually stable, regulated constructions suitable. Limitations at places possible due to other type of hazard as flood, river bank collapse seismic hazard etc. Stabilization measures only required at river banks, and slope edges.
Moderate	Presence of shallow active landslides at some places. Presence of dormant landslide possible. Deep erosion of an individual unit slope especially during heavy rainfall possible developing landslide or debris slide or flow. Possibility of developing a new or reactivation of old landslide. High susceptibility to sliding on cultivated slope steeper than 20°. Possible damage to infrastructure and cultivated land.	Urban development and planning possible if appropriately executed and safety measures taken. Heavy construction needs detail site investigation. Proper management of natural drainage and sewage or irrigated water is recommended. Any construction in the area exceeding 25° should be cautiously carried out.
High	Frequent occurrence of active old or dormant landslides. Slopes in precarious condition present at places. High risk to human life and property possible at some places. Frequent loss of soil and arable land very likely at some places.	Presence of limited stable area for infrastructure development. Stability measure is most for any type of constructions. In case of slope failure preventive measures involving high cost is likely.

NOTE

This map is a product of visual evaluation of individual slope units and statistical and empirical evaluation of various causative factors related to slope instability and their relationship with existing landslide distribution within the area. The map relies on the surface information obtained by ground survey of accessible areas and data from aerial photographs. Direct mapping of all individual landslides was not possible due to inaccessibility, concealment in densely vegetated areas and limited time.

The map is exclusively intended for planning at a regional scale. It should not be used as the only basis of investigation for individual buildings. The map cannot replace detailed site investigations. It is time dependent and needs periodic revision. Change in any single factor by natural or human activities needs reevaluation because change of a single factor can be sufficient to exceed the threshold for slope failure.

General Symbol

- River with flood plain
- Highway / motorable road
- Hot Spring
- Active landslide
- Old / dormant landslide
- g Village

First edition June, 2010

Fig. 3 Landslide Hazard Zonation map of the study area.

Conclusion

- Areas susceptible to landslides can be delineated based on the physical factors associated with landslide activity like past landslide history, geology, slope steepness and landuse.
- Kunchha and Dandagaon Formation of Nawakot Group were found to be more vulnerable to landslide than other types of rocks.
- Most of the landslides were found to be occurring in forest and cultivated land.
- In most of the cases landslides were occurring due to the toe erosion by river/stream or road construction, steepness of slope, deep weathering in soft nature of rock or unfavorable discontinuity configuration to the slope etc. However, manmade causes were also found to play considerable role in landslide occurrences mainly in the area occupied by colluvial soil deposit or deeply weathered rock slopes. Man made causes of landslides were mainly confined to construction of road by toe cutting of vulnerable slopes and deforestation.
- The landslide hazard zonation map provides a good geo-scientific base of the study area for planers policy makers and developers in minimizing the risk.
- The landslide hazard zonation map is exclusively intended for planning at a regional scale. It cannot replace detailed site specific investigations. Change in any natural factor or any human intervention may change the whole hazard scenario by exceeding the threshold value for the slope stability of the individual unit slope.
- Geographic Information System can be considered as a powerful tool for representation and analysis of spatial information related to geosciences.

Acknowledgement

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Engineering and Environmental Geological Mapping of Birendranagar Municipality and its Surrounding Area, Surkhet

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Abstract

The present study "Engineering and Environmental Geological Mapping" of Birendranagar Municipality and its surrounding area deals with the engineering properties of the hard rocks as well as soft valley sediment and also deals with geological hazards and environmental problems and their mitigation. The central part consists of fluvio-lacustrine sediments which were formed by the deposition of the sediment brought up by the rivers from the nearby surrounding hills both from the northern part of the valley as well as from the southern part of the Siwalik Hills. The northern hill slopes of Surkhet Valley are moderate to steep with Lower Himalayan rocks whereas southern hill slopes are low to moderate. The field survey include auguring, Standard Penetration Test with soil samples from various depths to estimate bearing capacity and liquefaction potential of the ground and to delineate different Quaternary geological units. A number of traverses were taken along rivers, tributaries, trails, and road for delineating geological unit and to identify areas prone to geo-hazard such as landslides, flooding, riverbank erosion etc. Natural resources and environmental concerned topics such as waste disposal sites and ground water resources were also identified.

Introduction

Birendranagar lies approximately 575 Km from Katmandu and 85 km from Kohalpur, Banke District of Bheri Zone along Ratna Rajmarg. It is a Regional Head Quarter of the Mid-Western Development Region. The town is situated at the foot of Lesser Himalaya in north and Siwalik hills in south.

Surkhet Valley is a tectonic valley and consists of fluvio-lacustrine sediments which were formed by the deposition of sediments brought by the rivers from the nearby surrounding hills. Kakre Bihar (Historical monument) is situated at the centre of the valley as part of Siwalik hill. Average altitude of Surkhet Valley is 680 m from msl with elliptical shape covering an area of 68 sq. km. The study area covers 100 sq. km between 3156000m and 3166000m North and 556000 and 566000m East which lies in the part of Toposheet No. 2881-07C and 2881-07D at the scale of 1:25,000. (Fig.1)

The main rivers flowing in the study area are Jhupra, Itram and Khorke Kholas. Others smaller tributaries are Bhureli, Amdali, Duwali, Sisneri, Gholghole, Neware, Tuni and Bame. Most of these rivers flow from north to south which joins Nikash Khola and then flows ultimately out of valley to join the Bheri River..

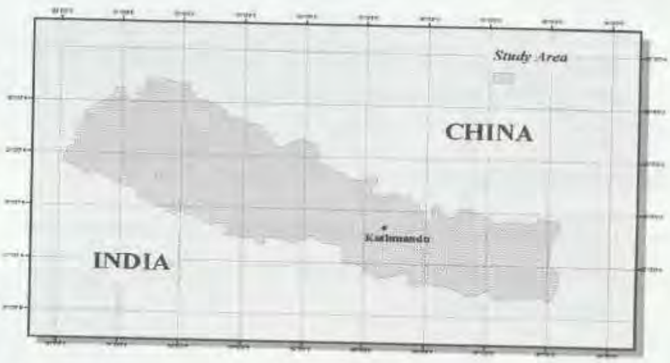


Fig.1 Location map of study area.

The present study is intended to provide information on surface and sub-surface geology for selecting suitable areas for future development planning. The investigation is also focused on the suggestion provided by the Birendranagar Municipality personnel to supply with necessary information for their future development activities.

Objectives

The main objectives of the present study are:

- To identify the various soil units and prepare Engineering Geological map at the scale of 1:25,000.

- Urban and Environmental Geological Mapping at 1:25,000 scale consisting information of Quaternary Geology, Landuse, Waste Disposal sites, Natural Hazards, Natural Resources etc.

- To identify the Hazardous and risk area and recommend proper mitigation measures.

- To determine the surface and sub-surface ground condition of unconsolidated sediment and its bearing capacity

- Identify the existing environmental problems which may affect human health.

- To delineate the area susceptible to liquefaction and ground settlement and associated risks so as to provide suitable preventive measures to reduce its effect on existing environment and structures.

- To prepare a Liquefaction Hazard Map (1:25,000 scale) of Birendranagar Municipality and its surrounding areas of the Surkhet Valley.

- Compile engineering geological information, urban and environmental geological data and prepare Engineering and Environmental Geological Map at 1: 25,000 scale and the report.

Methodology

- Existing relevant literature on geology, geohazards and regional geological as well as landuse maps were reviewed.

- Aerial photographs in 1: 15,000 scale of January 1997 were studied and necessary information were gathered. The digital topodata was acquired from Topographical Survey Branch of the Survey Department. They were used to prepare a base map

- Information was also gathered using Google Earth in internet.

- The result obtained from Engineering Geological Mapping and the Urban and Environmental Geological Mapping with Geo-Hazard studies was incorporated and the final Engineering and Environmental Geological Map was prepared by using softwares such as Arcinfo, Arcview and Freehand.

Field Activities

- The fieldwork was carried out in dry season of 2066 B.S. for 40 days.

- Field survey enabled to delineate areas of low bearing capacity, potential areas of instabilities on the ground, flood prone areas and liquefaction potential areas.

- In total 75 auger holes were drilled for the investigation of the subsurface soil layer from which required soil samples were collected from different depth of the boreholes for laboratory analysis. Similarly 40 SPT were performed to determine the stiffness of the ground at different locations.

- 61 Power Auger drill holes were made besides other geological investigations. The sediment up to depth of 11 m is broadly classified into 4 different lithological units.

- A number of traverses were taken along rivers, tributaries, trails, and road to delineate geological unit and to identify areas prone to flooding, riverbank erosion/cutting and soil erosion. Field survey also enabled to delineate areas of waste disposal and environmental concerned.

- In the field, necessary information was gathered from Birendranagar Municipality regarding their infrastructure development plan. Some information was gathered from District Office of the Department of Urban Development and Building Construction and also from District Office of Drinking Water and Sewerage for water supply system in urban and ruler areas.

- Samples Collected from the field were analyzed in the geotechnical laboratory of Department of Mines and Geology for Liquid limit, plastic limit, Sieve analysis, Moisture content etc. Engineering and Environmental Geological Map is prepared by applying GIS using ARC/INFO, ARCVIEW, Winsieve 5, Ilwis 3.2, Rockworks 2002 software, Spreadsheet and free hand software.

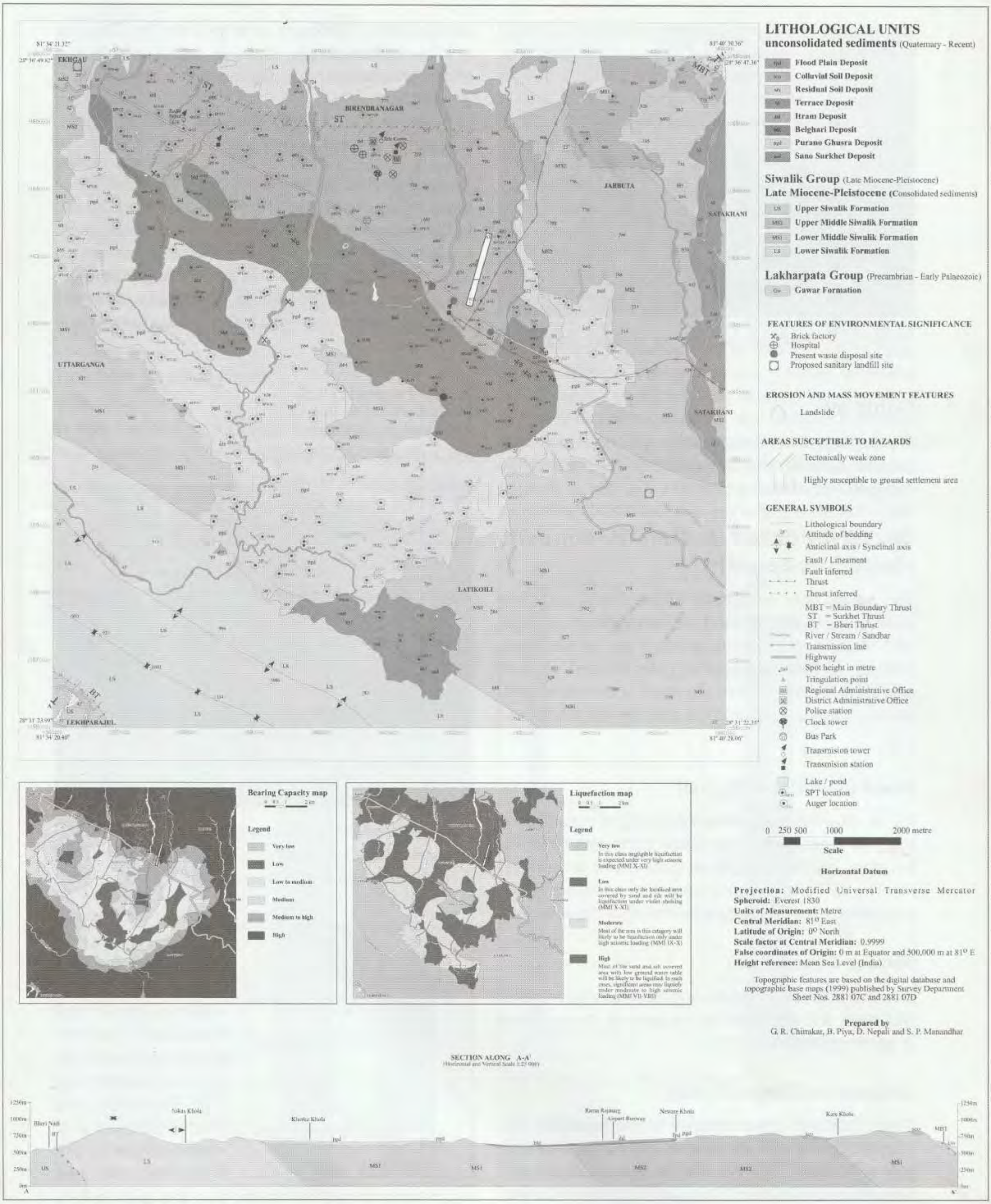


Fig. 2 Engineering and Environmental Geological Map of Surkhet Area

Photo 1 Field personnel preparing for Standard Penetration Test

Geolo gy

The Geology of the Surkhet Valley and its surroundings can be divided into two groups. Unconsolidated sediment deposits and Bedrocks (Fig. 2)

Unconsolidated sediment deposits (Quaternary-Recent)

The valley floor comprises of the fluvio-lacustrine sediments made up of sand, silt, clay, pebbles, cobbles and boulder size particle brought up by the rivers from the northern and southern hills. Alluvial, residual and colluvial soil are also observed in the study area. Unconsolidated sediments can be differentiated into:

Flood plain Deposits (sal)

It is an alluvial loose sediment deposit that occurs along the river course and flood plain. It consists mainly of boulders, cobbles and gravels in the matrix of sand and silt. The SPT and auguring were not carried out due to coarseness and highly abrasive nature of the sediment.

Terrace Deposit (td)

It consist of boulder,cobbles and gravels in the matrix of silty sand. It is distributed in the bank of Jhupra Khola at south of Dubichaur.

Colluvial soil Deposit (sco)

These deposits are developed at the footslope and gentler slopes due to transportation of the material from above. It consists of sand, silt and coarser materials. It is developed in eastern and western parts of Surkhet valley. Such deposits are found in north of Sitapur of Jarbuta VDC. Thickness is more than 1m. This soil is slight to non-plastic, loose to slightly dense and improper drainage may lead to ground movements in this soil.

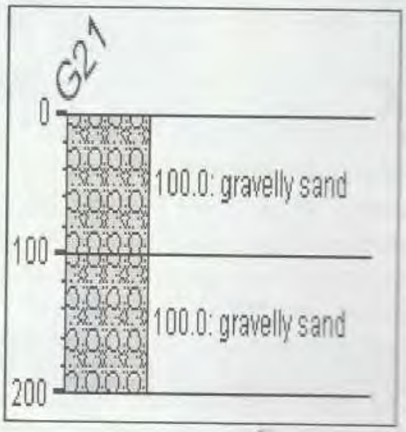
Residual soil Deposit (srs)

These deposites are developed along hill slopes due to weathering of rocks. Such soils have been developed in the eastern parts of Barakuna and Bastipur, south of Sano Surkhet, Koldanda, Kakre Bihar and in Solughupte. It is also developed in Gagretal ridge, Bhusal danda, Chauke Dhunga, Bhattekuna. It consists of mainly yellow to grayish yellow sandy gravels and sandy silt.

Itram Deposit (itd)

This unit is distributed mainly in the northern part of the valley above the Jumla Highway and consists of

Photo 2. Uneven distribution of cobbles and gravels in the matrix of sandy silt exposed at the bank of Itram Khola, north of Khajura (Itram Deposit).



gravel to boulder size materials in the matrix of sand. Most of the district offices are located in this deposit. Cobbles and gravels are sub-rounded (Fig. 3). This unit is covered by sand, silt and clayey silt. The field N-values in this area is very high. Thickness of

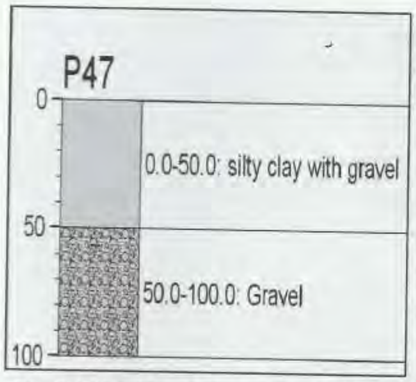
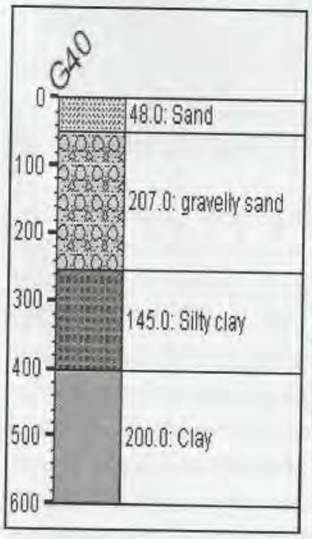


Fig.3 Litho-log of Itram Deposit

this unit is more than 8m and the groundwater table in this region is very high. Liquefaction hazard cannot be expected in such type of sediments. Compaction of the soil sediments in this unit is medium to dense with high Permeability. Allowable bearing capacity in this unit is high and hence is good for foundation purpose.

Belghari Deposit (bgd)



This unit is distributed along the Jumla Highway and extends towards south and consists of grey to yellowish grey silty clay to clayey silt with presence of gravels and at some places pebbles and boulders (Fig. 4). Silty clay and clayey silt is dominant over sand. However at some places thickness of sand exceeds 3 m. In this deposit, black carbonaceous clay is found denoting marshy lake deposits. Its western boundary is close to Bhureli south of Bangesimal while eastern boundary is close to Dholdhunga. Gravels are rounded to sub rounded consisting of sandstones and siltstones. Gravels occupy about 50% of the volume at some places. Upper part of this unit consists of brown to light grey clayey silt. This unit is sloping 5° to 10° towards south. It is more than 7 m thick.

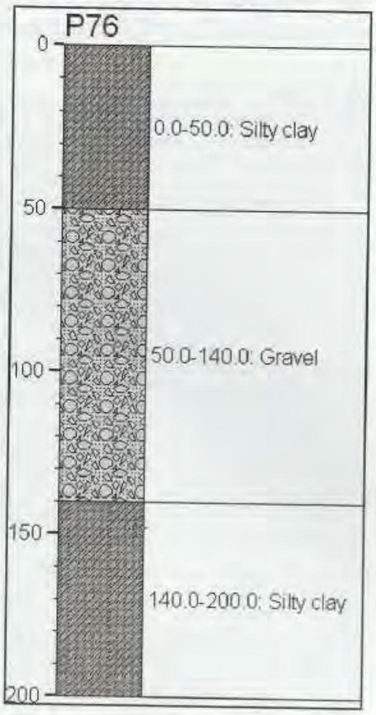


Fig. 4 Litho-log of Belghari Deposit

Plasticity is slight to none. Groundwater table is 1 to 2 m deep in general. At some places, groundwater is emerged out as springs (Bulbule Tal) on the ground surface. It is moderately good for foundation purpose; however some protective measures are to be applied where N-value is low. Engineering geological constraints to be considered in this unit are shallow groundwater table and lateral erosion of banks. This formation also covers most part of the southern cultivation land of the Surkhet Valley.

Purano Ghushra Deposit (pgd)

It is distributed in the southern part of Surkhet valley and consists of mainly grey to dark grey silty clays and black carbonaceous clays. Sometimes silty sand and fine sand layers are also interbedded (Fig. 5). It is mainly lacustrine deposits with thickness of more than 5 m. Consistency of this soil is very soft to soft and plasticity is intermediate to high. Allowable bearing capacity is very low to low. The liquefaction potential in this deposit ranges from low to moderate and some places of this deposit (in the eastern part) lie in high

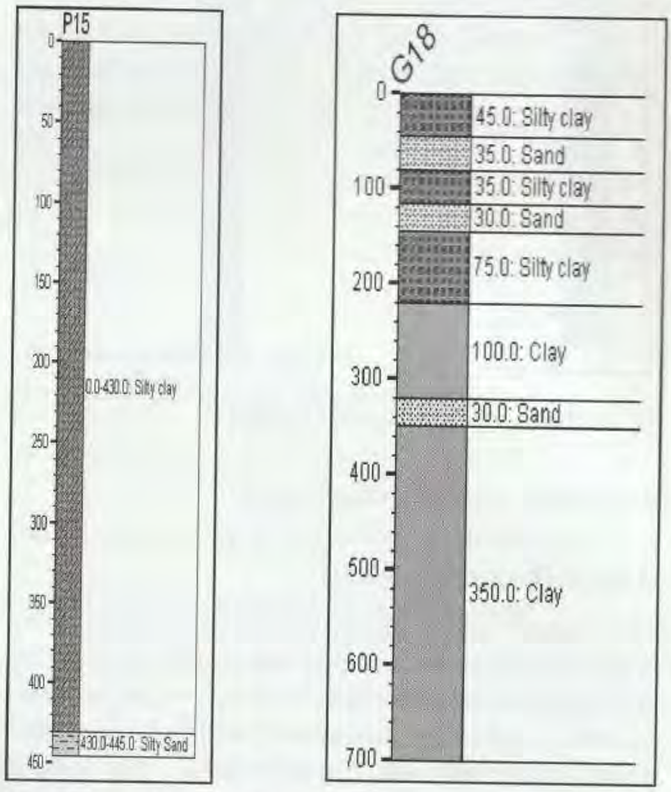


Fig. 5 Litho- log of Purano Ghusra

potential zone. Water table is very low and at some places found at ground surface. This unit is poor for foundation purpose due to possibility of settlement. Heavy structures should use pile foundation. The area is suitable for an agricultural development purpose.

Sano Surkhet Deposit (ssd)

This unit consists of light yellow to brownish yellow silty clay to clayey silt and occurs only in Sano Surkhet (Fig. 6). Sano Surkhet valley is separated from Surkhet valley by a small ridge and this valley forms tip of the whole valley.

This unit is of low plasticity and firm to stiff consistency. Groundwater table is more than 6 m deep. This soil has moderate bearing capacity and has moderate to low liquefaction potential zone. Its thickness is more than 6 m. The soil is very dry indicating the deep ground water table.

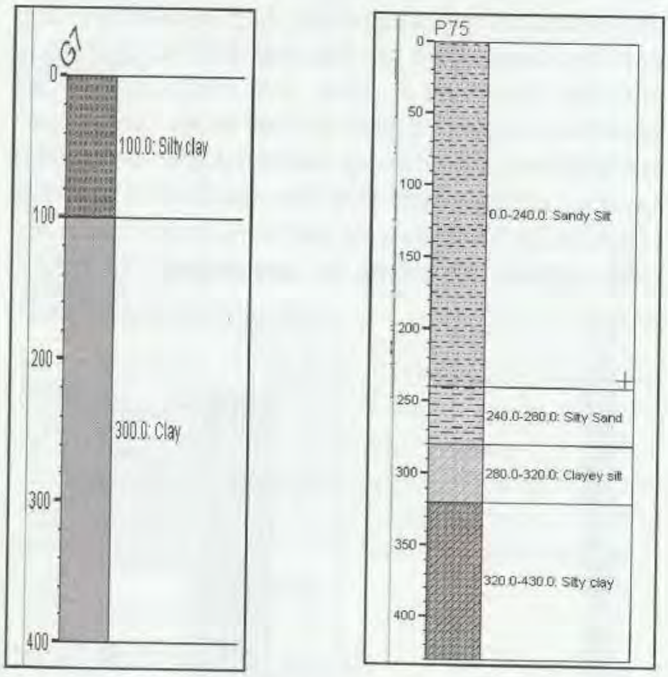


Fig.6 Litho-log of Sano Surkhet Deposit

Bedrocks of the study area include:

Gawar Formation (Gw)

The Gawar Formation (Gw) of Lakharpata Group has been exposed at the north-eastern corner of the study area just after Siwalik rocks. It consists of limestone, dolomite and shale. Limestone is greyish blue and dolomite is light to medium grey in colour. The individual thickness of the bed ranges from few millimeters to few centimeters. The rocks are highly disturbed near the Main Boundary Thrust (MBT) (Photo 3). The actual contact passes through the valley having small stream on the right bank of Jhupra khola, NW of Bagtar. The limestone bed has been thrust over the rocks of Lower Middle Siwalik (MS1).

Photo. 3 Highly disturbed bedding plane of Limestone and dolomite of Gawar Formation

Siwalik Group

The rocks of Siwalik Group found in the study area are:

Lower Siwalik (LS)

Lower Siwalik rocks are exposed in the north, northeastern and southwestern part of the study area. It consists of fine grained purple sandstone interbedded with variegated mudstone, shale and siltstone. The mudstone dominates over sandstone. Purple shale is well dominant in the southern part around Nikash khola. The siltstone is chocolate in colour where as shale is light greenish. The attitude of the bed at Nikash Khola (Photo. 4) where it crosses the valley is N50^{0}W/50^{0}N. The exposed thickness of mudstone bed is 3 m and the individual beds of sandstone are 30-50 cm.

Photo 4 Exposure of Lower Siwalik rocks at Nikash Khola

Lower Middle Siwalik (MS1)

MS1 is characterized by presence of salt and pepper like sandstone, mudstone and shale. Sandstone is medium to coarse grain. MS1 is well exposed around Neware khola bridge with an attitude of N30°W/18°N. Here the sandstone is thinly bedded while mudstone is very thick. They are highly weathered in Chaukune of Latikoili VDC. MS1 is also well exposed along the road from Bheri bridge towards Birendranagar, Surkhet. MS1 is well exposed in the north of Dubichaur (Photo.5).

Photo.5 Exposure of sandstone and mudstone of MS1 in the north of Dubichaur.

Upper Middle Siwalik (MS2)

The Upper Middle Siwalik (MS2) mainly consists of medium to coarse grained sandstone, pebbly sandstone with siltstone and mudstone. These pebbles are mostly constituted of quartzite, phyllite, limestone, dolomite, shale etc. MS2 is exposed at Solughupte (northwestern corner of the study area), with an attitude of N65°W/30°N; and Dhulabid with an attitude of N40°W/25°N and on the right bank of Jhupra khola, east of Barakuna. It is also exposed at Dubichaur (Photo. 6).

Photo 6 Pebbly Sandstone of MS2 exposad at Dubichaur

Upper Siwalik (US)

The upper Siwalik (US) rock has been exposed only in the south-western part of the study area I and consists mainly of conglomerate, sandstone and mudstone.

Structure

The present study area of investigation has been affected by major folding and faulting. The Main Boundary Thrus t(MBT) lies in the north-eastern corner and is observed at Jhupra Khola. Surkhet Thrust lies in the northern part while Bheri thrust is situated at the south- western part of the study area. MBT passes through a small stream forming the valley where sandstone and limestone are found below and above the thrust respectively. Similarly Nikash Khola Anticline and Chhinchhu Khola Syncline are the major folds in the study area (Shrestha, 1999). Some lineaments are found in the northern part of the valley within the study area.

Laboratory Tests

The soil and rock samples collected during the field investigation are subjected to various tests in geotechnical lab of DMG to determine their engineering properties, which are generally required for civil constructions. The laboratory tests are conducted in accordance with the test procedures recommended by ASTM and BS standards. The following tests were performed in the geotechnical lab of the department.

a) Natural moisture content,
b) Grain Size Analysis (Sieve curve), c) Liquid Limit, and
d) Plastic Limit,

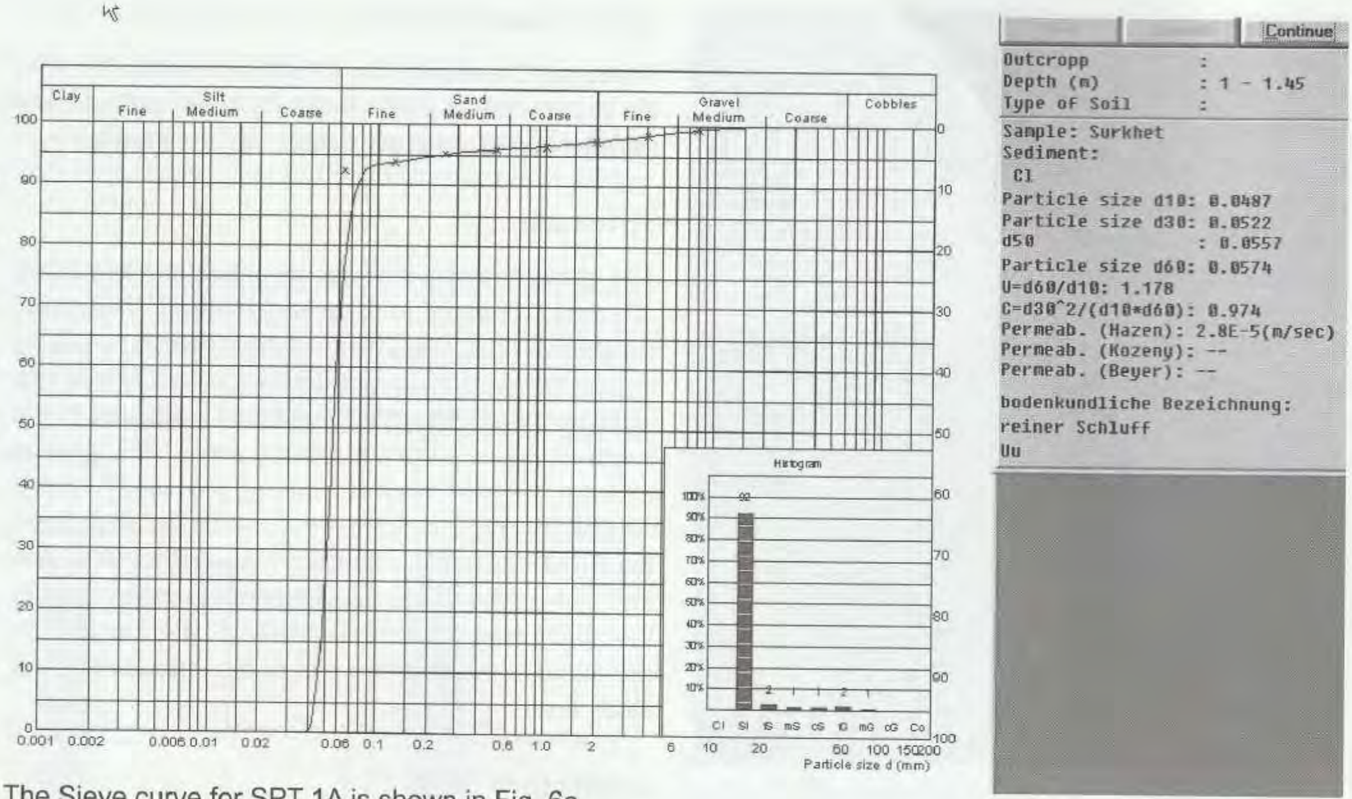
The Sieve curve for SPT 1A is shown in Fig. 6a.

Liquefaction Susceptibility Mapping

In the liquefaction susceptibility study, a total of 70 shallow boreholes data were used. The depth of all these boreholes is limited up to 6 m only due to time constraints and equipment limits. Final liquefaction susceptibility map with four different zones, High, Moderate, Low and Very low are shown below in Fig. 7.

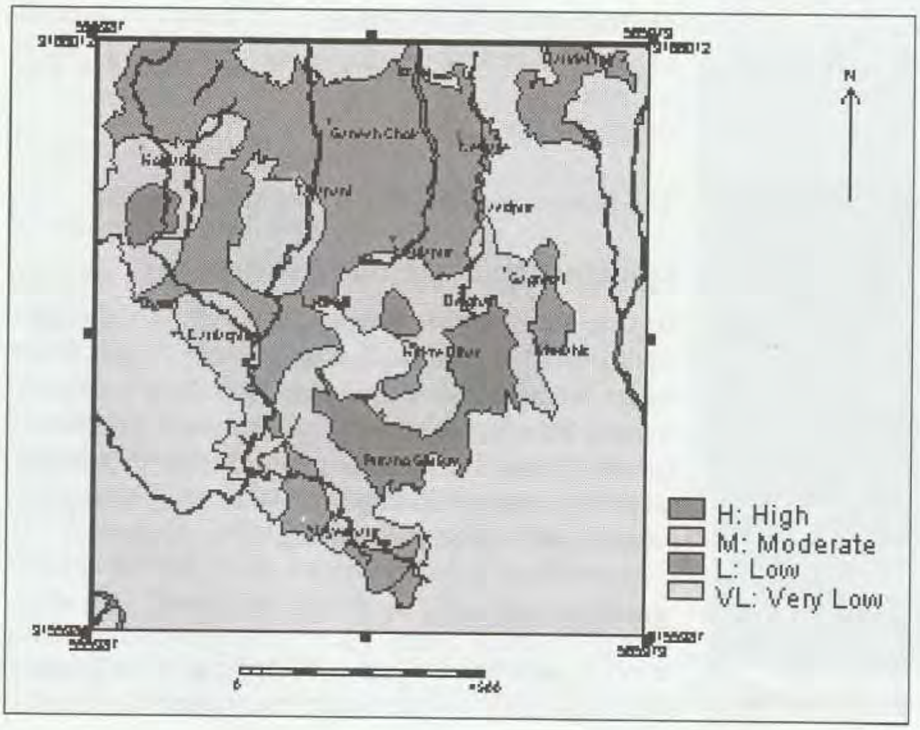
Bearing Capacity

Bearing capacity analysis is carried out according to Peck et al (1974). According to the analysis it is found



The Sieve curve for SPT 1A is shown in Fig. 6a.

that the bearing capacity of the study area is medium to very low. Bearing Capacity map is shown in Fig. 8. Soil condition in the study area varies from very low to medium with SPT value ranging from 0 to 10. The greater value is normally encountered at a greater depth, and hence the bearing capacity gradually increases with the increase in depth. The result shows that 96.2 % of the total area has low bearing capacity, about 2.66 % of the total area has moderate and about 1.14% area has very low bearing capacity.



Ground Water Condition

Depth of groundwater table in Surkhet valley is variable due to different topographical situation and geological conditions of the valley. In the northern part, groundwater table is deep due to thick permeable layer of fan deposits,

Groundwater table in the middle and southern parts are shallow. They are confined mainly within silt beds. Depth to groundwater table in this area varies between 0.5 m to 2 m in general. At places water is flowing freely to the surface like in the wells south of Padampur, near Gupitpur, Jaypur and Raharpur etc.

Free flowing spouts can also be observed in Surkhet valley. Prominent among them is Bulbule Tal in the central part of the valley. Other free flowing spouts arê in Kholigaun in the southern

Conclusion

- Areas susceptible to landslides can be delineated based on the physical factors associated with landslide activity like past landslide history, geology, slope steepness and landuse.
- Kunchha and Dandagaon Formation of Nawakot Group were found to be more vulnerable to landslide than other types of rocks.
- Most of the landslides were found to be occurring in forest and cultivated land.
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Abstract

The present study "Engineering and Environmental Geological Mapping" of Birendranagar Municipality and its surrounding area deals with the engineering properties of the hard rocks as well as soft valley sediment and also deals with geological hazards and environmental problems and their mitigation. The central part consists of fluvio-lacustrine sediments which were formed by the deposition of the sediment brought up by the rivers from the nearby surrounding hills both from the northern part of the valley as well as from the southern part of the Siwalik Hills. The northern hill slopes of Surkhet Valley are moderate to steep with Lower Himalayan rocks whereas southern hill slopes are low to moderate. The field survey include auguring, Standard Penetration Test with soil samples from various depths to estimate bearing capacity and liquefaction potential of the ground and to delineate different Quaternary geological units. A number of traverses were taken along rivers, tributaries, trails, and road for delineating geological unit and to identify areas prone to geo-hazard such as landslides, flooding, riverbank erosion etc. Natural resources and environmental concerned topics such as waste disposal sites and ground water resources were also identified.

Introduction

Birendranagar lies approximately 575 Km from Katmandu and 85 km from Kohalpur, Banke District of Bheri Zone along Ratna Rajmarg. It is a Regional Head Quarter of the Mid-Western Development Region. The town is situated at the foot of Lesser Himalaya in north and Siwalik hills in south.

Surkhet Valley is a tectonic valley and consists of fluvio-lacustrine sediments which were formed by the deposition of sediments brought by the rivers from the nearby surrounding hills. Kakre Bihar (Historical monument) is situated at the centre of the valley as part of Siwalik hill. Average altitude of Surkhet Valley is 680 m from msl with elliptical shape covering an area of 68 sq. km. The study area covers 100 sq. km between 3156000m and 3166000m North and 556000 and 566000m East which lies in the part of Toposheet No. 2881-07C and 2881-07D at the scale of 1:25,000. (Fig.1)

The main rivers flowing in the study area are Jhupra, Itram and Khorke Kholas. Others smaller tributaries are Bhureli, Amdali, Duwali, Sisneri, Gholghole, Neware, Tuni and Bame. Most of these rivers flow from north to south which joins Nikash Khola and then flows ultimately out of valley to join the Bheri River..

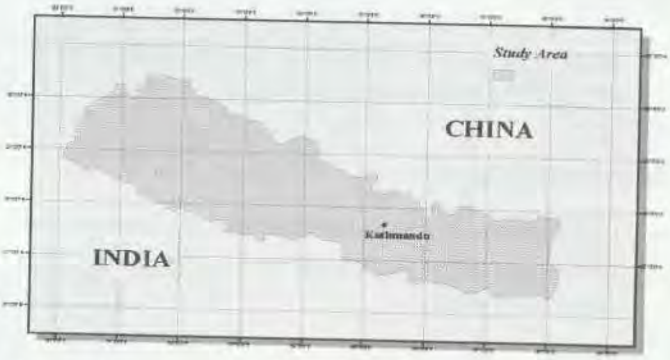


Fig.1 Location map of study area.

The present study is intended to provide information on surface and sub-surface geology for selecting suitable areas for future development planning. The investigation is also focused on the suggestion provided by the Birendranagar Municipality personnel to supply with necessary information for their future development activities.

Objectives

The main objectives of the present study are:

- To identify the various soil units and prepare Engineering Geological map at the scale of 1:25,000.

- Urban and Environmental Geological Mapping at 1:25,000 scale consisting information of Quaternary Geology, Landuse, Waste Disposal sites, Natural Hazards, Natural Resources etc.

- To identify the Hazardous and risk area and recommend proper mitigation measures.

- To determine the surface and sub-surface ground condition of unconsolidated sediment and its bearing capacity

- Identify the existing environmental problems which may affect human health.

- To delineate the area susceptible to liquefaction and ground settlement and associated risks so as to provide suitable preventive measures to reduce its effect on existing environment and structures.

- To prepare a Liquefaction Hazard Map (1:25,000 scale) of Birendranagar Municipality and its surrounding areas of the Surkhet Valley.

- Compile engineering geological information, urban and environmental geological data and prepare Engineering and Environmental Geological Map at 1: 25,000 scale and the report.

Methodology

- Existing relevant literature on geology, geohazards and regional geological as well as landuse maps were reviewed.

- Aerial photographs in 1: 15,000 scale of January 1997 were studied and necessary information were gathered. The digital topodata was acquired from Topographical Survey Branch of the Survey Department. They were used to prepare a base map

- Information was also gathered using Google Earth in internet.

- The result obtained from Engineering Geological Mapping and the Urban and Environmental Geological Mapping with Geo-Hazard studies was incorporated and the final Engineering and Environmental Geological Map was prepared by using softwares such as Arcinfo, Arcview and Freehand.

Field Activities

- The fieldwork was carried out in dry season of 2066 B.S. for 40 days.

- Field survey enabled to delineate areas of low bearing capacity, potential areas of instabilities on the ground, flood prone areas and liquefaction potential areas.

- In total 75 auger holes were drilled for the investigation of the subsurface soil layer from which required soil samples were collected from different depth of the boreholes for laboratory analysis. Similarly 40 SPT were performed to determine the stiffness of the ground at different locations.

- 61 Power Auger drill holes were made besides other geological investigations. The sediment up to depth of 11 m is broadly classified into 4 different lithological units.

- A number of traverses were taken along rivers, tributaries, trails, and road to delineate geological unit and to identify areas prone to flooding, riverbank erosion/cutting and soil erosion. Field survey also enabled to delineate areas of waste disposal and environmental concerned.

- In the field, necessary information was gathered from Birendranagar Municipality regarding their infrastructure development plan. Some information was gathered from District Office of the Department of Urban Development and Building Construction and also from District Office of Drinking Water and Sewerage for water supply system in urban and ruler areas.

- Samples Collected from the field were analyzed in the geotechnical laboratory of Department of Mines and Geology for Liquid limit, plastic limit, Sieve analysis, Moisture content etc. Engineering and Environmental Geological Map is prepared by applying GIS using ARC/INFO, ARCVIEW, Winsieve 5, Ilwis 3.2, Rockworks 2002 software, Spreadsheet and free hand software.

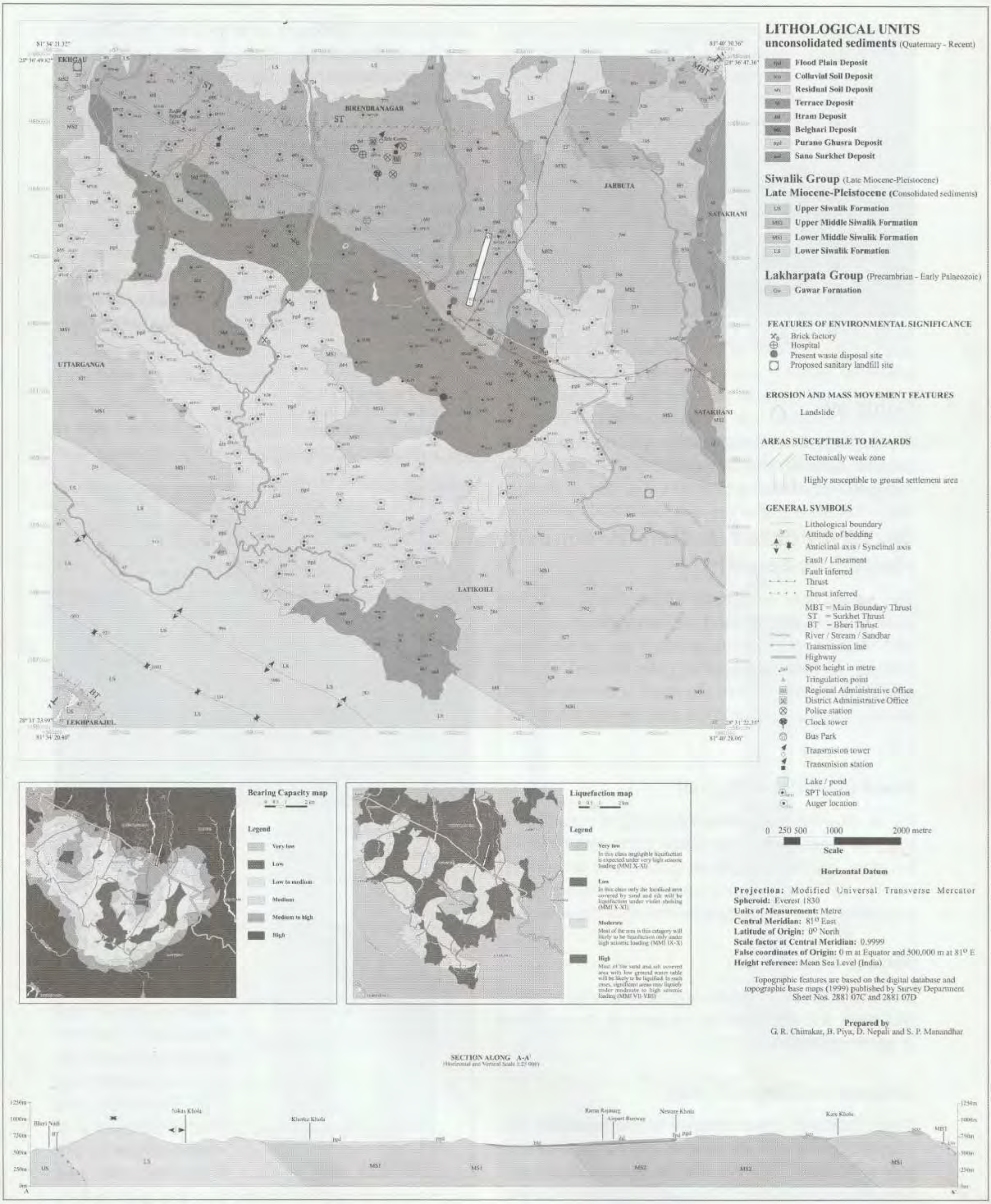


Fig. 2 Engineering and Environmental Geological Map of Surkhet Area

Photo 1 Field personnel preparing for Standard Penetration Test

Geolo gy

The Geology of the Surkhet Valley and its surroundings can be divided into two groups. Unconsolidated sediment deposits and Bedrocks (Fig. 2)

Unconsolidated sediment deposits (Quaternary-Recent)

The valley floor comprises of the fluvio-lacustrine sediments made up of sand, silt, clay, pebbles, cobbles and boulder size particle brought up by the rivers from the northern and southern hills. Alluvial, residual and colluvial soil are also observed in the study area. Unconsolidated sediments can be differentiated into:

Flood plain Deposits (sal)

It is an alluvial loose sediment deposit that occurs along the river course and flood plain. It consists mainly of boulders, cobbles and gravels in the matrix of sand and silt. The SPT and auguring were not carried out due to coarseness and highly abrasive nature of the sediment.

Terrace Deposit (td)

It consist of boulder,cobbles and gravels in the matrix of silty sand. It is distributed in the bank of Jhupra Khola at south of Dubichaur.

Colluvial soil Deposit (sco)

These deposits are developed at the footslope and gentler slopes due to transportation of the material from above. It consists of sand, silt and coarser materials. It is developed in eastern and western parts of Surkhet valley. Such deposits are found in north of Sitapur of Jarbuta VDC. Thickness is more than 1m. This soil is slight to non-plastic, loose to slightly dense and improper drainage may lead to ground movements in this soil.

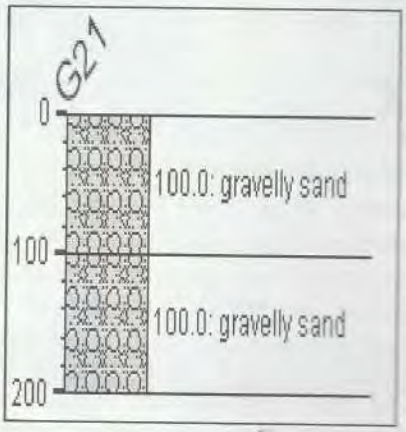
Residual soil Deposit (srs)

These deposites are developed along hill slopes due to weathering of rocks. Such soils have been developed in the eastern parts of Barakuna and Bastipur, south of Sano Surkhet, Koldanda, Kakre Bihar and in Solughupte. It is also developed in Gagretal ridge, Bhusal danda, Chauke Dhunga, Bhattekuna. It consists of mainly yellow to grayish yellow sandy gravels and sandy silt.

Itram Deposit (itd)

This unit is distributed mainly in the northern part of the valley above the Jumla Highway and consists of

Photo 2. Uneven distribution of cobbles and gravels in the matrix of sandy silt exposed at the bank of Itram Khola, north of Khajura (Itram Deposit).



gravel to boulder size materials in the matrix of sand. Most of the district offices are located in this deposit. Cobbles and gravels are sub-rounded (Fig. 3). This unit is covered by sand, silt and clayey silt. The field N-values in this area is very high. Thickness of

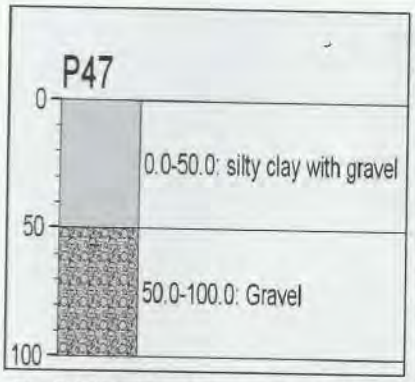
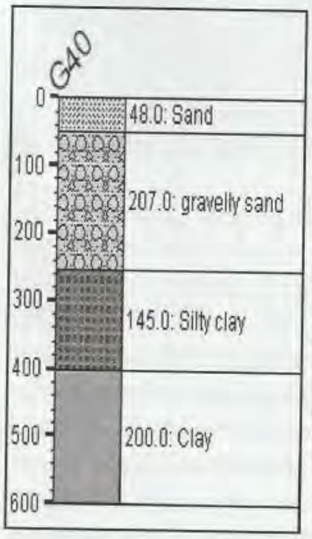


Fig.3 Litho-log of Itram Deposit

this unit is more than 8m and the groundwater table in this region is very high. Liquefaction hazard cannot be expected in such type of sediments. Compaction of the soil sediments in this unit is medium to dense with high Permeability. Allowable bearing capacity in this unit is high and hence is good for foundation purpose.

Belghari Deposit (bgd)



This unit is distributed along the Jumla Highway and extends towards south and consists of grey to yellowish grey silty clay to clayey silt with presence of gravels and at some places pebbles and boulders (Fig. 4). Silty clay and clayey silt is dominant over sand. However at some places thickness of sand exceeds 3 m. In this deposit, black carbonaceous clay is found denoting marshy lake deposits. Its western boundary is close to Bhureli south of Bangesimal while eastern boundary is close to Dholdhunga. Gravels are rounded to sub rounded consisting of sandstones and siltstones. Gravels occupy about 50% of the volume at some places. Upper part of this unit consists of brown to light grey clayey silt. This unit is sloping 5° to 10° towards south. It is more than 7 m thick.

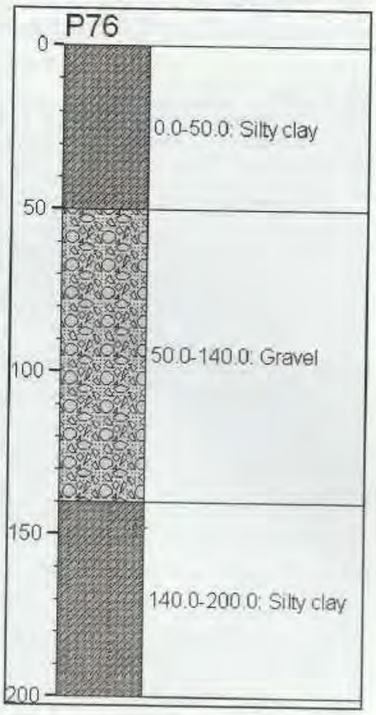


Fig. 4 Litho-log of Belghari Deposit

Plasticity is slight to none. Groundwater table is 1 to 2 m deep in general. At some places, groundwater is emerged out as springs (Bulbule Tal) on the ground surface. It is moderately good for foundation purpose; however some protective measures are to be applied where N-value is low. Engineering geological constraints to be considered in this unit are shallow groundwater table and lateral erosion of banks. This formation also covers most part of the southern cultivation land of the Surkhet Valley.

Purano Ghushra Deposit (pgd)

It is distributed in the southern part of Surkhet valley and consists of mainly grey to dark grey silty clays and black carbonaceous clays. Sometimes silty sand and fine sand layers are also interbedded (Fig. 5). It is mainly lacustrine deposits with thickness of more than 5 m. Consistency of this soil is very soft to soft and plasticity is intermediate to high. Allowable bearing capacity is very low to low. The liquefaction potential in this deposit ranges from low to moderate and some places of this deposit (in the eastern part) lie in high

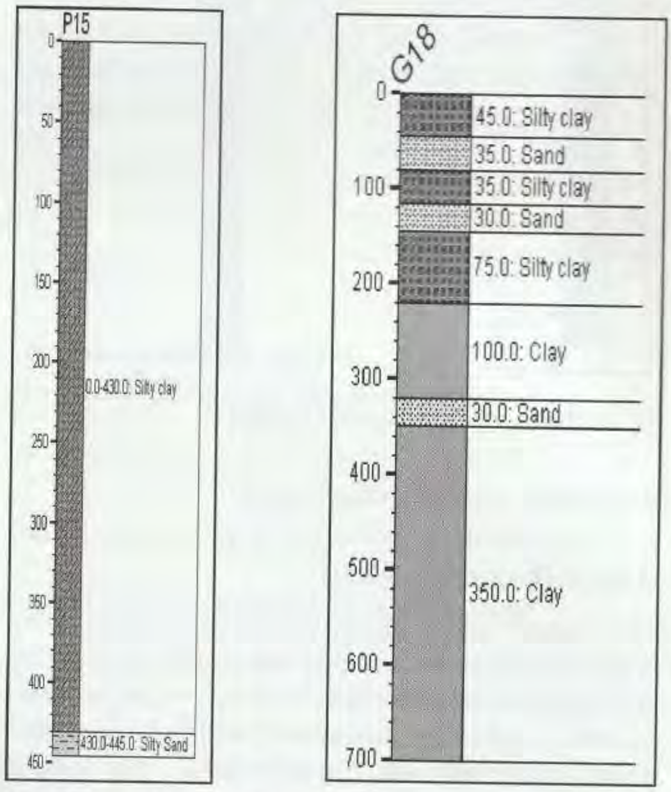


Fig. 5 Litho- log of Purano Ghusra

potential zone. Water table is very low and at some places found at ground surface. This unit is poor for foundation purpose due to possibility of settlement. Heavy structures should use pile foundation. The area is suitable for an agricultural development purpose.

Sano Surkhet Deposit (ssd)

This unit consists of light yellow to brownish yellow silty clay to clayey silt and occurs only in Sano Surkhet (Fig. 6). Sano Surkhet valley is separated from Surkhet valley by a small ridge and this valley forms tip of the whole valley.

This unit is of low plasticity and firm to stiff consistency. Groundwater table is more than 6 m deep. This soil has moderate bearing capacity and has moderate to low liquefaction potential zone. Its thickness is more than 6 m. The soil is very dry indicating the deep ground water table.

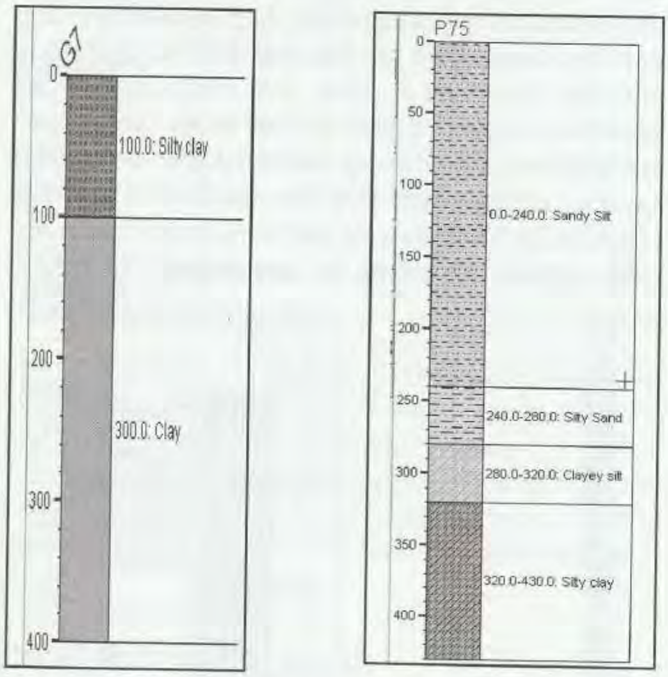


Fig.6 Litho-log of Sano Surkhet Deposit

Bedrocks of the study area include:

Gawar Formation (Gw)

The Gawar Formation (Gw) of Lakharpata Group has been exposed at the north-eastern corner of the study area just after Siwalik rocks. It consists of limestone, dolomite and shale. Limestone is greyish blue and dolomite is light to medium grey in colour. The individual thickness of the bed ranges from few millimeters to few centimeters. The rocks are highly disturbed near the Main Boundary Thrust (MBT) (Photo 3). The actual contact passes through the valley having small stream on the right bank of Jhupra khola, NW of Bagtar. The limestone bed has been thrust over the rocks of Lower Middle Siwalik (MS1).

Photo. 3 Highly disturbed bedding plane of Limestone and dolomite of Gawar Formation

Siwalik Group

The rocks of Siwalik Group found in the study area are:

Lower Siwalik (LS)

Lower Siwalik rocks are exposed in the north, northeastern and southwestern part of the study area. It consists of fine grained purple sandstone interbedded with variegated mudstone, shale and siltstone. The mudstone dominates over sandstone. Purple shale is well dominant in the southern part around Nikash khola. The siltstone is chocolate in colour where as shale is light greenish. The attitude of the bed at Nikash Khola (Photo. 4) where it crosses the valley is N50^{0}W/50^{0}N. The exposed thickness of mudstone bed is 3 m and the individual beds of sandstone are 30-50 cm.

Photo 4 Exposure of Lower Siwalik rocks at Nikash Khola

Lower Middle Siwalik (MS1)

MS1 is characterized by presence of salt and pepper like sandstone, mudstone and shale. Sandstone is medium to coarse grain. MS1 is well exposed around Neware khola bridge with an attitude of N30⁰W/18⁰N. Here the sandstone is thinly bedded while mudstone is very thick. They are highly weathered in Chaukune of Latikoili VDC. MS1 is also well exposed along the road from Bheri bridge towards Birendranagar, Surkhet. MS1 is well exposed in the north of Dubichaur (Photo.5).

Photo.5 Exposure of sandstone and mudstone of MS1 in the north of Dubichaur.

Upper Middle Siwalik (MS2)

The Upper Middle Siwalik (MS2) mainly consists of medium to coarse grained sandstone, pebbly sandstone with siltstone and mudstone. These pebbles are mostly constituted of quartzite, phyllite, limestone, dolomite, shale etc. MS2 is exposed at Solughupte (northwestern corner of the study area), with an attitude of N65°W/30°N; and Dhulabid with an attitude of N40°W/25°N and on the right bank of Jhupra khola, east of Barakuna. It is also exposed at Dubichaur (Photo. 6).

Photo 6 Pebbly Sandstone of MS2 exposad at Dubichaur

Upper Siwalik (US)

The upper Siwalik (US) rock has been exposed only in the south-western part of the study area I and consists mainly of conglomerate, sandstone and mudstone.

Structure

The present study area of investigation has been affected by major folding and faulting. The Main Boundary Thrus t(MBT) lies in the north-eastern corner and is observed at Jhupra Khola. Surkhet Thrust lies in the northern part while Bheri thrust is situated at the south- western part of the study area. MBT passes through a small stream forming the valley where sandstone and limestone are found below and above the thrust respectively. Similarly Nikash Khola Anticline and Chhinchhu Khola Syncline are the major folds in the study area (Shrestha, 1999). Some lineaments are found in the northern part of the valley within the study area.

Laboratory Tests

The soil and rock samples collected during the field investigation are subjected to various tests in geotechnical lab of DMG to determine their engineering properties, which are generally required for civil constructions. The laboratory tests are conducted in accordance with the test procedures recommended by ASTM and BS standards. The following tests were performed in the geotechnical lab of the department.

a) Natural moisture content,
b) Grain Size Analysis (Sieve curve), c) Liquid Limit, and
d) Plastic Limit,

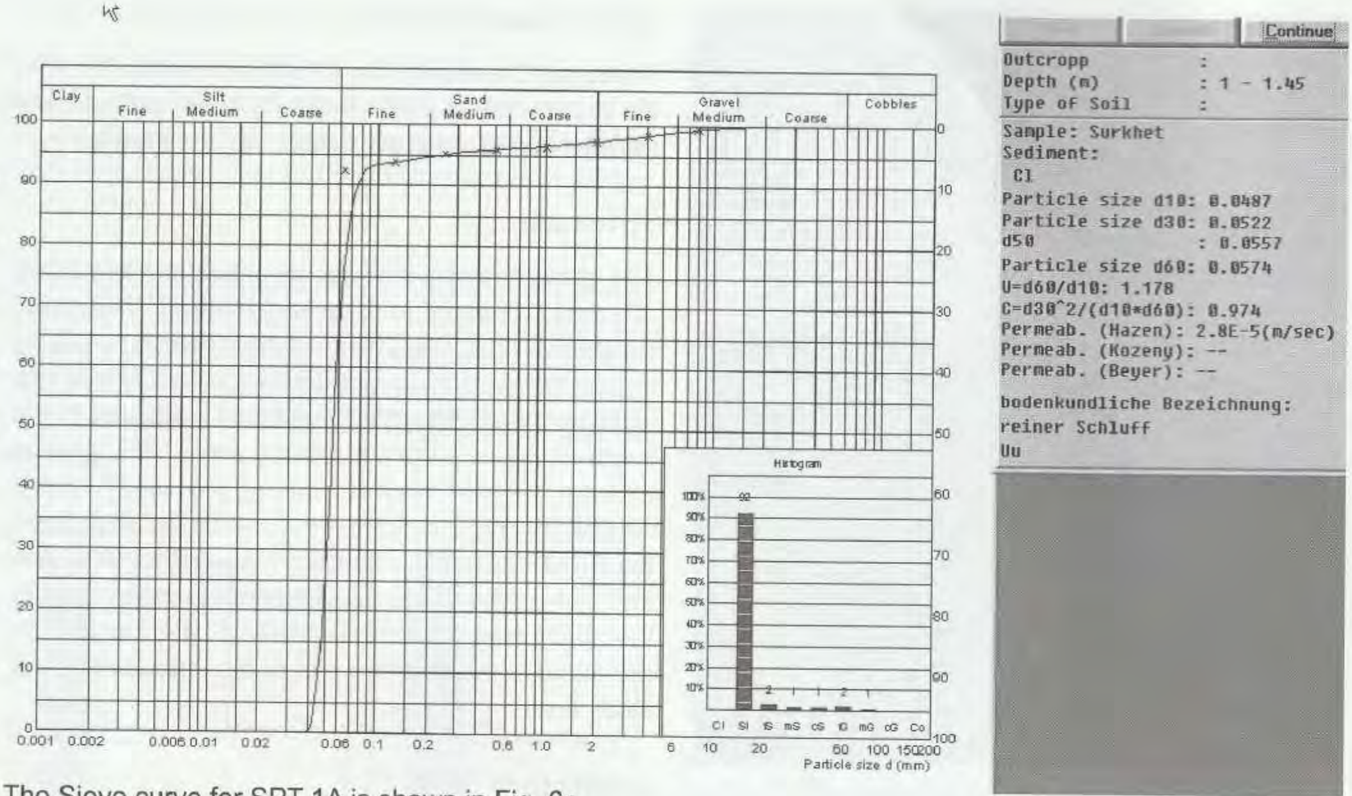
The Sieve curve for SPT 1A is shown in Fig. 6a.

Liquefaction Susceptibility Mapping

In the liquefaction susceptibility study, a total of 70 shallow boreholes data were used. The depth of all these boreholes is limited up to 6 m only due to time constraints and equipment limits. Final liquefaction susceptibility map with four different zones, High, Moderate, Low and Very low are shown below in Fig. 7.

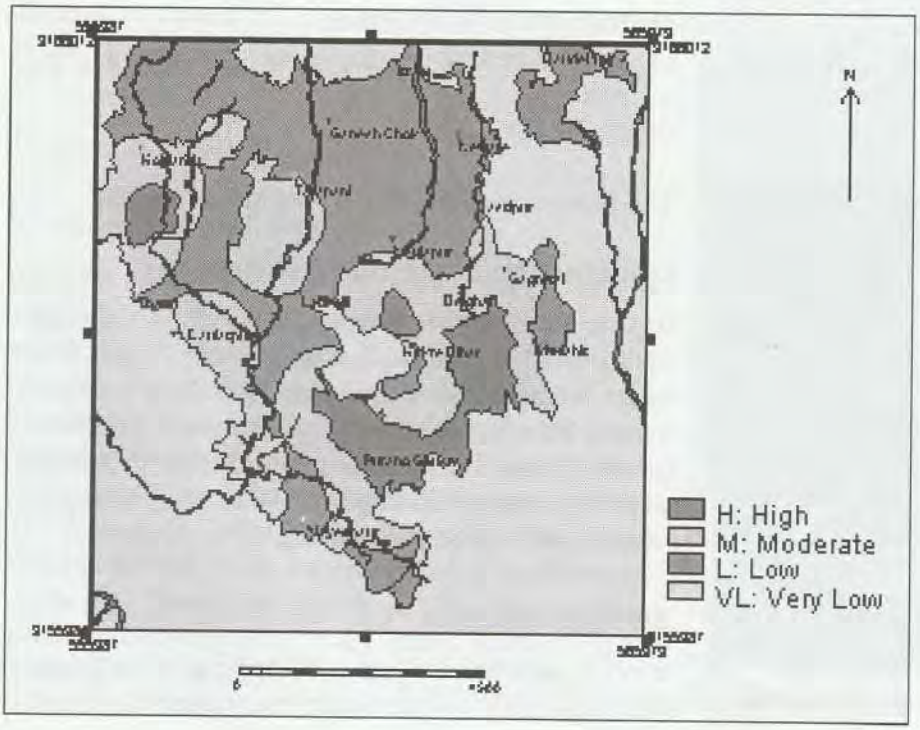
Bearing Capacity

Bearing capacity analysis is carried out according to Peck et al (1974). According to the analysis it is found



The Sieve curve for SPT 1A is shown in Fig. 6a.

that the bearing capacity of the study area is medium to very low. Bearing Capacity map is shown in Fig. 8. Soil condition in the study area varies from very low to medium with SPT value ranging from 0 to 10. The greater value is normally encountered at a greater depth, and hence the bearing capacity gradually increases with the increase in depth. The result shows that 96.2 % of the total area has low bearing capacity, about 2.66 % of the total area has moderate and about 1.14% area has very low bearing capacity.

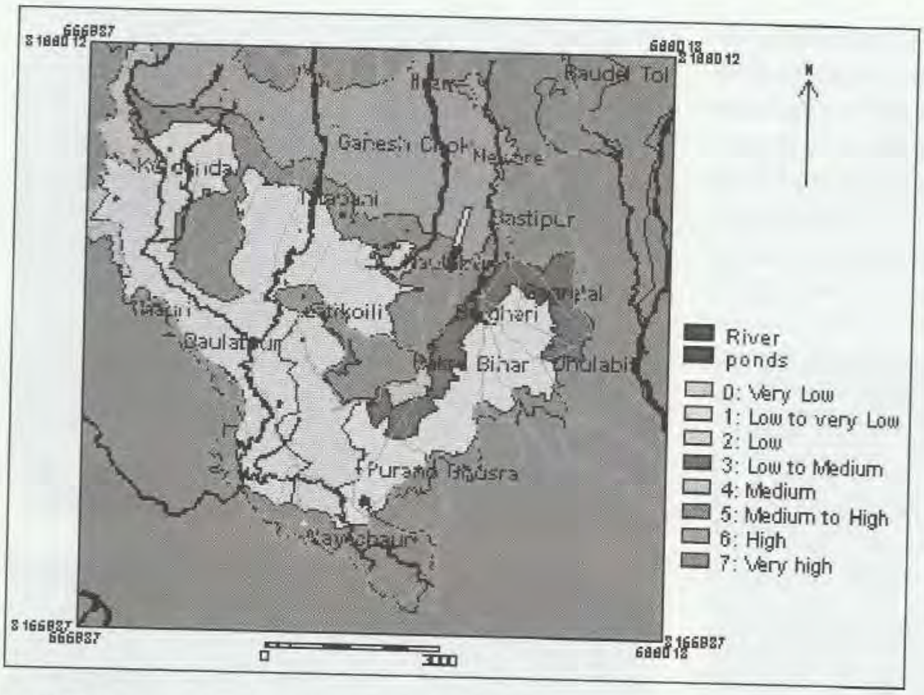


Ground Water Condition

Depth of groundwater table in Surkhet valley is variable due to different topographical situation and geological conditions of the valley. In the northern part, groundwater table is deep due to thick permeable layer of fan deposits,

Groundwater table in the middle and southern parts are shallow. They are confined mainly within silt beds. Depth to groundwater table in this area varies between 0.5 m to 2 m in general. At places water is flowing freely to the surface like in the wells south of Padampur, near Gupitpur, Jaypur and Raharpur etc.

Free flowing spouts can also be observed in Surkhet valley. Prominent among them is Bulbule Tal in the central part of the valley. Other free flowing spouts arê in Kholigaun in the southern



part, Uttarganga in the western part and Chisapani in the northern part. Volume of waterflow in these spouts is 1000L/min, 50L/min, 15L/min and 45L/min respectively. (Shrestha, 2001).

Land Use/Cultural Heritage/Historical Monument/Industrial areas

The study area can be divided into settlement, cultivation, forest and grassland area. The settlement area is mainly concentrated in Birendranagar Municipality area which lies north of the Jumla Highway. Cultivation area covers mainly in central and southern portion of the valley. Rice, mustard, wheat, corn and vegetables are grown here. Forest and grassland surround the valley mostly in the southeastern and southwestern part.

There are many cultural heritage and historical monument such as gumbas, temples in the study area. Among them Kakre Vihar, Bulbule Tal (Photo. 7) and Deuti Bajai are note worthy.

The industrial area is located northern side of the airport. There are some factories which are very small as compared to other parts of Nepal. Weaving, saw mill, Poultry farm and Nepali paper industries are running smoothly. Brick factories are mostly located south of highway in the agricultural land.

Waste disposal site

There is no permanent waste disposal site in the Surkhet valley. Waste disposal is a common problem where urbanization is taking place due to increase in population growth and development activities. Rapid assessment carried out in Birendranagar on September 2007 shows the generation rate of wastes to be 0.14 kg/person/day. 73% of the waste was found to be organic if only household wastes are considered. 1.5 tons of waste is collected every day by the Municipality. The open pits, Itram and Khorke Khola are used for dumping waste. The waste materials are also dumped into land of private house Photo (8) upon request to raise the level of ground especially during construction of the building. In the Municipality area, number of collection centre has been constructed for dry and wet waste collection.

Photo 7 Bulbule Tal (a touristic place)

Photo. 8 Dumping of waste material along the road side just northeast of Belghari close to high way filling the depression near newly constructed building

Municipality is planning to select two sites within the study area. One in Solughupte which lies in the north of Bangesimal at a distance of 5 km from the city centre and next in the southeast of Subakuna at a distance of 3 km from the city centre. The proposed landfill site of Solughupte is situated in the rocks of Upper Middle Siwalik (MS2). Most of the rocks have been converted into residual soil and bedrocks can be seen at few places only. There is no settlement in the proposed landfill site within the radius of 3 km except the area leading to that site. The other proposed landfill site lies in the rocks of Lower Middle Siwalik (MS1). There is no settlement within radius of 1 km, but the highway lies within 0.5 km. The municipality is making processes for Environmental Impact Assessment (EIA) for permanent landfill site in the north of Bangesimal.

In case of Surkhet valley sediment, ideal waste deposal site should be located in the clayey soil to obstruct the movement of leachate and other gases. Permeable soil such as gravel and sand pose a significant threat to ground water quality. Percolation of water into the landfill site can collect and transport substances and chemicals from the decomposition and leaching processes can contaminate nearby ground leading to different kind of diseases. The Sano Surkhet Valley can be considered for temporary landfill site. Human settlement is not so far from this site (~1km) and is very good in terms of the nature of the soil for landfill site. Due to thick deposit of clay, leaching processes leading to ground water contamination will be slow. The selection of waste disposal site at Solughupte is quite suitable as compared to Subakuna. However detail studies and environmental impact assessment should be carried out.

Natural Resources

The development of any country largely depends on the proper utilization of its natural resources which should be exploited economically and carefully. The present study area does not have any potential economic metallic mineral resources. However non-metallic mineral resources like construction materials (boulder, cobbles, gravels and sand) are available in the rivers of Surkhet valley. Quarrying activities of construction material are going on in Itram, Khorke Khola. Jhupra Khola has extensive cobble and boulder deposits. There is depletion of sand in the Surkhet valley and it is brought to the valley from Bheri River. Mining of construction materials from Itram Khola and Jhupra Khola is shown in Photo 9 and huge deposits of it is shown in Photo 10 respectively..

Photo. 9 Mining of construction materials from Itram Khola

Photo. 10Huge deposits of onstruction materials in Jhupra Khola

The Surkhet valley is rich in clay and silty clay deposit as evidenced by number of brick factories at different places. Such clay deposits are found in the area of Patini, Itaura and Tilpur.

Geo-Environment & Pollution

The drainage system of Surkhet valley is not properly managed. Dumping of solid waste in the bank of the river especially from squatter and riverside dweller has created river water pollution specially in Itram and Khorke Khola. The household waste dumped into the roadside creates health hazard. However there is not much environmental pollution as compared to other cities of Nepal. The smoke from brick factory close to human settlement may create health hazard and such factories should be located far from human settlement. The brick factories are located in Pateni, Itaura, Tatapani, and Pipira. Brick factory of Itaura is shown in Photo. 11.

Photo 11 Brick factory at Itaura polluting the nearby villages

Geo-hazard

The flooding is common in Intram and Khorke khola due to small difference between riverbed level and bank endangering the settlement areas and submerging the agricultural land in the valley. Gabion walls have been constructed in these rivers at place but their proper repairing works have not been carried out. Shallow river bed Photo. 12) close to houses is vulnerable to flooding. Landslides are found in the north of Surkhet Valley and also in Jhupra khola.

Photo.12 Shallow river bed close to houses with possibility of flooding in the monsoon season (Itram Khola)

Landslide

A landslide has occurred at places along the roadside between Subakuna and Bheri Bridge. The landslide blocked the road by which the road has to be diverted for vehicles. Other landslide has occurred in the Middle Siwalik rock on the right bank of Jhupra khola (Photo.13) north of Maumara. There are 5 houses lying below this landslide. Further landslide may damage those houses. This is the landslide that occurred during Bhadra 2065 in the rainy season.

Photo 13 Landslide on the right bank of Jhupra khola

River bank erosion/cutting

The river bank erosion (Photo 14) and failure of bridge due to poor construction is common phenomena and occurs specially during rainy season, which widens the rivers. River bank cutting (photo. 15) is seen in Khokre khola near Jitlpur and Itaura.

Photo 14 Collapse of bridge at Bame Khola. Poor construction material and weak anchoring led to foundation failure.

Photo 15 River bank cutting near Jitpur (Khorke Khola)

Seismicity

The study area (Surkhet) shows lesser events in the Seismicity Map of Nepal (1994-2005) published by (DMG). The earthquake disasters at any place is governed by the magnitude of an event, population density, local site condition (local geology), construction practices, and technological development for search and rescue as well as reconstruction and rehabilitation. MBT is an active fault which lies in the northeastern part within the study area where as the Main Frontal Thrust (MFT) which is also an active fault lies about 70 km south of the study area separating the Siwalik mountain from the Indogangetic plain (Terai). The strong motion data is not available for the study area. However, the seismic hazard map produced by National Seismological Centre of (DMG) shows that the Surkhet Valley lies in pga value of 0.2g (calculated for bedrock).

The study area lies in the tectonic basin consisting of sediments like clay, silt, sand and gravels that have been deposited during the Quaternary period. The areas with loose sediments are highly vulnerable to earthquake shaking. The soft soil may be liquefied due to intense shaking of loose sediments during earthquake. The seismic waves of high magnitude may be amplified (Resonance effects) in such soft valley sediment which may cause a lot of damages. Western and Southwestern boundary of Kakre vihar are highly susceptibne to ground settlement.

Conclusions and Recommendation

- Surkhet valley consists of fluvio-lacustrine sediments.
- The valley sediments is classified into seven different deposits.
- Most of the hill slopes around Surkhet valley are stable due to gentler slopes and thick forest cover. Few small landslides have occurred in the northern slopes.
- Central and the southern part of the valley consist of areas of low bearing capacity.
- Liquefaction prone areas mainly cover in southeastern part of the valley.
- Flood plain deposit provide source of construction material like sand gravel and clays. Jhupra khola provides construction material such as boulder, cobble and pebble.
- Itram Deposits provide suitable sites for construction of infrastructure and for human settlement.
- Groundwater table in the northern part is deep, whereas it is shallow in the central and southern parts.
- Repairing work of gabion wall along the riverbank of Itram and Khorke khola should be carried out in time to safeguard the settlement especially during rainy season.
- Since Surkhet valley is rich in clay, construction material like brick can be produced in large quantity. But their location should be far from human settlement to reduce health hazard.
- The spring water occurring inside the valley should be properly utilized for domestic purposes.
- The proposed landfill site at Solughupte is better than the one proposed at Suba kuna which require detail investigation of environmental impact on human settlement.
- The southern parts which are close to highway should be developed as agricultural land.
- The final outcome of the present study should be made available to the Birendranagar Municipality Office so that the municipality could implement suitable landuse practice during their planning stage.

- The areas like Kakre Bihar, Bulbule Tal and Uttarganga temple can also be developed as a touristic spot.

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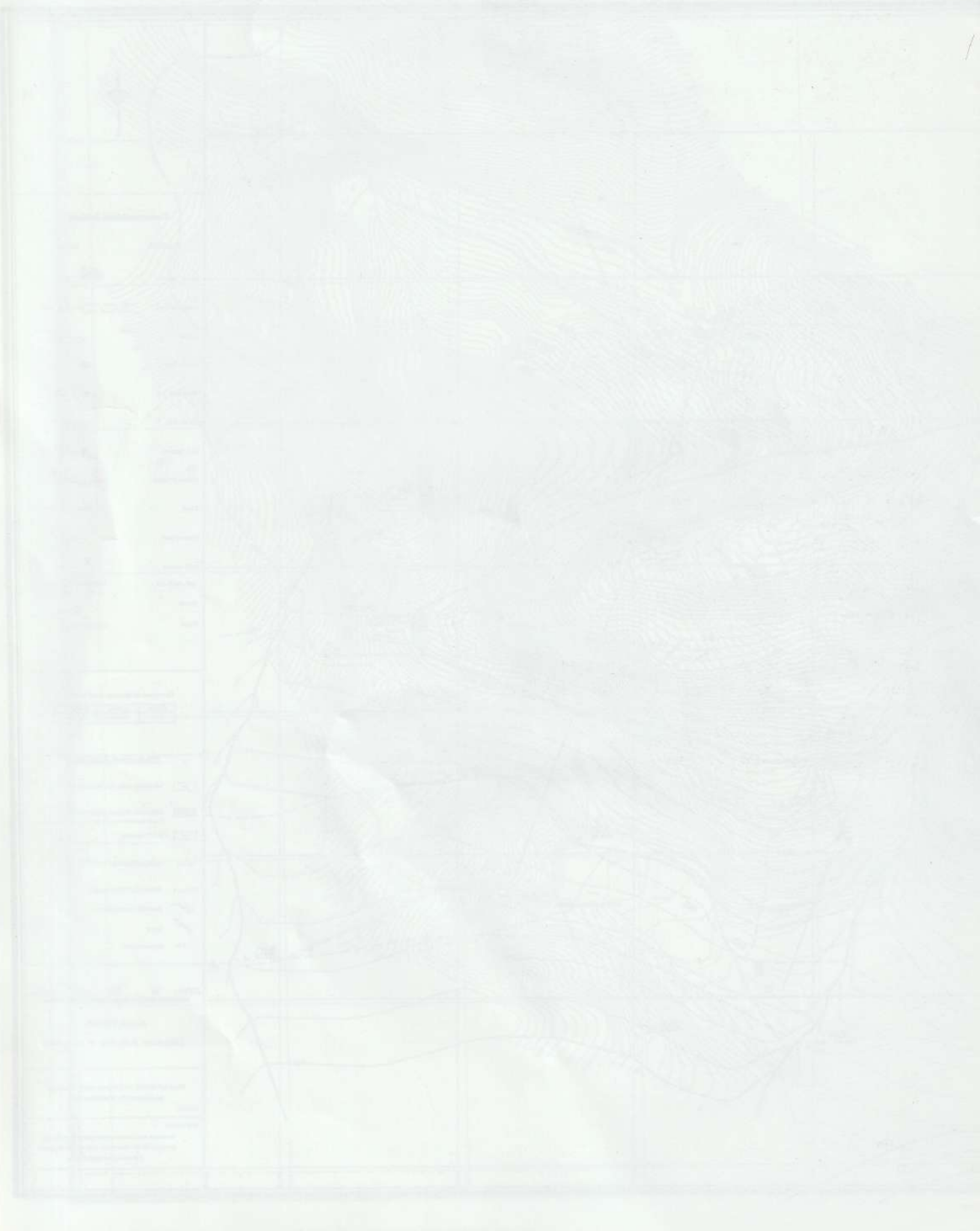

Fig. 3 [illegible]

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Geological Studies and Section Measurement of Parts of Sunsari, Dhunkuta, Udayapur, Saptari and Khotang Districts, Eastern Nepal

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ABSTRACT

This field investigation was carried out in accordance with the annual field programme of Petroleum Exploration Promotion Project (PEPP), Department of Mines and Geology (DMG) for the fiscal year 2065/66 BS. The fieldwork involved geological section measurement of 100 km length, geological mapping along major rivers such as Saptakoshi River, Seti, Murti, Yosada, Sisuwa, Gideri, Materi, Ghare Kholas and its adjacent areas of Sunsari, Dhankuta and Udayapur Districts of Eastern Nepal. The study area is represented by sedimentary, metasedimentary and metamorphic rocks belonging to Quaternary sediments of Terai, Siwalik Group of Sub-Himalaya as well as Gondwana and Midland Groups of Lesser Himalaya. Grey to dark grey shales and diamictites (thickness varies from 19 m to 28 m of Gondwana rock) is observed in the study area, which is the important source rock for hydrocarbon.

INTRODUCTION

The study area lies in between latitudes 26° 47' 30" N to 26° 55' 00" N and longitudes 86°55'00" E to 87°15'00" E (Fig. 1) in the parts of toposheets 2686 04B, 2686 04D, 2687 01B, 2687 01C, 2687 01D prepared by Survey Department, Government of Nepal (Scale 1:25,000) in 1995.

OBJECTIVES

The objectives of the investigation are:

- to carry out geological section measurement along rivers and roads
- to prepare geological map of the study area
- to collect petrogeochemical samples from shale horizon for source rock investigation

Fig. 1: Location map of the studied area

METHODOLOGY

To identify the possible trace of major structural features such as Main Frontal Thrust (MFT), Main Boundary Thrust (MBT), and Mahabharat Thrust (MT) satellite images mainly Google earth image and aerial photos were studied. Available literatures on geology of eastern Nepal are also reviewed before the fieldwork. The following methods are adopted during the fieldwork:

- Geological mapping and section measurement were carried out using topographic base map at scale of 1:25,000.
- Lithological units and structural features were identified on the basis of field observation. Traverses were made along Saptakoshi river, Seti, Murti, Yosada, Sisuwa, Gideri, Materi, Ghare Kholas and its adjacent areas of Sunsari, Dhankuta and Udayapur Districts of Eastern Nepal.
- The details of the lithological units were studied and mapped to find out the lateral extension and variation of the different rock types to understand the source, seal, and reservoir potential for hydrocarbon.
- Compass and tape survey method (brunton compass, measuring tape, hammer, chisel and altimeter) were used to measure the geological section and collect the rock samples.

GEOLOGY OF THE STUDY AREA

The study area is represented by sedimentary, metasedimentary and metamorphic rocks belonging to Quaternary sediments of Terai, Siwalik Group of Sub-Himalaya as well as Gondwana and Midland Groups of Lesser Himalaya from south to north respectively (Kayastha 1971, Bashyal, 1973, Subedi and K.C. 1995, Shrestha and Sharma 1995, Pradhan et al., 2006, Khanal 2009). The Terai is the northern extension of Indo-Gangatic Plain, which consists of Quaternary sediments of different grain size. The rocks of the Siwalik Group consist of claystone, mudstone, siltstone, and sandstone. The Mahabharat Range or the Lesser Himalaya constitutes the sedimentary to metamorphosed rocks like shale, slate, quartzite, dolomite, phyllite etc. (Kayastha 1971, Bashyal 1973). The geological setting and geological cross section of the studied area are shown in Fig. 2 and Fig. 3. Similarly, the stratigraphic sequence of the studied area is shown in Table 1.

In general, the strike of the rock in the area is NE-SW, sometimes NW-SE and the bed dips NE to NW and sometimes SW at an angle of 20° to 85°.

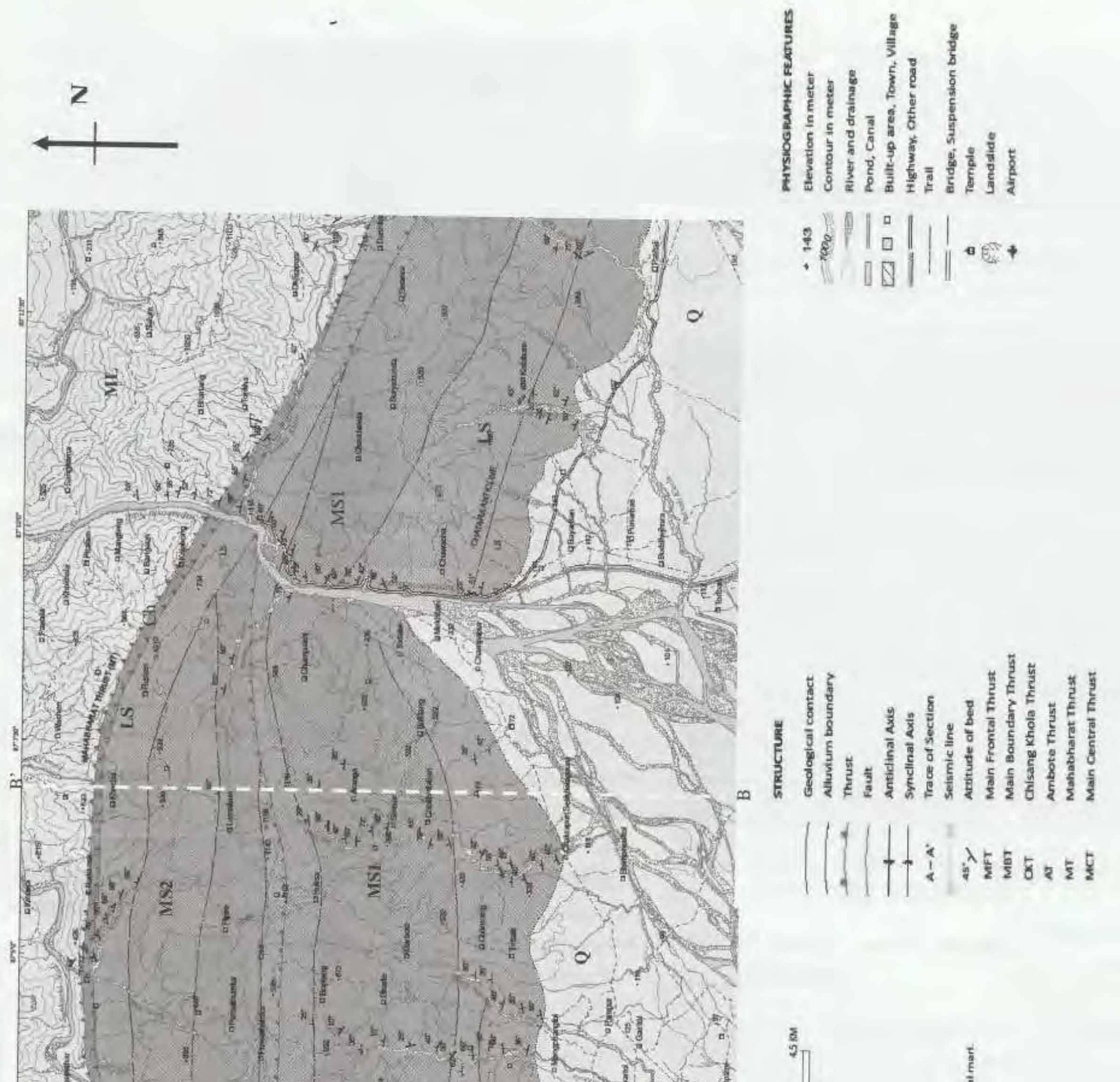

Fig.14: Geological Map of Parts Sunsari, Udayapur, Saptari, Khotang and Dhankuta Districts (Petroleum Exploration Block No: 9)

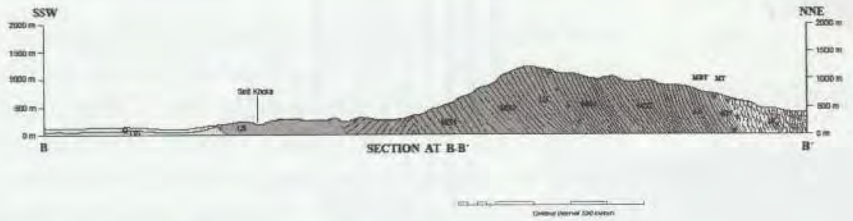

Fig.15: Geological Cross Section along B-B

Table 1: Stratigraphic Sequence of the Study Area

Tentative Age	Group	Formation	Lithology
Quaternary (Q)			Alluvial, gravels, sand, silt, and clay
Miocene-Lower Pleistocene	Siwalik Group	Upper Siwalik (US)	Gravel, conglomerate and mudstone
		Upper Middle Siwalik (MS2)	Medium to coarse grained, light grey to grey, arkosic pebbly sandstones interbedded with grey, dark grey, brown clays. Coal lenses and plant fossils are present
		Lower Middle Siwalik (MS1)	Fine to medium grained sandstone with interbeds of siltstone and mudstone. Coaly materials and plant fossils are present.
		Lower Siwalik (LS)	Fine grained sandstone with interbeds of variegated shale, siltstone and occasional marl.
Lower Carboniferous -Lower Cretaceous	Gondwana Group	Charchare Formation	Grey to dark grey carbonaceous shale with some quartz veins and diamictites of different clasts ranges from coarse grained to pebble size.
Precambrian	Midland Group		Grey and greenish grey chloritic phyllite, gritty phyllite and white grey quartzites with amphibolites

Midland Group

The rocks of the Midland Group are clearly exposed in the northern part of the study area. The rocks of this group are thrusted over the rocks of the Gondwana Group along the Mahabharat Thrust (MT). It is the Precambrian rock in the studied area and consists of grey to greenish grey phyllite and grey to white sericitic quartzites (Photo 1). It is well exposed along Kokaha Khola, Sapta Koshi, Materi Khola, Ghare Khola sections.

Photo 1: Grey phyllite and grey to white sericitic quartzites of Midland Group in Materi Khola

Gondwana Group

Charchare Formation:

The outcrop of this formation comprises mainly dark grey to black, carbonaceous silty shale, quartzites with ferrugionous coatings. The rocks of this formation are clearly observed on the north- west from the confluence of Kokaha Khola and Sapta Koshi along foot tracks of Barahachhetra-Tribeni along Saptakoshi river section. Similarly, this dark grey black carbonaceous shale with diamictites also observed along the Materi Khola section. From Materi Khola toward west, the rock of Gondwana extends along Dudhkosi river and sometimes it appears in the north of Dudhkoshi river in Khotang District.

Photo 2: Gondawana shale with quartzites along Barahachhetra- Tribeni Section, Dhankuta District

The Charchare Formation comprises shales, quartzites, and diamictites. Shales are very thin bedded and found as intercalations with quartzites. The shale contains coal bearing materials (Photo 2). These are very soft and crushed. Diamictites shows wide variation in the proportion of clasts ranges from coarse grained to pebble size and made of the granite gneissose rocks, limestone, dolomites and sandstones (Photo 3).

Photo 3: Diamictites of Charchare Formation of Godwana Rocks along Materi Khola

Siwalik Group

The Siwalik Group (Middle Miocene - Lower Pleistocene) is composed of sandstone, mudstone, siltstone, shale, clay and conglomerates (Fig. 2) in the studied area. It is bounded by MFT to the south and MBT to the north. The sandstone of the Siwalik group is medium grained, porous, and permeable. It can be considered as the good reservoir for hydrocarbon accumulation. The Siwalik group has been divided into three formations: Lower Siwalik (LS), Middle Siwalik (MS) and Upper Siwalik (US) on the basis of lithological variations. The Middle Siwalik can be further divided into the Lower Middle Siwalik (MS1) and Upper Middle Siwalik (MS2). The Upper Siwalik (US) is observed in the Galeni area (south of Gideri Khola).

Lower Siwalik (LS)

Lower Siwalik is the oldest formation in the Siwalik Group. It is composed of fine to medium grained light grey to grey sandstone, maroon nodular clay and reddish brown marl). It occupies the southern part of the mapped area just north of Terai plain in all river sections. It is repeated again in Babala Katunje, Kokaha Khola and Kopchhe area (Photo 4).

Photo 4: Outcrop of the mudstone dominated Lower Siwalik along Murti Khola Section

Photo 5: Outcrop of MS1 observed in Murti Khola, Udayapur District

Sandstones are fine to medium grained and grey in colour. Thickness of the sandstone increases towards the top. Sandstone beds are thin to medium bedded and attain unto 75 cm. Mudstone is medium to very thick bedded. It has purple to greenish grey colour. The thickness of the individual beds of clay varies from 1.1 m to 3.5 m. In general, the strike of the formation is NW-SE with dip amount 30°- 75° towards north and sometimes south. It is conformably overlain by the MS1.

Middle Siwalik (MS)

The Middle Siwalik has normal and gradational contact with the underlying Lower Siwalik. It consists of fine to medium and coarse grained sandstones, pebbly sandstones interbedded with greenish grey shale and clay. The lower portion of the Middle Siwalik contains alternate bands of sandstone, shales and clays. In the upper horizon, the coarseness of the sandstone increases. The sandstone becomes more coarse, and gritty and eventually pebbly towards the top. The Middle Siwaliks are repeated again in the middle of the mapped area. The Middle Siwalik is also classified into Lower Middle Siwalik (MS1) and Upper Middle Siwalik (MS2) based on the presence of pebbly sandstone horizon and a few conglomerate bands.

Lower Middle Siwalik (MS1)

Lower Middle Siwalik (MS1) consists of sandstone, mudstone, claystone, siltstone and shale (Photo 5). Sandstone of MS1 is light grey to grey coloured, medium grained and interbedded with green to greenish gray clay. MS1 is repeated again in the central parts of the study area due to faulting. It is mainly characterized by arkosic sandstone.

It is quite thicker in Sisuwa Khola and Murti Khola Sections than in Barahachhetra- Chatara Section along Saptakoshi. The dip direction of MS1 is NW-SE, sometimes NE-SW and amount of dip varies from 25° to 65°.

Upper Middle Siwalik (MS2)

The upper Middle Siwalik (MS2) conformably overlies the subunit MS1 with gradational contact. It is mainly composed of grey to grayish white fine to medium grained pebbly sandstone with little intercalation of grey to grayish white shale and clay. Interbands of pebbly conglomeritic horizons along with occasional silty sandstone are very common (Photo 6).

The individual bed of clay varies 0.75 m to 3.5 m in thickness. Thickness of the individual sandstone

Photo 6: Pebbly sandstone observed in the MS2 along Ghare Khola Section

bed varies from 2 m to more than 5 m. Sandstones are often pebbly and at places 0.5 to 2.0 m bands of conglomerate are found. Pebbles of pebbly sandstones are made of mainly white, pink quartzites and occasional Siwalik sandstone and clay fragments. In general, the strike of the unit is NW-SE, sometimes NE-SW with dipping 25° to 70° towards NE and NW and sometimes SW.

Upper Siwalik

Gravel bearing poorly bedded Upper Siwalik (US) is also observed in south-west part of the study area.

GEOLOGICAL STRUCTURE

Main Boundary Thrust (MBT) separates Tertiary sedimentary Siwaliks from the earlier Tertiaries and the older rocks in the area. The trend of MBT is almost NW to SE direction and can be distinguished in the field mainly along Kokaha Khola, Materi Khola and western parts of Sapta Koshi in the study area because of strong lithological contrasts across the thrust plane. Landslides, macro folds, joints, and shearing effect is the strong evidence for thrusting (Photo 7).

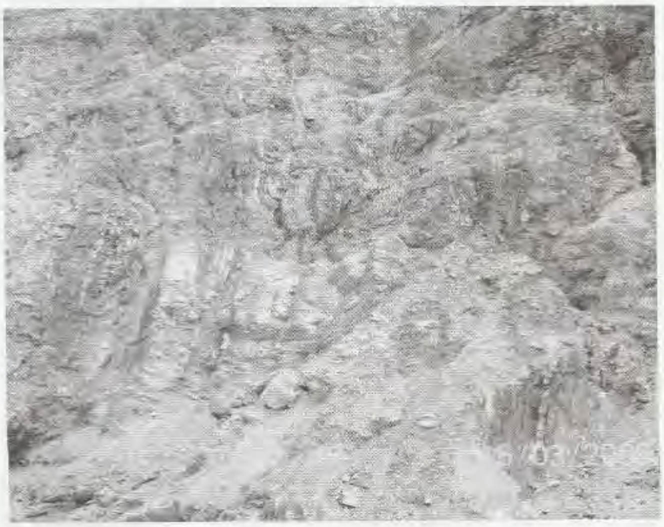

Photo 7: Macrofolds observed along Main Boundary Thrust (MBT) in the Kokaha Khola

The trace of Main Frontal Thrust (MFT) cannot be observed in the study area. The Lower Siwalik (LS), Lower Middle Siwalik (MS1) and Upper Middle Siwalik (MS2) are repeated in the middle part of the study area due to faulting (Fig. 2). The rocks of the Midland Group are thrusted over the rocks of the Gondwana Group along the Mahabharat Thrust (MT). The trend of MT is almost same as the MBT (Fig. 2). Beside these the cross bedded structure are clearly observed in the pebbly sandstone of MS2 along Murti Khola Section (Photo 8). The rocks of Midland Group are faulted and jointed (Photo 9).

The Chatara Anticline is the major anticline observed in the North of Chatara - Dharan Road Setion in eastern part, and south of Asare and Uchaladhunga of western part of the study area. Beside this, a minor syncline and anticline folds are observed in the west of Ramite area (Fig. 2).

Photo 8: Cross laminated pebbly sandstone of MS2

Photo 9: Minor fault observed in the Midland Group rocks along Kokaha Khola

GEOLOGICAL SECTION MEASUREMENT

Thickness of various rock units and formations were measured made along Saptakoshi, Seti, Murti, Yosada, Sisuwa, Gideri, Materi and Ghare Kholas and its adjacent areas of Sunsari, Dhankuta and Udayapur Districts of Eastern Nepal.

Thickness of Gondwana shale has been measured along all sections in the study area. Gondwana shale is quite thicker in Materi Khola, Saptakoshi section and it is comparatively thinner in the eastern and western sides of the mapped area. Lower Siwalik is thick in the eastern side of the area. Thickness of Upper Middle Siwalik and Lower Middle Siwalik are measured whereas no Upper Middle Siwalik is observed in the eastern side of the area. Upper Siwalik is also observed in the Galeni area. Thickness of Gondwana rocks of Charchare Formation (grey to dark grey shales in Barachhetra-Tribeni section along Saptakoshi and Ghare Khola section and grey to dark grey shales with diamictites in Materi Khola section) varies from 19m to 28m in the area.

CONCLUSION AND RECPMMENDATION

Sedimentary rocks belonging to the Siwalik Group of Sub-Himalaya and sedimentary rocks of Gondwana Group as well as metasedimentary to metamorphic rocks belonging to Midland Group of Lesser Himalaya represent the area. Detail geological sections measurement of different rock units / formations along major streams and river were carried out in the studied area. Different geological contact and thrusts were identified to trace the lateral extension. Grey to dark grey shales and diamictites (thickness varies from 19 m to 28 m of Gondwana rock) is clearly observed, which is the important source rock for hydrocarbon in the study area.

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National Seismological Network of DMG

Seiemic Stations under NSC, Kathmandu	
Stations	**District**
Taplejung.	Taplejung
Odare	Dhankutta
Ramite	Udaypur
Jiri	Dolakha
Gumba	Sindhupalchowk
Phulchouki	Lalitpur
Kakani	Nuwakot
Daman	Makawanpur
Gorkha	Gorkha
Koldanda	Palpa
Dansing	Kaski
Pyuthan	Pyuthan

Semic Stations under RSC, Surkhet	
Stations	**District**
Megha	Rukum
Harre	Surkhet
Bhimchula (Relay)	Surkhet
Gaibanna	Surkhet
Gainekanda	Surkhet
Badegauja	Kailali
Pusma	Surkhet
Bayana	Bajhang
Ghanteshwor	Dadeldhura
Ganjari	Baitadi

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