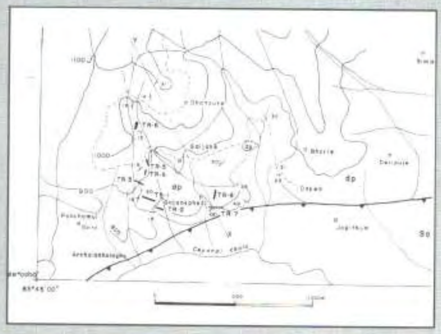

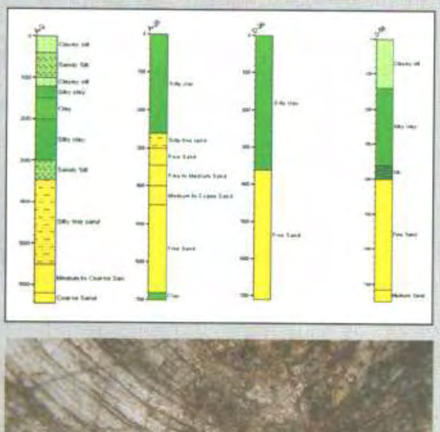

ANNUAL REPORT OF

DEPARTMENT OF MINES AND GEOLOGY

Annual Report No. 5, DMG

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FOREWORD

The present Annual Report No. 5 of the Department of Mines and Geology (DMG) represents continuation of publication of the Departmental activities as in the past . The information contained in this volume is based on the geo-scientific study and mineral exploration work conducted by the Department in the preceding year. So this volume can be considered as a single book conglomerating all the technical activities done by the Department which is published with the purpose to disseminate mainly the technical information to the concerned agencies. The information and data of the report is a valuable asset of the Department which is open for all the planners, geoscientists, geoscience students, investors, entrepreneurs and others interested in geoscientific study and researches and mineral exploration.

The present report is a compiled form of reports being published as per the approved Annual Program of the Department for the fiscal year B.S. 2064/65. It represents mainly the Geoscientific and Mineral Resources Development Activities of the year B.S. 2063/64 of the Department, Government of Nepal. I am sure that this report containing scientific papers on various topics will be a substantial asset of the Department and the Government as well as for future endeavors.

I therefore, would like to express sincere appreciation to all professionals who wrote their individual reports and to the contributors and service providers to bring this Report in this shape. My special thanks goes to all the members of the Editorial Board who has made valuable contribution with patience to bring this report in printed form in time.

Pranab Lal Shrestha
Director General

EDITORIAL

The Department of Mines and Geology as per its annual program for the fiscal year 2007-08 is bringing out this volume of 'Annual Report No. 5, DMG'. With the purpose of disseminating the information on geoscientific survey and researches as well as mineral exploration activities conducted by the Department annually to the public as well as concerned governmental and non-governmental agencies, the Department has given importance to the publication program also. Thus, the Department has been publishing books, booklets, information brochures and various geo-scientific maps etc. This issue is a continuation of preceeding volumes and it is hoped that it will also fulfill the intended purpose as in the previous years.

The Editorial Board is very much delighted to publish this volume and would like to extend its sincere appreciation and express thanks to all the authors and staff of the Department for their contribution and co-operation in its publication.

Rajendra B. Shrestha
Chief Editor

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Follow-up Investigation of Limestone and Dolomite in Some Parts of Syangja District, Western Nepal

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INTRODUCTION

According to the annual field program of the Department of Mines and Geology for the fiscal year 2063/64 under the Mineral Exploration and Development Project, the follow-up exploration of cement grade limestone and industrial dolomite in some parts of Syangja District around the Siddhartha Highway was undertaken. The study area lies in between 27° 57' 30" to 28° 02' 13.8" north and 83° 41' 15" to 83° 49' 33" east. The investigated area is easily accessible with the Siddhartha Highway from Pokhara to Syangja (35km) and Syangja to Waling (30km).

Madhikarmi (2000) carried out geological investigation for cement grade limestone and industrial dolomite in some parts of the Syangja district around Siddhartha Highway.

Khadka (2006) did preliminary and follow-up limestone and dolomite investigation in the area. A total of 78 continuous chip samples over the five limestone domains were chemically retained on assay results conforming that the Dhanpure Limestone (Left) has cement grade limestone dominant over a significant dimension. A total of 22 dolomite chip samples over the area show that the chemistry of Chiuri Dolomite domain could have possibilities of industrial grade dolomite. The chemical grading of Dhanpure Limestone (Left) revealed from assay values has mean 46.83% and standard deviation of 3.439% CaO content. Alike the assay returns of MgO content has mean 2.743% and standard deviation of 1.699%.

Present work is the continuation of the preliminary and follow-up limestone and dolomite in the previous year's regional mineral exploration in order to establish sound limestone resources of the cement grade and locate some of the industrial dolomite bands in the area.

OBJECTIVE

The objective of the study was to carry out geological investigation within 75 sq. km. area in the scale of 1:25,000 for locating the cement grade limestone and industrial grade dolomite bands, finding out their extension and thickness, and continuous channel and chip sampling for determination of their grade.

METHODOLOGY

Geological investigation of the limestone and dolomite bands was carried out simultaneously with channel and chip sampling. The sampling interval was approximately 2-3m and channel width was approx. 10cm and depth 3cm for channel samples in the Dhanpure Limestone. The fresh chips over approx. 3m true thickness were collected weighing about 1 kg and packed and labeled as a single chip sample. Samples were collected from the different areas to analyze for the confirmation of the grading in the laboratory.

WORKDONE

Geological investigation of the 75sq.km area in the scale of 1: 25,000 was carried out along with the total numbers of channel samples of limestone were 86, covering line length of 204m with trenching of 50m^3. The total numbers of chip samples of limestone were 18 covering line length of 60m. The total numbers of dolomite chip samples were 24 from the Chiuri area.

GEOLOGY

The present study area is a part of the Inner Lesser Himalaya around Sidhartha Highway of Syangja District. Startigraphically, it consists of the Lower Nawakot, Upper Nawakot and Sirkot Group of rocks from older to younger sequence. The lithostatigraphic subdivisions and lithology are summarized in Table-1.

Structurally, the area consists of thrust faults and folds. A thrust passes through Phaudi-khola-Bayatari-Phulbari has the footwall of Benighat Slates and the hanging wall of Nourpul Formation. And a thrust passes through Dauwa-Odare areas has the Sorek Formation and the Dhanpure Limestone overridden by Sorek Formation (Fig.1 and 2). A series of Chevron folds are common in the dip slope of the Dhanpure Limestone.

LIMESTONE RESOURCES

Dhanpure Limestone

Dhanpure Limestone consists of parallel laminated limestone. Basal part consists of 1cm to 10cm thick light gray to dark gray limestone and sometimes with mm scale cross cutting calcite veins. It grades up to the medium bedded limestone at the middle part of the deposit. The weathered surface shows brown to maroon discoloration. The upper part consists of thin to wavy laminations. Sometimes it shows ribs and furrow structures due to differential weathering. Structurally, it has a syncline passing through the upper middle part of the deposit. The true thickness of the deposit is about 100m. The strike extension of the deposit is about 600m at the basal part and upper part has nearly 80m as a result of erosion in the dip slope of the deposit. The dip slope of the deposit has up to 500m exposure. It has been truncated by a thrust at the base. The dip slope has gentle topography and has no overburden. The section shows a series of dragging i.e. pairs of anticlines and synclines along the dip. The overall dipping is towards the south.

It is about 2.5km NE of Waling, Siddhartha Highway. A village road passes at the base and middle of the deposit and also has 33 KVA transmission line nearby. There is a water reservoir at the upper reaches of the Archalekhola and remains till the month of Falgun before spring disappears in the dry season. Another source of water is about 1km away from the deposit for the purpose of core drilling. Gajane village is about 80m away from the deposit. Archalekhola gaon lies at the base of the deposit. Deposit itself is barren with houses and agricultural fields and also devoid of jungle. Altogether about 50 houses lie in the influence area. The Dhanpure Limestone has

Table-1: Generalized lithostratigraphy of the study area (after Dhital et al. 2002)

Group	Formation	Lithology	Age
Sirkot	Dhanpure Limestone	Parallel laminated gray and light gray limestone with shale and slate partings	?Late Proterozoic
	Sorek Formation	Gray- green, dark green and red purple slate with light yellow, light green, pink and white orthoquartzite	
	Ripa Member	Gray dolomite with columnar and dome shaped stromatolites	
Upper Nawakot	Benighat Slates	Gray and light gray slate and shale, carbonaceous slate and interlaminated shale with sporadic carbonate bands	
Lower Nawakot	Dhading Dolomite	Gray and light gray dolomite with dark gray and black slate partings and interbeds. The dolomite frequently contains dome shaped, columnar shaped and branching stromatolites.	Middle Proterozoic
	Nourpul Formation	Red-purple, gray and gray green slate or phyllite alternating with light yellow, white, pink and light gray quartzite.	

been sampled from the Archalekhola section and Gajane Khola section. Altogether 8 trenches with 86 channel samples were taken.

Archale Khola Section (Figs. 1 and 3) consists of 6 trenches. This represents a part of the dip slope section of the Dhanpure Limestone. The dip slope length is about 500m and has no overburden. The lowest portion of the deposit near Archalekhola is having exposed thickness of 70m. It has thrusted contact with the Sorek Formation at the base. Channel samples were taken only from bedding thickness sometimes representing from upper and lower level according to field conditions. A series of mesoscopic folds (anticlines and synclines) are common in the middle part of the deposit. Average strike length is about 80m.The Trench 1has total channel length of 22.55m and has 10 samples with average sample interval of 2.25m. The weighted average value for CaO is 50.82%and MgO is 1.95%. The Trench 2 has total channel length of 21.84m and has 10 samples with average sample interval of 2.184m. The weighted average value for CaO is 48.49%and MgO is 3.5%.The Trench 3 has total channel length of 18.5m and has 11 samples with average sample interval of 1.68m. The weighted average value for CaO is 50.82%and MgO is 1.95%. The Trench 4 has total channel length of 14.18m and has 8 samples with average sample interval of 1.77m. The upper 4 samples with channel length of 6.16m consists of weighted average value for CaO 49.62% and MgO 2.61%. The lower 4 samples have weighted average CaO 48.62% and MgO 3.59% within the channel length of 8.02m. The Trench 5 has total channel length of 14.04m and has 7 samples with average sample interval of 2.02m. The weighted average value for CaO is 51.4% and MgO is 1.98%. The Trench 6 has total channel length of 26.7m and has 13 samples with average sample interval of 2.05m. The weighted average value for CaO is 50.3% and MgO is 2.45%.

The Gajane Khola Section (Fig. 1) consists of Trench 7 and 8. The Trench 7 has total channel

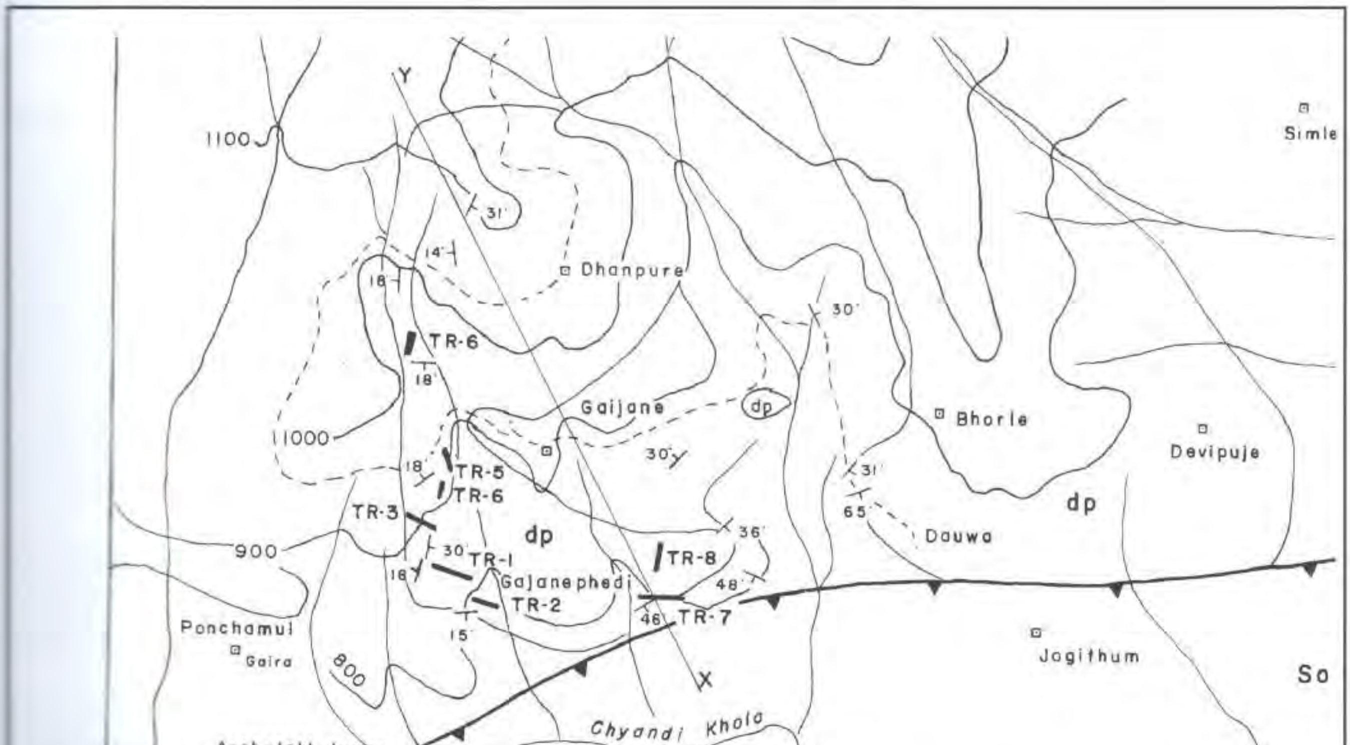

Fig.1. Detailed geological map of Dhanpure Limestone (left) with trench locations.

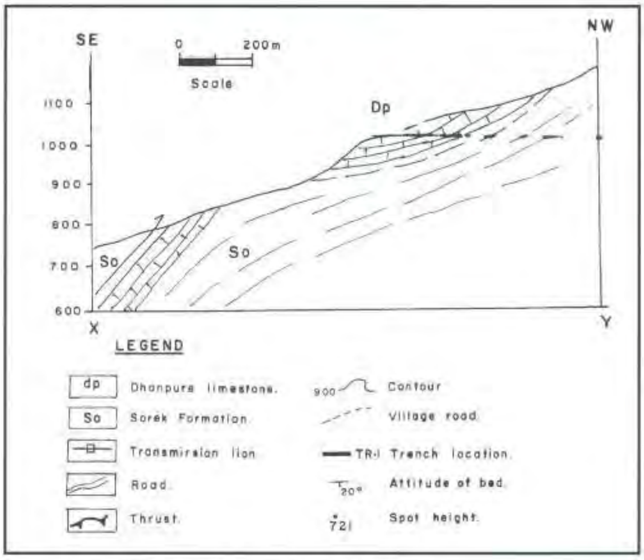

Fig. 2. Geological section along XY

Fig. 3. Dip slope section of Archalekhola, Dhanpure Limestone

length of 22.65m and has 11 samples with average sample interval of 2.42m. The weighted average value for CaO is 49.38% and MgO is 2.16%. The Trench 8 has total channel length of 37.33m and has 16 samples with average sample interval of 2.33m. The weighted average value for CaO is 49.29% and MgO is 2.95%.

The weighted average value of channel samples from Archalekhola and Gajane Khola sections show CaO 49.86% and MgO 2.48%.

Statistical Analysis

Mean and standard deviation of the chemical results of CaO, MgO, R_2O_3, Insoluble, and LOI calculated using line plot of the chemical results (Fig. 4, Table-2) show CaO ranges from 44.5% to 53.28% with standard deviation of 1.786. Similarly, MgO ranges from 0.5 to 6.552% with standard deviation of 1.124.

The line plot (Fig. 4) of chemical results of channel samples from Archalekhola and Gajanekhola sections show the following results-

- Lower the CaO, higher the MgO value
- Lower the CaO, higher the Fe_2O_3
- Lower the CaO, higher the R_2O_3
- Lower the CaO, lower the LOI
- Lower the CaO, higher the insoluble

Reserve Estimation

The following assumptions were taken into consideration for reserve estimation

- Beds are homogeneous along strike and towards the dip
- Tonnage factor 2.6
- Smooth topography

A) Archale Khola section
Thickness=70m
Strike length=70m
Along the dip=500m
Tonnage factor=2.6
Geological reserve=6.37MT

B) Gajane khola section
Thickness=70m
Strike length=400m
Along the dip=100m
Tonnage factor=2.6
Geological reserve=7.28MT

Total estimated geological reserve (category III or possible) = 13.65MT

Khahare Khola section, Archalekhola gaon and Gajane upper

The total number of chip samples collected from

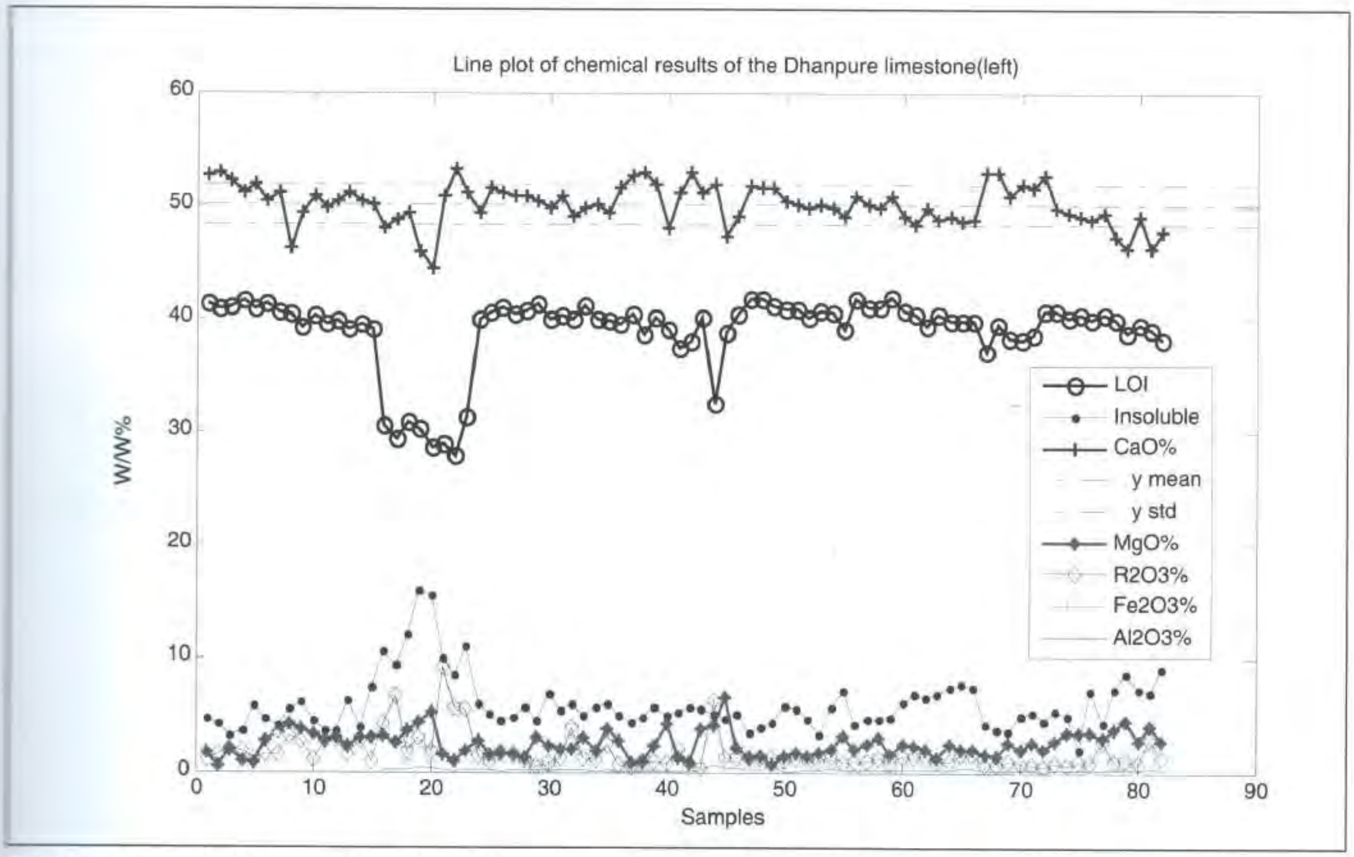

Fig. 4. Line plot of chemical results of channel samples from Archalekhola and Gajane Khola sections of Dhanpure Limestone.

three different locations is 18 in which 9 samples from Khahare Khola (Fig. 5), 9 samples from Archalekhola gaon, 2 grab samples from Gajane upper were collected. Khahare Khola is about 1 km west of Archale Khola. Its strike extension is about 200m considering mineability and thickness is about 60m. It is a western extension of the Dhanpure Limestone. Archalekhola gaon is the area lies just left flank of the Archale Khola. Gajane upper is the area just above the motor road from Gajane to uphill.

The statistical analysis of chemical results of Khahare Khola section, Archalekhola gaon and Gajane upper(Table-3) shows that the CaO ranges from 43.81 to 51.87 with standard deviation of 2.02. Similarly MgO content ranges from 0.252 to 5.7 with standard deviation of 1.27.

DOLOMITE RESOURCES

Chiuri Dolomite (1)

The deposit is located between Bayatari and Chiuri on the down hill side of the Sidhartha Highway (Fig.8). The lower part of this domain consists of gray to green gray dolomite with less than 1mm to 1cm thick gray slate partings. The middle and upper part of the deposit has pink dolomite (Fig. 6). Structurally the deposit has attitude of 250°/

Table-2: Statistical analysis of chemical results of channel samples from Archalekhola and Gajane Khola sections

	Minimum	Maximum	Mean	Std. deviation
CaO%	44.5	53.28	50.12	1.786
MgO%	0.5	6.552	2.476	1.124
R_2O_3%	0.4	9.32	1.736	1.526
LOI%	27.96	41.86	38.97	3.32
Ins%	2	16	5.98	2.43

Table-3: Statistical analysis of chemical results of Khahare Khola section, Archalekhola gaon and Gajane upper

	Min.	Max.	Mean	Std. deviation
CaO%	43.81	51.87	48.27	2.02
MgO%	0.252	5.7	2.67	1.27
R2O3%	6.62	2.75	1.26	0.48
LOI%	37.35	41.13	39.47	1.04
Ins%	3.38	11.52	7.89	2.23

30°. The true thickness of the deposit is about 150m. The extension of the deposit is about 300m and has no overburden. It is about 0.5km from the road head. Since the deposit is at the hilltop and dip slope situation predicts significant mining condition.

Chiuri Dolomite (2)

The deposit is located about 1km SE of Sidhartha Highway from Bayatari along the right bank of Andhi Khola. It is on the down hill side of the Sidhartha Highway (Fig. 8). The upper part of this domain consists of gray to green gray dolomite with <1mm to 1cm thick gray slate partings. The middle and upper part of the deposit has gray dolomite. Structurally the deposit has attitude of 220°/65° S. The true thickness of the deposit is about 250m (Fig. 7). The extension of the deposit is about 800m and has no overburden. Since the deposit is at the hilltop dip slope situation predicts significant mining condition.

Chemical results of the Chiuri Dolomite based on chip samples (Table-4) shows that Chiuri Dolomite

Fig. 6. Chiuri dolomite (1)

(1) has low grade dolomite and the Chiuri Dolomite (2) has intercalation of low grade and industrial grade dolomite.

DISCUSSION

Two limestone and two dolomite domains were investigated. Limestone domains stratigraphically crop out in the Dhanpure Limestone. Dolomite

Fig. 5. Limestone band at Khahare Khola section

Fig. 7. Chiuri Dolomite (2)

Table-4: Chip and grab sample chemical results of Chiuri Dolomite 1 and 2

S.No.	LOI%	Ins%	CaO%	MgO%	R_2O_3%	Thickness(m)	Remarks
DK/CP/150	23.91	45.38	15.28	15.28	1.43	3	Chiuri 1
DK/CP/151	22.25	47.78	14.93	14.93	1.64	3	"
DK/CP/152	34.69	24.45	20.97	18.6	1.3	3	"
DK/CP/153	16.5	61.21	12.08	8.92	1.29	3	"
DK/CP/154	17.75	58.62	15.28	7.19	1.15	3	"
DK/CP/155	19.98	53.11	13.05	11.94	1.51	3	"
DK/CP/156	34.5	21.58	24.17	18.6	1.42	4	"
DK/CP/160	33.5	21.54	24.16	19.09	1.56	5	Chiuri 2
DK/CP/161	27.25	36.82	18.19	16.36	1.5	5	"
DK/CP/162	36.17	18.5	25.58	18.6	1.2	6	"
DK/CP/163	34.96	20.86	26.36	16.12	1.44	5	"
DK/CP/164	30.63	29.76	28.98	8.42	1.6	5	"
DK/CP/165	32.74	24.8	27.42	13.64	1.36	5	"
DK/CP/166	29.46	32.3	21.24	15.13	1.86	5	"
DK/CP/167	33.47	22.16	23.83	17.64	2.37	5	"
DK/CP/168	32.41	24	22.43	17.38	2.12	5	"
DK/CP/169	27.74	31.56	21.03	15.37	2.37	5	"
DK/CP/170	30.21	28.92	20.68	16.88	2.62	5	"
DK/CP/181	33.18	17.02	26.28	19.4	2.52	10	"
DK/CP/182	28.14	27.1	28.04	12.85	2.35	10	"
DK/CP/183	29.56	26.88	21.73	17.38	2.9	10	"
DK/CP/184	32.76	23.3	21.73	20.41	2.3	10	"
DK/CP/185	34.32	21.42	25.58	16.12	2.42	10	"

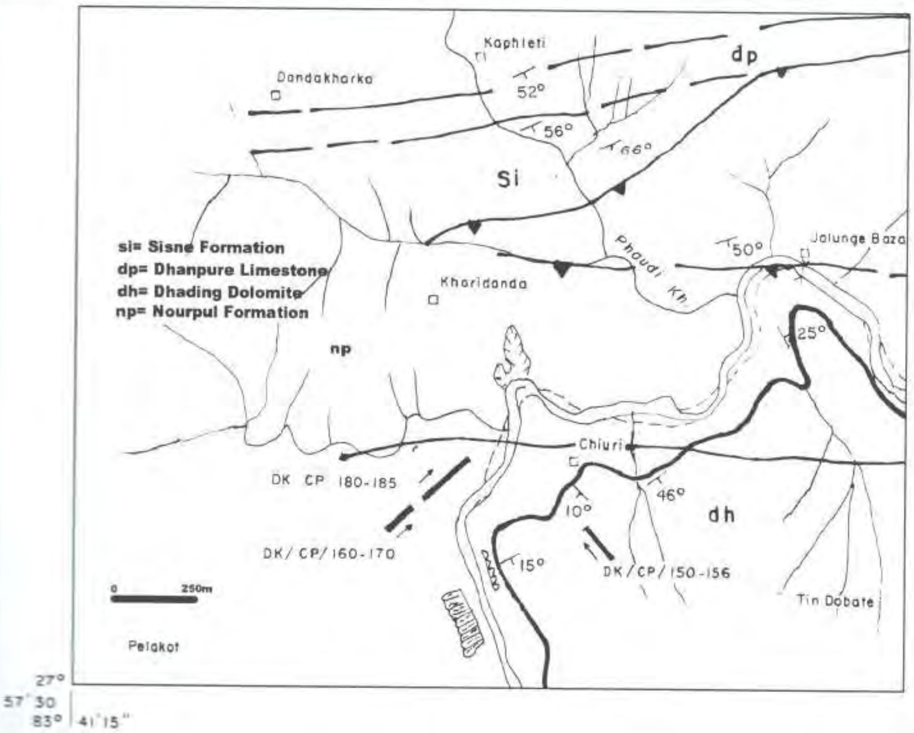

Fig. 8. Geological map showing dolomite sample location

domains fall under the Dhading Dolomite. Based on the grading scheme for cement grade limestone, CaO content more than 44% and MgO%~3, Dhanpure Limestone has cement grade limestone. Khahare Khola section also consists of cement grade limestone. Reserve estimation has been considered only for the Archale Khola section and Gajane Khola section. Based on the industrial grade, dolomite with MgO content more than 18%, Chiuri (1) and (2) domains of Dhading Dolomite can have selective bands to meet this grade.

CONCLUSION AND RECOMMENDATION

Dhanpure Limestone has been continuously channel and chip sampled. Dhanpure Limestone has weighted average CaO 49.86 % and MgO 2.48 %. The estimated geological reserve is 13.65 MT for cement grade limestone. Dhanpure Limestone should be carried out detailed follow-up exploration in order to establish an iso-grade map with the help of topo-geological survey along with systematic channel and chip sampling from the Archale Khola, Gajane Khola and Gajane upper within 5 Sq. km. area. The interval of channel sampling should be about 2mx10cmx3cm to analyze the weighted average value of cement grade limestone. Two dolomite domains viz Chiuri (1) and (2) have been chip sampled. The chemical grading of samples of Chiuri Dolomite shows industrial quality for a few bands. Further follow-up investigation for the industrial dolomite has been warranted for Chiuri dolomite (2) in this area.

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Exploration of Coal in Parts of Palpa and Arghakhanchi Districts, Western Nepal

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INTRODUCTION

The Department of Mines and Geology (DMG) preliminarily investigated the parts of Palpa and Arghakhanchi districts for coal occurrences in 2007. The investigated area lies between the latitude of 27° 48' 36"N and 27° 54' 18"N and the longitude of 83° 12' 30"E and 83° 21' 56"E. The area extends for about 15 km in east-west direction and 10 km in north-south direction. It covers about 150 square kilometers, including the western part of Palpa and eastern part of Arghakhanchi districts. The topographical maps of Sheet Nos. 098-07 (POKHARATHOK) and 098-06 (SIMALPANI) published by Survey Department, Government of Nepal, encompass the study area. The area is accessible by road, and lies about 35 km west of Tansen, the district headquarter of Palpa district.

Sakai (1983) mapped the section south and southwest of Pokhara around Tansen including the present study area, and divided the rocks into Precambrian to Early Paleozoic Kaligandaki Group and Permo-Carboniferous to Early Miocene Tansen Group. The rocks of the Kaligandaki Group are correlated with the rocks of the Nawakot Complex (Stöcklin and Bhattarai, 1977) in central Nepal (Sakai, 1984). The regional geology of the area has also been worked out by the Petroleum Exploration Promotion Project (PEPP, 1999; Map scale- 1:250,000) and the DMG (DMG, 2000; Map scale- 1: 50,000).

Bhargav (1947), Dutta (1949), Sharma (1962) investigated the parts of western Nepal for coal occurrences before the DMG initiated the 'Coal Exploration Project' by exploring the Tosh and Seuza areas of Dang district in the year 1995 (Aryal and Shrestha, 1996). The study was followed by drilling in the years 1996 and 1997 (Aryal et. al, 1997; Shrestha, 1998). Similarly, Tulsipur-Harthok area of Dang District in 1998 and eastern and western part of Tansen of Palpa District in 1999 and 2000 were preliminary investigated for coal deposits (Aryal and Shrestha, 1999, 2000 and 2003). Some of the coal seams in the area were reported to be promising. The exploration work carried out so far has estimated a total possible reserve of 5 million tons of sub-bituminous coal (DMG Précis, 2003).

OBJECTIVE AND METHODOLOGY

The objective of the present study was to carry out the geological mapping for coal occurrences within the Tansen Synclinorium that lies in parts of Palpa (western part) and Arghakhanchi (eastern part) districts. Geological mapping of about 150 km^2 was completed on 1:25,000 scales locating the investigated coal seams (Fig. 1). Trenching and pitting in the required sections were carried out to determine the thickness and extension of the seams. The representative coal samples were collected for quality assessment.

GEOLOGICAL SETTING

The study area lies broadly in the Lesser Himalaya, including also a small part of the Sub-Himalaya in the south (Table-1, Fig. 1). The Lesser Himalaya consists of the rocks of Kaligandaki Group and the Tansen Group separated by a distinct unconformity (Sakai 1983, 1984). The rocks in the area are folded to a syncline with a western fold closure, and the fold axis runs almost east-west direction along Neta – Tingire – Meldhap ridge. The rocks generally dip either toward north or south with dip amount varying from 17°-81°.

Kaligandaki Group

The Kerabari Formation and the upper parts of the Angha Khola Formation of Kaligandaki Group present in the study area are mapped.

Table-1: Litho-tectonic subdivisions of parts of the Palpa and Arghakhanchi Districts (after Sakai, 1984)

Tectonic unit	Group	Formation	Age	Thickness (m)
Sub-Himalaya	Siwalik	Middle Siwaliks	Middle Miocene-Pleistocene	500+
		Lower Siwaliks		500
		MBT		
Lesser Himalaya	Tansen	Dumri Formation	Oligocene – Early Miocene	1000
		Bhainskati Formation	Early – Late Eocene	250
		Amile Formation	Late Cretaceous – Paleocene	800
		Taltung Formation	Late Jurassic – Early Cretaceous	200
		Sisne Formation	Permian – Late Carboniferous	1000
		Unconformity/ fault		
	Kaligandaki	Kerabari Formation	Late Precambrian- Early Paleozoic	1200
		Angha Khola Formation		1300+

Angha Khola Formation

It is the oldest formation mapped within the study area. The formation is thrusted over the rocks of the Lower Siwaliks in the south, whereas it shares fault contacts with the Sisne and Kerabari Formations in the north. The formation consists of white to pink quartzite intercalated with light green shale, purple shale and black slate. Thin-bedded, laminated purple, light gray and gray limestone and thin-bedded, gray dolomite are also interbedded with the quartzite and the shale. The formation is discontinuous in the southern eastern part of the study area as the MBT has directly brought the younger Kerabari Formation over the Siwaliks.

Kerabari Formation

The formation rests over the Angha Khola Formation with a transitional boundary and consists of thin-bedded, laminated, light gray to gray dolomite as the principal lithology interbedded with subordinate amount of laminated to massive, light gray limestone. The proportion of the limestone is higher in the western part compared to the eastern part. The dolomite shows a poor development of stromatolite.

Tansen Group

All the five formations of the Tansen Group present within the study area are mapped.

Sisne Formation

It is the oldest formation of the Tansen Group and rests unconformably over the rocks of the Kerabari Formation in the south, whereas it has a fault contact with the Angha Khola Formation in the north. The formation consists mainly of diamictite, mudstone and claystone. The diamictite dominates the lower section of the formation, while the mudstone, claystone and slate constitute the upper section. The diamictite consists of clasts of sandstone, quartzite, granite and gneiss ranging in size from few mm up to 1.2 m in diameter in muddy and sandy matrix. At the base, proportion of clasts increases and the diamictites are found to look like conglomerate.

Taltung Formation

The formation has an unconformable boundary with the underlying Sisne Formation. The formation starts with the clast-supported conglomerate at the base. The conglomerate mainly consists of the clasts of quartzites, with occasional presence of agate. The lower part consists of the fining upward fluvial sequences starting with conglomerate to sandstone and finally ending with the mudstone while the upper part consists of an alternation of sandstone and mudstone.

Amile Formation

The formation also bears an unconformable contact with the underlying Taltung Formation. It consists of carbonaceous quartzite, carbonaceous slate, purple and pale green limestone in the lower part, and ferruginous quartzite, white quartzite and carbonaceous shale/slate in the upper part. The carbonaceous shale/slate and the white quartzite at many

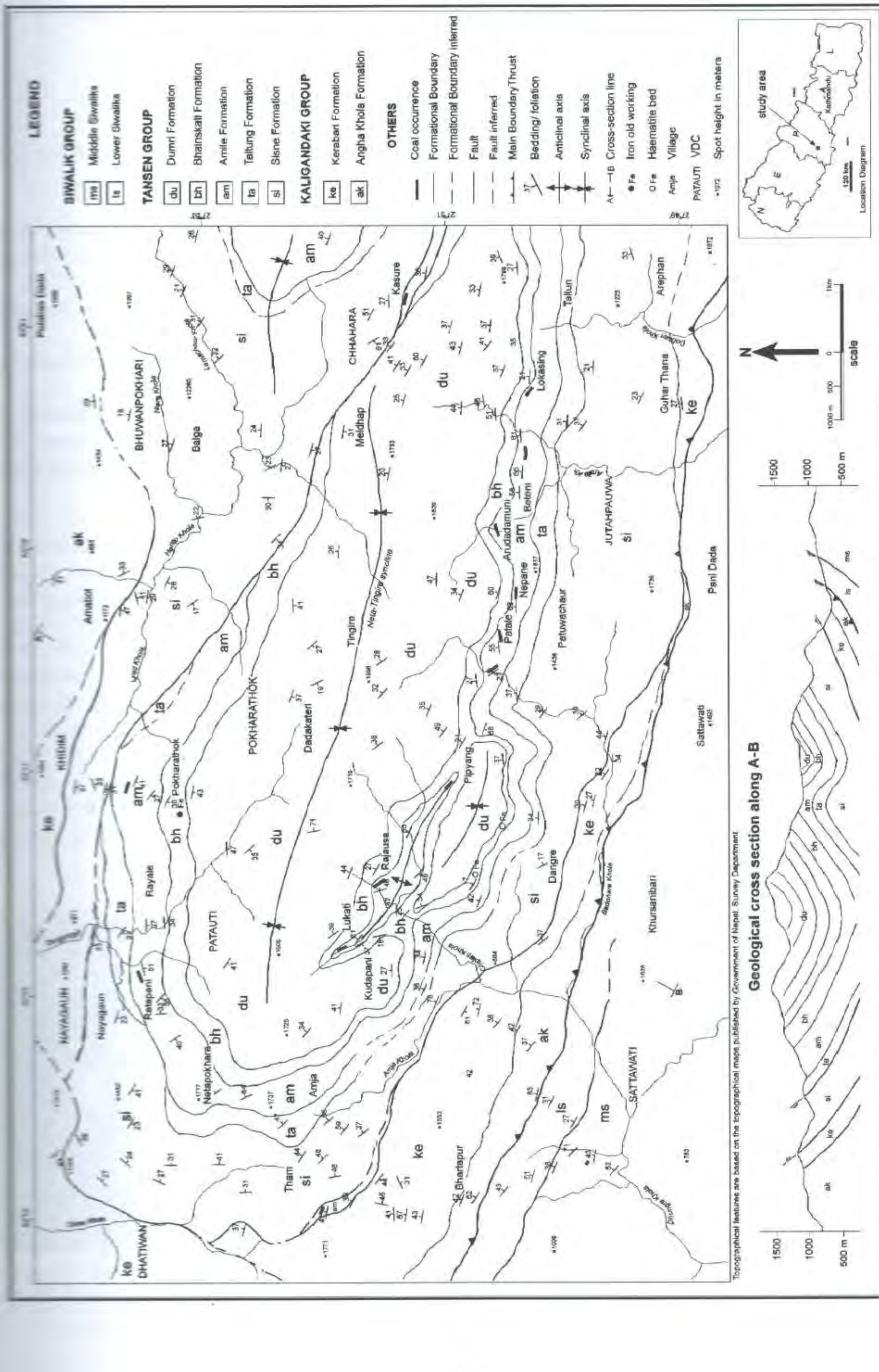

Fig. 1. Geological Map of Parts of Palpa and Arghakhanchi districts showing coal occurrences

places consist of coal seams. The formation also consists of conglomerates in the lower section. Some of these conglomerate beds consist of angular to sub-rounded fragments of different colored jasper (vermillion, light pink, bluish gray, flesh etc.) in clast.

Bhainskati Formation

The Amile Formation passes transitionally upward into the Bhainskati Formation. The formation consists mainly of gray shale/slate and carbonaceous shale in the lower part, and some green, reddish purple and black carbonaceous shale and oolitic hematite beds in the upper part. It is a fossiliferous horizon consisting of gastropods and *Nummulites.*

Dumri Formation

It is the youngest formation of the Tansen Group with an unconformable boundary with the Bhainskati Formation. It forms the core of the Neta-Tingire syncline.

The formation consists of the alternating fining upward fluvial sequences: starting with bluish and greenish gray sandstone and ending with either red purple or greenish shale, or both. The formation also consists of coalified wood fragments.

Siwalik Group

Lower Siwaliks

Lower Siwaliks, the oldest formation of the Siwalik Group, is mapped just south of the MBT and found to rest over the younger Middle Siwaliks due to a reverse fault. It consists of alternating beds of fine-grained, gray sandstone, siltstone and variegated mudstone representing the typical fluvial fining upward sequence. The proportion of the mudstone found to progressively decrease in the upper part of the formation.

Middle Siwaliks

The formation consists mainly of thick–bedded, pepper and salt sandstone and subordinate siltstone and mudstone..The upper part of the formation is intercalated with pebbly sandstone. The pebbly sandstone and the siltstone in the upper section are found to consist of scattered coal and coalified wood fragments.

COAL OCCURRENCES

The previous studies have stated four major types of coal occurrences in Nepal as:

1. Quaternary Lignite of the Kathmandu Valley,
2. Miocene to Pliocene Siwaliks Coal of the Sub-Himalaya,
3. Cretaceous to Paleocene Coal of the Lesser Himalaya, and
4. Gondwana Coals of the Lesser Himalaya.

Among them, the Cretaceous to Paleocene coal of the Lesser Himalaya have been seen to be economically important by the researches carried out to date.

The coal deposits of different thickness and extension were explored from fourteen locations in the present study area (Figs. 1, 2, 3 and 4; Table-2). The coal deposits are found mainly confined to the Amile Formation of the Tansen Group (equivalent Melpani Formation of the Surkhet Group; Kayastha, 1992), though scattered coal and coalified wood fragments (fossilized wood fragments) were also observed in the Middle Siwaliks. Twenty-eight samples were collected and proximate analysis has been carried out for the determination of Calorific values in the DMG laboratory.

Fig. 2. Coal seam exposed at Ratapani; the samples RAT CS-1, 2 and 3 were collected from this seam.

Table 2: Location of coal seams and proximate chemical analysis results of the collected coal samples

S. N.	Location	No. of coal seam	Seam dimension (m)		Sample	Chemical Analysis					Remarks
			Thickness	Length		Moisture[1]	Ash[1]	Volatile Matter[1]	Fixed Carbon[1]	CalorificValue[2]	
1	Ratapani	1	2	12+	RAT CS-1 RAT CS-2 RAT CS-3	3.39 1.6 1.44	17.64 84.65 85.88	13.19 9.91 9.95	65.78 3.84 2.73	7003.1 <524.25 <432.81	*Sub-bituminous* - -
2	Tham	1	0.3	3+	THA CS-1	9.16	58.23	23.12	9.49	3205.8	*Lignite*
3	Bhartapur	-	scattered		BHA CS-1 BHA CS-2	22.05 -	59.95 -	6.70 -	11.30 -	2905.3 -	*Lignite* -
4	Lukati	3	0.6 0.3 0.2	14+ 9+ 7+	LUK CS-1 LUK CS-2 LUK CS-3	1.73 1.49 2.72	13.72 85.30 79.45	11.63 9.47 10.58	72.92 3.74 7.25	7439.1 <505.55 975.38	*Sub-bituminous* - -
5	Rajausa	2	0.25 0.15	7+ 4+	RAJ CS-1 RAJ CS-2	3.60 0.58	53.20 86.15	20.96 10.45	22.25 2.82	4088.2 <450.69	*Lignite* -
6	Pipyang	1	0.32	3+	PIP CS-1	-	-	-	-	-	-
7	Pokharathok	1	0.15	2+	POK CS-1	-	-	-	-	-	-
8	Patle	1	0.2	27+	PAT CS-1	4.51	80.71	13.39	1.39	<395.17	-
9	Patle	2	0.25 0.2	7+	PAT (D) CS-1 PAT (D) CS-2	5.19 0.95	71.0 82.88	13.71 10.43	10.1 5.74	1390.31 689.71	- -
10	Nepane	1	0.15	5+	NEP CS-1	2.16	84.53	12.73	0.58	<314.89	*Lignite*
11	Arudadamuni	1	1.15	11+	ARU CS-1 ARU CS-2 ARU CS-3 ARU CS-4	0.27 0.8 0.66 10.96	82.80 79.76 84.87 48.94	9.47 9.6 8.35 10.06	7.46 9.84 6.12 30.04	1028.40 1363.68 844.00 3499.46	*Lignite* *Lignite* - -
12	Beteni	1	1.5	19+	BET CS-1 BET CS-2	5.79 5.84	46.17 44.20	17.58 17.13	30.46 32.83	4059.78 4319.41	- -
13	Lokasing	1	0.25	13+	LOK (1) CS-1 LOK (1) CS-2	1.29 1.27	81.96 81.88	9.31 9.6	7.44 7.25	1010.41 988.1	- -
14	Lokasing	1	1.25	11+	LOK (2) CS-1 LOK (2) CS-2	2.3 1.67	71.59 72.58	13.47 11.8	12.63 13.95	1709.16 1897.9	- -
15	Kasure	1	0.35	7+	KAS CS-1 KAS CS-2	3.49 0.78	82.14 74.41	12.98 9.53	1.39 15.28	<386.56 2063.01	- -

Note: *Units[1] weight percent;[2] Kcal/kg; the locations S.N. 1-7 are in Arghakhanchi district and the rest in Palpa district.*

Fig. 3. Coal seam exposed at Lukati; the samples LUK CS-1 and 2 were collected from this seam.

Fig. 4. Coalified wood fragments from the Middle Siwaliks in Bhartapur from where sample BHA CS-1 was collected.

The coal occurrences in the study area are found to be of different thickness ranging from thin layers to thin seams. It is found to vary from 0.15 to 2 m in general. The coal occurrences with considerable thickness are found to have considerable lateral extensions also. Some thick seams are exposed to lateral extension for more than 15m by escarping at several places during the field work. The lateral extension of such seams could be expected to be much higher than the presently exposed extensions. The coal so found is generally gray to dark gray in color, friable and soft in nature, and dull to bright in luster.

The explored seams are within the altitude of 1000 to 1700 m (except that of Siwaliks ~ 550 m). The country rocks hosting the coal seams dip either towards north or south (due to the syncline) with dip amount ranging from 21° to 66°. The seams are stratified and mostly found associated with the slate or carbonaceous quartzite.

On the basis of proximate chemical analysis, calorific value of the coals from Ratapani and Lukati are under Sub-bituminous grade with calorific value ranging from 7003 to 7439 Kcal/kg. Similarly, the coals of Beteni, Arudadamuni and Rajausa are under Lignite grade with calorific value ranging from 3205 to 4319 Kcal/kg. The rest of the samples show low to very low calorific values.

CONCLUSION

- The coal seams of Lukati, Ratapani, Rajausa, Beteni and Arudadamuni, which are under lignite or sub-bituminous categories, are seen to be of economic importance.
- The Cretaceous-Paleocene coal of the Amile Formation of the Tansen Group (equivalent Melpani Formation of the Surkhet Group) is an important geological formation for coal exploration as all the discovered seams are from the same formation.
- The study also shows that Siwaliks is not important from coal exploration point of view.

RECOMMENDATION

Since the Amile Formation of the Tansen Group and its equivalent exist also in other parts of west Nepal, they should be investigated for coal occurrences.

ACKNOWLEDGEMENT

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Preliminary Exploration of Limestone and Dolomite Around Shikharpur and Patana Bhanjyang Area of Udayapur District, Eastern Nepal

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INTRODUCTION

The growing demand of cement in the country is continuously ever increasing. The Department of Mines and Geology has been actively engaged in cement grade limestone and dolomite exploration in different parts of the country. The preliminary exploration for the cement grade limestone and dolomite around Shikharpur and Patana Bhanjyang, Udayapur District, Eastern Nepal was carried out as per the departmental programme of the fiscal year B.S. 2063-064. The field work was conducted for a duration of six weeks. Lab assistant Mr. Dil B. Khadka was involved during the field work.

The area of investigation lies in Government of Nepal, Survey Department's Toposheet Nos. 2686 02B, 2686 03A, 2786 13C and 2786 14D includes parts of Udayapur District. The area is accessible by Mirchaiya- Katari Road up to Katari Bazar and then 15 km seasonal road along the Tawa Khola up to Bahunitar.

During the field exploration work, geological mapping of limestone occurrences and systematic chip sampling and grab sampling has been done. As a result, geological map of 100 sq. km. area in 1:25,000 scale has been prepared. 37 continuous chip samples from different limestone and dolomite horizons had been collected.

OBJECTIVE

The main objective of the exploration work was to identify and explore the cement grade limestone and dolomite deposit around Shikharpur and Patana Bhanjyang area of the Udayapur District.

METHODOLOGY

The preliminary exploration work consists of geological mapping of the area, chip sampling and grab sampling of the limestone and dolomite.

The investigation work was carried out with the help of Brunton Compass, geological hammer, measuring tape, 1:25,000 scale topo base map and 10% dilute Hydrochloric Acid. Extensive geological traverses along streams, foot trail, road and ridges had been carried out.

Collected chip samples of the limestone and dolomite were chemically analyzed in the Chemical Laboratory of the Department for the identification of the grade.

REGIONAL GEOLOGY

Geologically, present area falls within the Lesser Himalaya of Eastern Nepal. It comprises of low grade metasedimentary rocks of Nawakot Complex and crystalline rocks of Bhimphedi Group of Kathmandu Complex (ESCAP/UNDP, 1993).

The Main Boundary Thrust (MBT) tectonically separates the Siwaliks and the Upper Nawakot Group of rocks. The Upper Nawakot Group here is represented by Benighat Slates. Benighat Slates consisted of phyllites interbedded with quartzites at the lower part and limestone and dolomites at the upper part. The Mahabharat Thrust (MT) tectonically separates low grade Benighat Slates with overthrusted crystalline Raduwa Formation. Raduwa Formation consisted of coarse garnet biotite schist with interbeds of quartzites. The general trend of the rock units is NW - SE and dipping towards N. It is a southern flank of the Mahabharat synclinorium.

The area is dominated with limestone, dolomite, phyllites, quartzites and schists (Karmacharya, 1999, 2000). The limestone bands rest over the phyllites of Benighat Slates lying at immediate north of Main Boundary Thrust (MBT). The upper sequence of limestone is truncated by Mahabharat Thrust (MT) separating the garnet biotite schists of Raduwa Formation. Thus it represents a marker horizon delineating phyllites and quartzite of Benighat Slates at the south and coarse textured garnet biotite schist of Raduwa Formation at the north. The lower contact of limestone is normal where as the upper contact is thrusted (Fig.1).

Benighat Slates

This rock unit comprises of phyllites with intermittent quartzite bands at the lower part and limestones and dolomites at the upper part. Phyllites are mostly gray to dark gray having carbonaceous partings. Towards the upper part, it becomes more sericitic and chloritic and shows white greenish gray to silvery gray color. The sericite and chlorite impart gray to silvery gray and greenish gray color to the phyllite. Quartzites are gray, whitish gray, greenish gray and ferruginous at places.

The uppermost part of the area is represented with limestone and dolomite. Limestone bands are found in Chuladhunga, Kholme and Chhaude Khola areas. They have been sampled and analysed for the confirmation of grading. Likewise, dolomite bands of Lakure area are also investigated.

Raduwa Formation

Garnet Biotite Schist is tectonically thrusted over the limestone beds of the Benighat Slates and hence serves as the overburden. The main rock type is mica schist of coarse crystalline aspect. The schists often contain lenses and nodules of quartz which imparts a gneissic aspect to the rock. Generally, it is found deeply weathered to few meters (2 -3 meters) in the hilltops and hill slopes.

The limestone band is situated in the north of Main Boundary Thrust (MBT) and south of Mahabharat Thrust (MT). Lower contact of the limestone band is normal with the lower phyllite unit where as the upper contact is a thrusted contact. The attitude of the rock is NW-SE with dip amount 50°-60° towards N.

FINDINGS

Occurrences of limestone existed at Chuladhunga, Ghyampethumka, Kholme, Shikarpur area, Galtar area, Patana Bhanjyang and Ahalepakha area. The band in the area is reported to be of swelling and pinching nature. The strike extension of the carbonate band from Baruwa Khola in the east to Tawa Khola in the west is reported to be continuous (25 km). From Tawa Khola towards northwest to Banchare, the limestone bands are reported to be pinched out. From Banchare to Mate Khola (10 km.) it again reappears. Thus the total strike extension of limestone in the region is considered to be of 35 km. Due to its swelling and pinching nature, its thickness is also reported to vary from 15 to 55 m. (Karmacharya, 1999).

The present study area covers the limestone bands around Tawa Khola, Shikarpur and Patana Bhanjyang areas.

At stated above, limestone beds are lying over phyllites of Benighat Slate in the south and are overlain by coarse textured garnet biotite schist of Raduwa Formation in the north. The dolomites occur at the lower contact of limestone. There are also some intermittent dolomite bands within limestone at places. Limestone is generally dark gray in colour. The attitude is NW-SE with dip amount up to 65° towards NE. The limestone bands are found to vary in thickness from 15 to 55 m. within the study area (Fig.1).

There is a limestone band of 15 to 55m. thickness and of about 8 km. strike extensions from Haretar (Tawa Khola) in the northwest to Kholme village in the southeast. In general, limestone is dark gray and dark bluish gray in colour, medium grained and homogeneous with a little or without phyllitic intercalation. It is of good grade throughout its strike length and along its thickness too. It is exposed at the top of the hills having only occasional thin cover of overburden, which makes the quarrying easy. At places, dense bushes, cultivated land, and houses are present within the limestone occurring area. In such cases, the actual limestone and overburden ratio can be calculated only after detail exploration work.

At Chuladhunga area, outcrops of highgrade limestone are present for about 600m strike length. At Ghympathumka, maximum thickness is about 40m and minimum thickness is about 15m Limestone is dark gray and dark bluish gray, medium grained and homogeneous with a little or without phyllitic intercalation. There is a considerable thickness of overburden from Chuladhunga to Ghyampathumka.

At Chhaude Khola, dark gray carbonaceous film or coatings are present within the joint planes or surfaces of highly fractured limestone.

Dolomite of 170m long and 72m thick is exposed at the hilltop of Lakure village as a lenticular body.

a. Limestone around Bakuwa Khola

This limestone is exposed at Bakuwa Khola, Thakle, north of Aptar village and south of Shikharpur village. Thickness of this limestone band is 10 - 20 meters. The limestone is dark gray colored, fine grained and medium bedded. The limestone band is in swelling and pinching form. In most of the places, the limestone is dolomitic in nature. Overburden is present in most of the areas. At Bakuwa Khola section, thickness of the limestone is 20 meters and overburden is also less. Strike extension in this section is 200 meters. Results of chemical analysis of chip samples of limestone collected at Bakuwa Khola and around Shikarpur Area is presented in Table-1.

Table-1: Chemical Analysis of Chip Samples of Limestone from Shikarpur Area

Chip Samples of Limestone, Bakuwa Khola							
Sample No.	LOI%	Insoluble%	R_2O_3%	Fe_2O_3%	Al_2O_3%	CaO%	MgO%
TR/UD/CP-1	41.930	1.880	2.825	0.164	2.661	30.844	19.404
TR/UD/CP-2	41.500	3.340	1.900	0.207	1.693	50.472	3.276
TR/UD/CP-3	42.790	2.180	2.200	0.207	1.993	33.648	19.404
TR/UD/CP-4	41.080	4.780	2.100	0.343	1.757	41.710	9.576
TR/UD/CP-5	40.250	5.320	3.675	0.422	3.253	32.246	17.388
TR/UD/CP-6	42.740	2.140	1.950	0.193	1.757	29.092	22.176
TR/UD/CP-7	41.900	3.820	1.900	0.157	1.743	49.421	4.538
Chip Samples, south of Shikharpur							
TR/UD/CP-8	42.740	2.060	3.650	0.307	3.343	27.690	22.176
TR/UD/CP-9	41.380	2.920	1.900	0.215	1.686	40.308	11.844
Chip Samples, southwest of Shikharpur							
TR/UD/CP-16	40.540	2.500	0.725	0.164	0.561	49.771	5.040
TR/UD/CP-17	40.580	3.280	0.750	0.150	0.600	49.421	5.292
TR/UD/CP-18	39.990	2.780	0.875	0.114	0.561	31.195	19.656
Chip Samples, north of Jyamire							
TR/UD/CP-10	38.560	2.240	1.775	0.129	1.646	54.328	1.008
TR/UD/CP-11	37.920	2.900	0.550	0.093	0.457	52.225	2.772
TR/UD/CP-12	41.240	4.080	0.550	0.207	0.343	51.173	4.788
TR/UD/CP-13	41.080	2.680	0.550	0.072	0.478	49.421	2.520
TR/UD/CP-14	40.650	3.580	0.550	0.164	0.336	52.225	4.284
TR/UD/CP-15	40.620	2.460	0.675	0.072	0.604	50.823	5.040

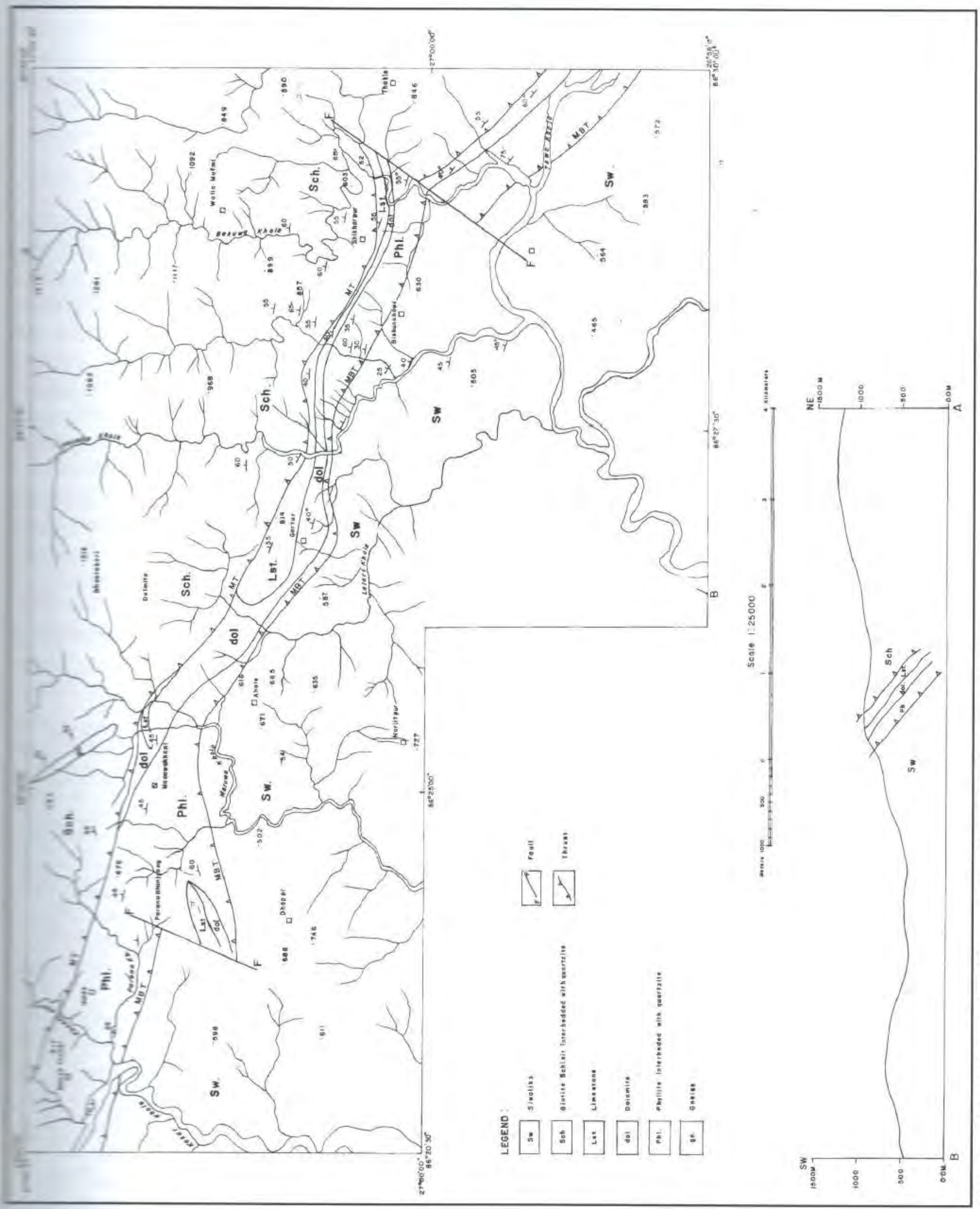

Fig. 1. Geological Map of Shikharpur - Patana Bhanjyang Area

b. Maruwakhanigaon Limesone

The limestone band is exposed at the eastern slope of the Khanigaon village. The limestone is dark grey colored, fine grained and medium bedded. Thickness of this limestone band is 25 - 30 meters with strike extension of 200 meters. Occasional dolomite bands are also present. There is no overburden on this limestone band. Results of chemical analysis of chip samples of limestone from Maruwakhanigaon is presented in Table-2.

c. Patana Bhanjyang Limestone

The limestone is exposed at Patana Bhanjyang 13 km. from Katari along Katari - Okhaldhunga Road. The Shikharpur Limestone band and Maruwakhanigaon Limestone band overlie the black carbonaceous shale whereas the Patana Bhanjyang Limestone band is underlain by the black carbonaceous shale. Patana Bhanjyang Limestone band is exposed immediately north of the MBT.

Thickness of this limestone band is 40 - 50 m and strike extension is 200 m. This limestone is purple colored limestone. It is present within the purple shale sequence. The limestone is fine grained, purple colored and thin to medium bedded. Chip samples of this limestone band has been collected from one section. There is no overburden on this limestone. Table-3 shows results of chemical analysis of chip samples collected from Patana Bhanjyang area.

d. Dolomite Occurrences

The objective of the field work was to identify and explore the cement grade limestone and also dolomite deposit around Shikharpur as well as Patana Bhanjyang area of Udayapur District. There is a high demand of cement grade limestone and dolomite around this area by the private entrepreneurs for industry development. During the field work, dolomite samples from 7 localities were collected. Dolomites from the Maruwakhani village, Bakuwa Khola, south and southwest of Shikharpur village are found to be of industrial grade. Dolomite near the Maruwakhani village is grayish white colored, fine grained and medium bedded. Thickness of this dolomite band is 40 meters and is homogeneous across the whole thickness. Dolomite at the Bakuwa Khola is light grey to

Table-2: Chemical Analysis of Chip Samples of Limestone from Maruwakhanigaon

Sample No.	LOI%	Insoluble%	R_2O_3%	Fe_2O_3%	Al_2O_3%	CaO%	MgO%
TR/UD/CP-19	39.670	2.900	0.550	0.093	0.343	31.545	20.664
TR/UD/CP-20	39.460	4.380	0.750	0.129	0.621	31.898	19.656
TR/UD/CP-21	44.200	3.360	0.875	0.114	0.761	30.494	20.160
TR/UD/CP-22	44.700	1.440	0.950	0.107	0.843	31.545	20.916
TR/UD/CP-23	42.380	4.420	1.350	0.307	1.043	30.844	19.908
TR/UD/CP-24	40.870	5.420	1.125	0.229	0.896	49.421	3.024
TR/UD/CP-25	41.060	4.880	1.550	0.207	1.343	48.369	3.276

Table-3: Chemical Analysis of Chip Samples of Limestone from Patana Bhanjayang

Sample No.	LOI%	Insoluble%	R_2O_3%	Fe_2O_3%	Al_2O_3%	CaO%	MgO%
TR/UD/CP-29	38.340	11.440	1.200	0.415	0.785	47.318	1.512
TR/UD/CP-30	38.100	11.040	1.375	0.365	1.010	46.967	2.016
TR/UD/CP-31	34.480	13.280	1.140	0.560	0.890	49.040	0.740
TR/UD/CP-32	35.970	11.720	1.070	0.290	0.780	47.260	2.730
TR/UD/CP-34	36.820	11.030	1.000	0.430	0.570	47.970	2.480
TR/UD/CP-35	35.010	13.510	1.150	0.570	0.580	46.560	3.720
TR/UD/CP-36	37.890	11.850	1.030	0.610	0.420	42.290	6.700
TR/UD/CP-37	35.670	13.910	1.100	0.330	0.770	34.460	12.910
TR/UD/CP-38	35.600	13.630	1.08	0.610	0.470	46.65	1.010

Table- 4: Chemical Analysis of Chip Samples of Dolomite

Sample No.	Location	LOI%	Insoluble%	R_2O_3%	Fe_2O_3%	Al_2O_3%	CaO%	MgO%
TR/UD/CP-19	Maruwakhani	39.670	2.900	0.550	0.093	0.343	31.545	20.664
TR/UD/CP-20	"	39.460	4.380	0.750	0.129	0.621	31.898	19.656
TR/UD/CP-21	"	44.200	3.360	0.875	0.114	0.761	30.494	20.160
TR/UD/CP-22	"	44.700	1.440	0.950	0.107	0.843	31.545	20.916
TR/UD/CP-23	"	42.380	4.420	1.350	0.307	1.043	30.844	19.908
TR/UD/CP-18	South west of Sikharpur	39.990	2.780	0.875	0.114	0.561	31.195	19.656
TR/UD/CP-8	South of Sikharpur	42.740	2.060	3.650	0.307	3.343	27.690	22.176
TR/UD/CP-1	Bakuwa Khola	41.930	1.880	2.825	0.164	2.661	30.844	19.404
TR/UD/CP-3	"	42.790	2.180	2.200	0.207	1.993	33.648	19.404
TR/UD/CP-5	"	40.250	5.320	3.675	0.422	3.253	32.246	17.388
TR/UD/CP-6	"	42.740	2.140	1.950	0.193	1.757	29.092	22.176

grayish white, fine grained, medium bedded and fractured. Thickness of the dolomite band is 35 meters. It is monotonous across the whole thickness.

Dolomite at the south of Sikharpur village is grayish white, fine grained, and fractured. Thickness of the dolomite band is 35 meters, is monotonous across the whole thickness.

Dolomite at the southwest of Shikaharpur village is light grey to grayish white, fine grained, medium bedded and fractured. Thickness of the dolomite band is 30 meters and it looks monotonous across the whole thickness. Chemical Analysis result of Dolomite is presented in Table-4.

CONCLUSION AND RECOMMENDATION

All the identified limestone occurrences are of small sizes although some of them are of high grade and can be mixed with low grade limestone for cement production. They do not have sufficient tonnage. Occasional bands are of chemical grade.

Dolomite from Maruwakhani village, Bakuwa Khola, South of Shikharpur and southwest of Shikharpur villages are of industrial grade.

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Preliminary Exploration of Polished and Dimension Stone in some Parts of Kavrepalanchoke District, Central Nepal

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INTRODUCTION

Preliminary exploration of Polished and Dimension stone in some parts of Kavrepalanchoke district is carried out as a part of annual mineral exploration program of the Depatment of Mines and Geology (DMG) of the fiscal year 2063/64. The exploration target covers an area of 125 sq. km. within the potential area as shown by geological map in the regional scale (UNDP, 1981). Granite, gneiss, marble and quartzite occurring within the study area are being considered as polished and dimension stone for preliminary exploration purpose.

The study area lies in the part of Government of Nepal, Survey Department's Toposheet Nos. 2785 07 A, 2785 07 D and 2785 11 A (scale 1:25,000) of Kavrepalanchoke district and is within latitudes 27° 27' 10" - 27° 32' 30"N and longitudes 85° 30' 00" - 85° 41' 14"E. It lies in the central and western part of the district and covers parts of Dhunkharka, Bhugdeumahankal, Khaharepagu, Shikhar Ambote, Chyasinkharka, Ganeshthan Chalal, Khanalthoke and Daraune Pokhari VDCs. Roshi Khola is the major stream passing through the area. Mahabharat Lekh passes along east-west in the southern part of the study area and has elevation higher than 2700 m. The northern parts of the study area including Kamidada, Bhugdeu, Ganeshchalal, Pipaltar, Katungebesi are accessible by motorable road from Dapacha, Panauti and Dhulikhel, where as the southern parts are not connected by motorable road.

OBJECTIVE

The objectives of the present study are:

- to find out the potential prospect areas suitable for polished and dimension stones,
- to delineate the deposit by examining its durability and suitability to assess the quality,
- to give an appropriate recommendation for the next phase of exploration, and
- to identify the areas for the construction stone

METHODOLOGY

During the field investigation geological traverses were taken along the road, foot tracks, rivers and ridges. Topography of the area from the mining point of view, physical properties of rocks e.g. appearance, color, texture, luster etc. were also studied. Different rock units as well as rock types were identified. The attitudes of beddings, joints, weathering nature, rock strength, roughness, block size etc were measured. About 105 m^3 of trenching / pitting works were carried out to expose the fresh rock and collect the samples. Granite, gneiss, marble and quartzite were considered for polished and dimension stone where as limestone and quartzite were considered for construction stone. Block, grab and chip samples from different rock units were collected to represent the rock unit and are located in the geological map. Geological map in the scale of 1:25,000 was prepared covering an area of 125 sq. km. Detail columnar section of granite zone in Khasre Danda area was measured over 500 m length in the scale of 1:1000.

Field investigation was supplemented by laboratory study of the rock samples to investigate the physical and chemical properties. The laboratory study included chemical analysis, cutting and polishing of the rocks to check for appearance and suitability. Similarly, petrographic study, ASTM specified physico-mechanical tests like compressive strength, modulus of rupture, absorption coefficient, bulk density for durability were also conducted. These results were compared with the ASTM Standards (ASTM, 1996).

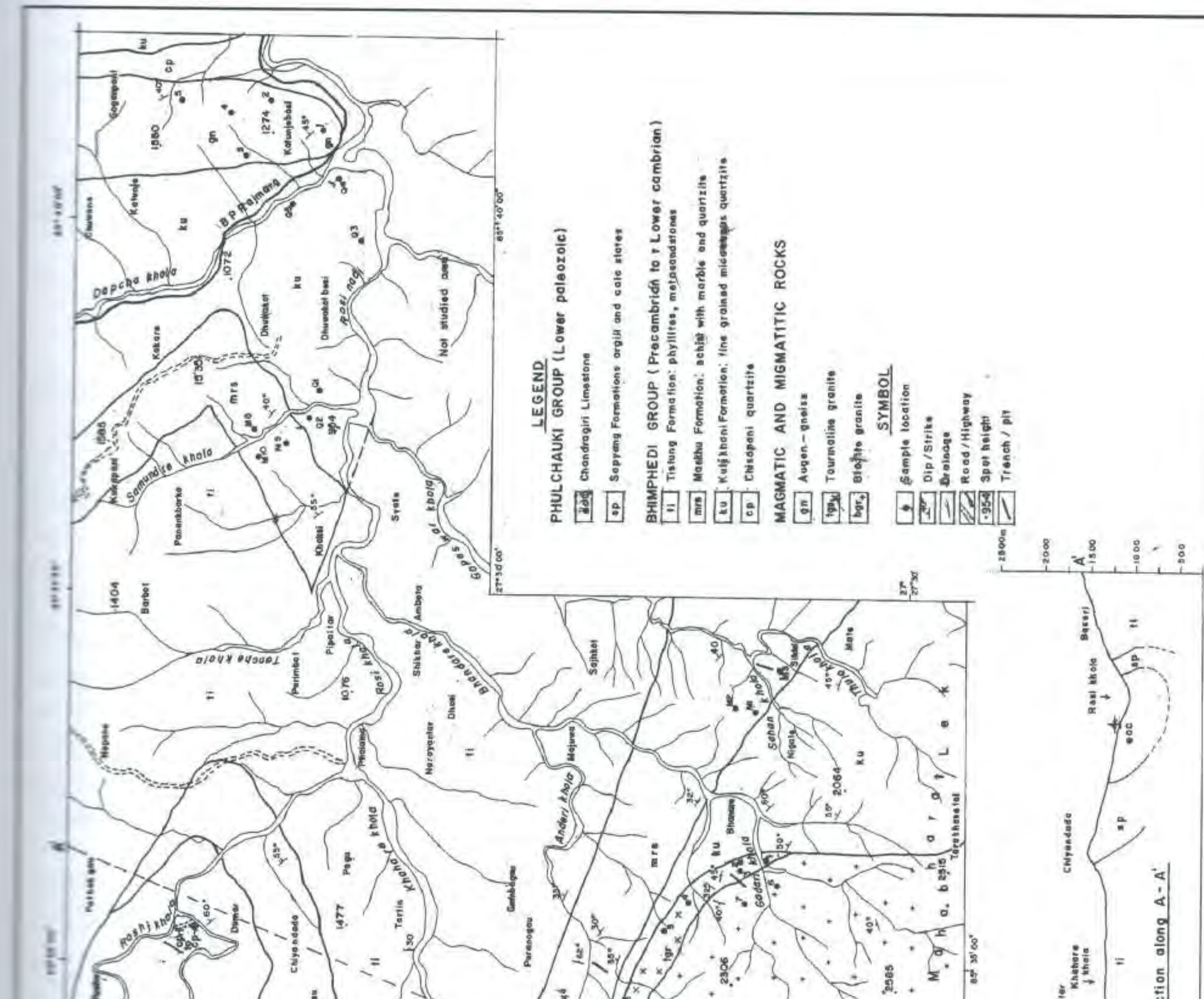

Fig. 1. Geological Map of Polished and Dimension Stone Exploration in some parts of Kavrepalanchoke district

GEOLOGY

Geologically the study area lies in the Lesser Himalayan Zone in Central Nepal. Mineral Exploration Map of Central Nepal and Photo Geological Map of 72 E/10, E/11 and E/14 (UNDP, 1981) have been used as base map of the study area. Rock types encountered in the study area belong to metamorphic rocks of Bhimphedi Group and metasedimentary rocks of Phulchauki Group of Kathmandu Complex along with Narayanthan Granite and Katungebesi Gneiss as intrusive bodies.

Geological map of the area of investigation is shown in Fig. 1. Narayanthan Granite is present along the Mahabharat Lekh in the southern part of the study area. It covers an east – west extension of 10 km from Wadane Bhanjyang in the west to Tarakhaseko Tal in the east. Narayanthan Granite has intruded into Kulikhani Quartzite and Markhu Marble. Two types of granite namely coarse grained biotite granite and fine to medium grained tourmaline granite are present. Granite is dominant in the Mahabharat Lekh and in the core areas. Tourmaline granite is present in the northern periphery in contact with the Kulikhani Formation.

The eastern part of the study area east of Dapcha Khola around Katungebesi has gneiss intrusion within Kulikhani Quartzite and is called Katungebesi Gneiss. The gneiss consists of augens of feldspars with quartz and biotite.

Marble bands belonging to Markhu Formation are present around the central part and also in the northern part of the study area. The central part of Markhu Formation runs in between Bhugdeu Khola to Sahan Khola and lies in contact with granite and Kulikhani Quartzite along the northern slope of Mahabharat Lekh. The northern part lies around Khaksi, Samundre Khola and Dhuwakot. These marble bands are underlained by Tistung Formation. Markhu Formation shows mixed lithology having schist-quartzite-marble-dolomite a typical characteristic of Markhu Marble Schist. The band of marble itself is not more than 5 m having alternating bands of marble schists that has more than 20 m thickness.

Northern part of the study area shows Chandragiri Limestone running from Ladku Khola to Roshi Khola in the east for a strike extension of about 8 km. The Chandragiri Limestone is overlain by Sopyang Formation consisting of argillaceous and calcareous slates. Rest of the study area is covered by Tistung Formation containing phyllite, and metasandstones.

FIELD INVESTIGATION

In the investigated area, tourmaline granite (aplitic), belonging to Narayanthan Granite is the main resource for polished and dimension stones. This granite extends from Newar Khola in the west to Gadare Khola in the east over a length of 5 km in contact with Kulikhani Formation in the north. Based on the nature, joints, weathering profile and mineability, the prominent potential site for further investigation is at Khasre Danda area. Khasre Danda is located in between Khahare Khola and Bhandare Khola extending over a length of about 2 km. Tourmaline granite with maximum thickness of about 500 m as measured along Khasredanda is presented in the columnar section (Fig. 2a and 2b). Granite is fine to medium grained and has mineral constituents of quartz, orthoclase, plagioclase with minor amount of tourmaline, muscovite and opaque minerals. Granite is fresh to weakly weathered on the surface. The joint pattern shows three major joint sets with joint spacing of about 30 cm to 200 cm. The block size available is fairly good having 1 m size.

The Katungebesi Gneiss present in the eastern part of the study area is highly weathered. The prospect cannot be used for the desired purpose. Due to its flaky nature, it is unsuitable to be used as stone aggregates either.

The field observation shows that marble band belonging to Markhu Formation may not be commercially viable due to poor mineability and the small thickness.

The Chandragiri Limestone is crystalline, siliceous and also dolomitic. The thin discontinuous and wavy nature of limestone bands has intercalation with thick argillaceous beds and cannot be used as cement grade limestone. Limestone and

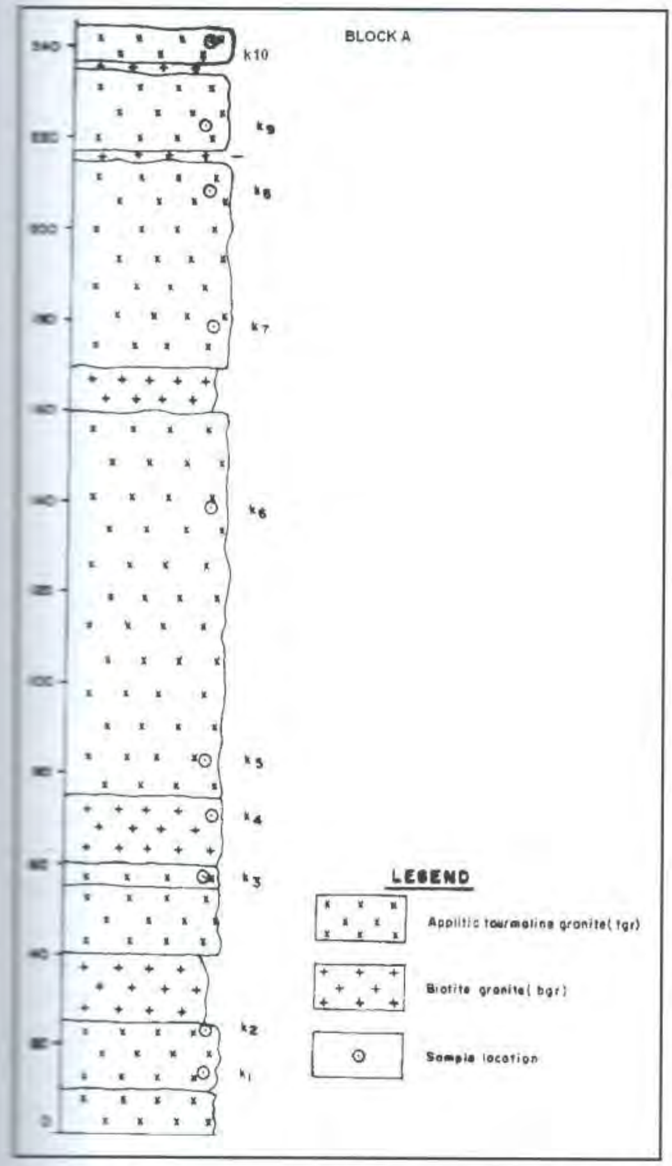

Fig. 2a. Columnar section of granite zonation at Khasre Danda area, Kavre

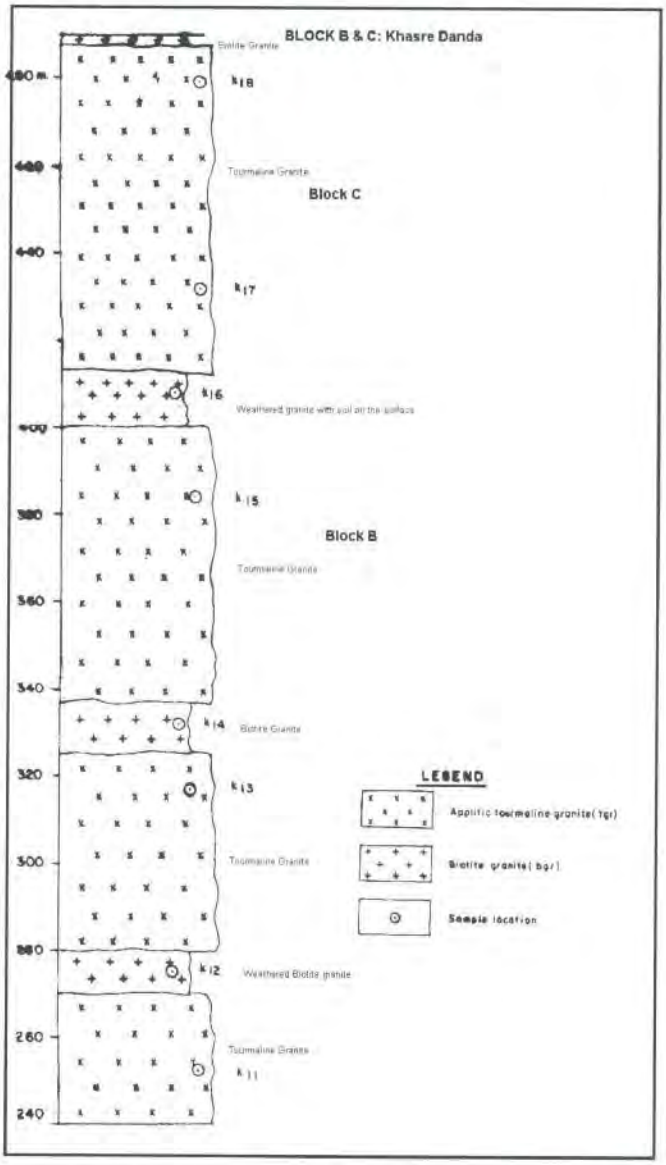

Fig. 2b. Columnar section of granite zonation at Khasre Danda area, Kavre

quartzite present within Chandragiri Limestone and Kulikhani Formation can be considered as the potential quarry sites for the stone aggregates. The potential sites are in the Ladku Khola to Roshi Khola in the west and around Samundre Khola in the east. Field investigation of the Tistung Formation shows economic importance neither for dimension stone nor for construction stone.

RESULTS OF LABORATORY TESTS

The samples collected during the field investigation were performed the laboratory tests in the DMG laboratory to supplement the field study data in order to delineate the possible prospect areas based on the suitability and durability tests.

(a) Suitability Tests

Cutting and Polishing

The polished surface of aplitic granite show good shining luster and attractive appearances. Fig. 3 shows the irregular crystal grains with abundance of feldspar and very little mica.

b) Durability Tests

Petrographic Study

The petrographic study is based on 10 thin sections of aplitic and biotitic granite. The summary of the results of petrographical study is presented in Table-1. The test results are generalized based on the limited thin sections study.

Chemical Analysis

Chemical analysis is based on the ten grab samples of granite of Tourmaline granite, seven grab samples of marble of Markhu Marble and 3 chip samples of limestone of Chandragiri Limestone. Average of chemical analysis of granite, marble and limestone are presented in Table-2. These results show that marble has more insoluble content and limestone has low calcareous content.

Physico-mechanical Study

ASTM specified physico-mechanical tests of 11 granite samples were conducted. Bulk Specific Density (D), Absorption Coefficient (Abs) @ 24 hours soaking with water, Compressive Strength (Cu) of cubical rock specimen of average surface area of 62 mm x 59 mm with average height of 67 mm was calculated. The Modulus of Rupture (E) was calculated from the breaking load applied. The test results are compared with the ASTM Standards. The results of physico-mechanical tests obtained from laboratory study on granite specimens are presented in Table-3.

Fig. 3. Polished surface of Tourmaline (aplitic) granite.

CONCLUSION

Huge quantity of granite and quartzite are available in the study area. Aplitic granite available at Khasredanda is less weathered and is mineable. Blocks of 1 m^3 can be obtained. This aplitic granite somehow meets the specifications required by ASTM Standards and is suitable for polished and dimension stone. On the other hand, biotite granite

Table-1: Results of Petrographic Study

Rock Type	Color Rock	Texture		Mineral Constituents (%)						
				qz	or	pg	tr	ms	bt	op
Granite (Aplitic)	white with black spot	Very fine to fine grained, anhedral to subhedral interlocked crystal	Average Max Min	50 68 42	39 52 20	6 30 < 1	3 6 < 2	1 1 1	0 0 0	1 1 1
Granite (Biotitic)	white with black spot	fine to medium grained, anhedral to subhedral interlocked crystal	Average Max Min	55 56 54	40 40 39	2 3 < 1	2 3 < 1	1 1 1	2 3 1	< 1 1 < 1

qz: quartz, or: orthoclase, pg: plagioclase, tr: tourmaline: ms: muscovite, bt: biotite, op: opaque minerals

Table-2: Results of Chemical Analysis

Rock Type	LOI%	SiO_2 %	CaO%	MgO%	R_2O_3 %	Fe_2O_3 %	Al_2O_3 %
Granite	0.65	76.54	4.34	2.61	15.20	0.57	14.63
Marble	23.29	42.09	22.89	7.57	3.56	1.92	1.64
Limestone	9.85	65.61	16.47	3.86	3.90	1.92	1.83

Table-3: Results of Physico-mechanical Tests

Rock Type	Bulk DensityD (Kg/m³)		Absorption by weight Abs. (%)		Compressive StrengthCu (Mpa)		Modulus of Rupture E (Mpa)	
	Required byASTM	Value Obtained	Required by ASTM	Value Obtained	Required byASTM	Value Obtained	Required by ASTM	Value Obtained
Granite (Aplitic)	2560 min.	2770 max.	0.40 max.	0.87 max.	131 min.	127 max.	10.3 min.	224 max.
		2470 min.		0.49 min.		96 min.		147 min.
		2620 av.		0.67 av.		115 av.		196 av.

available along the Mahabharat Lekh is weathered and is not suitable for the polished and dimension stone.

The marble band of Markhu Formation has thickness of about 5 m with frequent interbeddings of the quartzite schist. They are not mineable.

The Limestone available along the Roshi Khola are highly interbedded with the siliceous rocks and highly fractured. They are not suitable for the dimension stone, neither can be used as cement grade limestone. However, they can be used as stone aggregates for construction purposes. Similarly, quartzite of Kulikhani Formation shows economic importance only for the purpose of construction stone and stone aggregates.

The gneiss available in the eastern part of the study area around Katungebesi has been deeply weathered and contains abundant mica and thus is not suitable for polished and dimension stone.

RECOMMENDATION

Aplitic granite available between Khahare Khola and Gadare Khola needs further exploration for polished and dimension stone within an area of 8 sq. km.

Limestone and quartzite available around Ladku Khola and Roshi Khola for an area of 12 sq. km and around Samundrea Khola and Dhuwakotbesi for an area of 4 sq. km are recommended as good sites for construction stone.

ACKNOWLEDGEMENT

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Engineering and Environmental Geological Mapping of Biratnagar Sub-metropolitan City and the Surrounding Areas, Eastern Nepal

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INTRODUCTION

Duhabi village is nearly 535 Km and the Tankisinuwari of Biratnagar, Eastern Nepal is at about 542 Km far from Kathmandu. The study area is situated in the Terai plain and lies in the eastern development region of Nepal. It is one of the fast growing and developing urban area and is situated along a corridor of major industrial zones of Nepal. Most important manufacturing industries of the country are located in this region.

Geologically, the study area belongs to the southernmost tectonic division of Nepal known as Indogangetic Plain. The altitude of the study area varies from 70m up to 94m from msl. The temperature of the study area varies from 42°C (max.) in summer and 0°C (min.) in winter. It has humid type of climate. Singhiya Khola flowing in the east and Budhi Khola in the west are two main rivers draining the study area. In total present study area encompasses 19 VDCs.

It was carried out with an objective to prepare a comprehensive 'Engineering and Environmental Geological Map' of the area at 1: 25, 000 scale with a view to provide basic information on engineering geology, urban and environmental geology and geohazards.The Department of Mines and Geology (DMG) initiated such type of program of preparation of an Engineering and Environmental Geological Map of fast growing urban areas since 1998.

This map is intended to help the urban planners, engineers and decision makers in landuse, infrastructure development planning, hazard mitigation, sustainable development of natural resources and environmental management. The map includes the information on lithology, engineering properties of soil types and Geohazards (natural and manmade) in the area, mineral resources, features of environmental significance, riverbed mining sites, sanitary landfill site, landuse and urban geology etc. It is anticipated that the engineering and environmental geological map prepared by the study team of DMG will be highly useful for planning future development activities in the respective area.

The study was carried out in Duhabi VDC and its adjacent areas located between the coordinates latitude: 26° 30' 01" to 26° 35' 33.25"N and longitude 87° 13' 50.79" to 87° 19' 52.93"E covering an area of 100 Sq. Km (Fig. 1). Dharan Road connects the study area with East-West Highway in the north at Itahari and with the rest of the country.

PREVIOUS WORKS

Geological works have been carried out in this area by the Petroleum Exploration Pomotion Project (PEPP) of the Department of Mines and Geology (DMG) for the petroleum exploration in this area. The Shell and Triton Company drilled 3520m deep borehole in the course of petroleum exploration in a place called Radhanagar east of Biratnagar in 1989. Besides, this Ground Water Resources Development Board (GWRDB) also has carried out hydrogeological studies in the areas for drilling of deep and shallow tube wells.

Geological Map of Eastern Nepal (1984) at 1:250,000 scale published by DMG shows that this area is represented by Recent alluvial sediments consisting of boulders, gravels, sands, silt and clays in various proportion in different locations.
Amatya and Jnawali (1994) compiled the Geological Map of Nepal at a scale of 1:1,000,000.

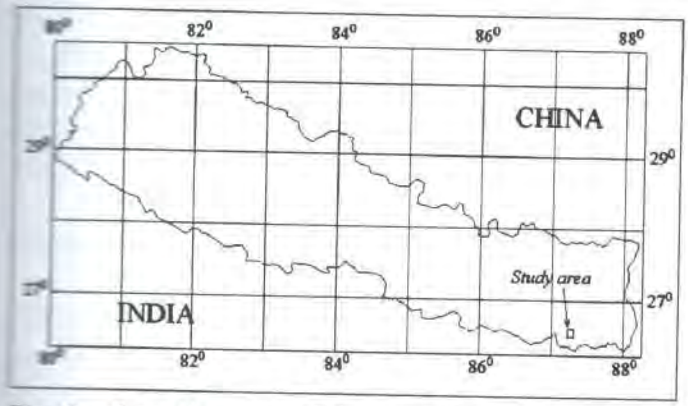

Fig. 1. Location map of the study area

In the map Quaternary Alluvial deposits of Indo-Gangetic Plain represent the area.

However no Engineering and Environmental Geological map of this area has been prepared before.

OBJECTIVE

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 type, Waste Disposal Sites, Natural Resources etc.
- To identify the hazardous/risk areas and recommend proper mitigation measures.
- Identify the existing environmental problems which may affect the human health.
- Delineation of 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.
- 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 literatures on geology, geohazards and regional geological as well as landuse maps were reviewed. Available reports on groundwater provided by GWRDB Babarmahal Kathmandu were also studied. Additional information was also collected from local individuals. LANDSAT TM Scenes of 1:125, 000 scale (November 1990); aerial photographs of 1: 15,000 scale (December 23, 1998) and of 1:50, 000 scale (1978-79) were studied and necessary interpretations were made. Topo maps of 1: 25, 000 scales (1992) and the digital database of this map was acquired from Topographical Survey Branch of the Survey Department. They were used to prepare a base map. The results obtained from Engineering Geological mapping and the Urban and Environmental Geo-Hazard studies were 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 2063 B.S for 45 days. It was planned with an aim to verify the previously interpreted work and investigate for possible neotectonic features as well as to compare the previously identified thrusts, faults, lithological formations, boundaries, landuse and the infrastructures.

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

In total, 100 auger holes (Fig. 2) 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 64 Standard Penetration Tests (SPT) was carried out to determine the stiffness of the ground at different locations. These tests were carried out to the maximum depth of 7 meter only because of the limitation of the type of the equipment used for the test.

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

A number of traverses were taken along riverbanks, trails and roads to delineate geological units and to identify areas prone to flooding, riverbank erosion and riverbed scouring. Soil sections exposed along riverbanks were measured. A number of pits were dug in order to expose the soil section in areas other than river sections. The sediments up to the depth of 7m are broadly classified into different lithological units. Field data and information collected from aerial photographs were transferred into the topographical base map. Analyses of collected samples from the field were carried out in the geotechnical laboratory of the department. Geographical Information System (GIS) analysis was carried out using ARC/INFO software. The process here includes the digitization of the map, input of data and its storage, data processing, plotting and then producing the Engineering and Environmental Geological Map.

GEOLOGICAL SETTING

The investigated area comprises of Holocene to Recent sediments. The Quaternary fluvial sediments of the study area is part of the Indo-Gangetic plains which extents in the south. The area consists of the sediments derived from the Singhiya Khola in the east and Budhi Khola in the west which originate all the way from the Siwalik Hills in the North. Based on the study of soils derived from the auger drill holes, along river sections, pits and existing litho logs, the study area is differentiated into four different groups. They are as follows;

1. Flood Plain Deposit (Fp)
2. Lakhantari Deposit (La)
3. Bhaluwa Deposit (Bh)
4. Sisuwa Deposit (Si)

Their brief descriptions are given below:

Floodplain deposit (Fp)

The deposit is distributed mainly along the course of Singhiya Khola in the East and Budhi Khola in the West. It consists of medium to coarse-grained sand with gravel mixed together. The bearing capacity of this deposit varies from moderate to high and possess moderate to high liquefaction susceptible zone.

Lakhantari Deposit (La)

This deposit is equivalent to Katahari deposit in the south of the present study area. The deposit is clay dominant in composition. It consists of brown to light gray clayey silt to silty clay up to the depth of 7 meters (Fig. 3). The field N-values in this area varies from 4 to 9. The zero N values are also observed at places (SPT 28) at Katahari village. In this unit, N-value increases as the depth increases. This unit indicates low bearing capacity. This deposit is mainly developed in the western

Fig. 2. Men performing Auger hole drill

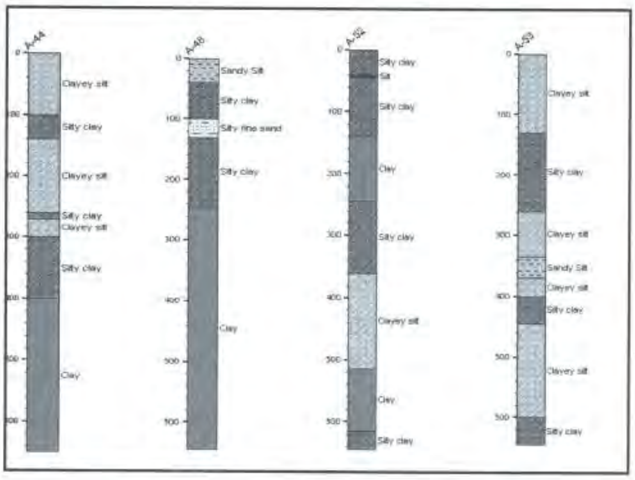

Fig. 3. Lithologs representing Lakhantari deposit

part of the study area and some in the central and southern part of the study area. The area possesses low N values and lies in moderate to high liquefaction potential area in case of high magnitude earthquake.

Bhaluwa Deposit (Bd)

This deposit is equivalent to the Ramgunj deposit (previously studied area situated in the south of the present study area). This unit consists of yellowish brown to bluish gray coloured clayey silt to silty clay up to the depth of 5 meters (Fig. 4). This unit covers most of the area in the western and the central block of the study area. The field N- values in this area varies from 3 to 8. The higher N- value is obtained at a depth below 3 meters with sediments mainly consisting of sand deposits and at shallower depth of less than 3m N–value is less.

The thickness of this unit is more than 6 meters. This unit indicates low to very low bearing capacity and lies in moderate to high liquefaction potential areas in case of big earthquake.

Sisuwa deposit (Si)

Sisuwa deposit is equivalent to Budhhanagar deposit (previously studied area located south of the present study area). It is sand dominant areas. This deposit occurs sparsely in the western part of the study area. It consists of brown to gray colored clayey silt and silty clay up to 3 meters from the ground surface and below it consists of fine to medium sand of greater than 4 m thickness (Fig. 5).The N- value at a depth less than 5 m is less than 10. The thickness of this unit is greater than 7 meters. This unit is found in Ramganj, Jhatiyahi areas. This unit indicates in general low to moderate bearing capacity. However, it shows moderate to high. The area lies in moderate to high liquefaction potential zone in case of big earthquake.

Laboratory Tests

During the fieldwork 100-auger drill holes were drilled and 64 SPT tests were conducted in order to investigate subsurface geology and the bearing capacity of different soil units in the area. Samples were also collected from the field and were brought to the geotechnical laboratory of the department for further test. A number of engineering tests such as grain size analysis; Atterberg's limit tests were conducted. The results of the laboratory tests of some of the samples are shown in Table-1 below. The sieve curves for some of the samples tested are shown in Fig. 6.

Natural hazards/Geo - hazards

Floods, River bank cutting and soil erosion are the major types of natural hazards frequently occurring in the Duhabi and in the surrounding area. Evidences of floods and soil erosions are observed along the Budhi Khola in the west and Singhiya Khola in the east.

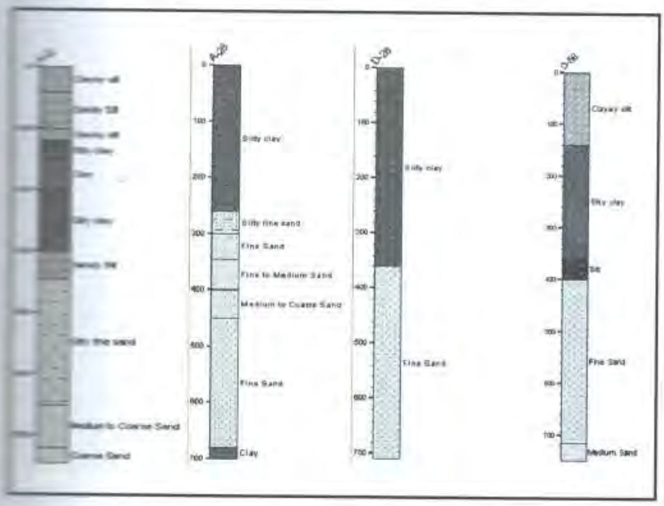

Fig. 4. Lithologs representing Bhaluwa Deposit

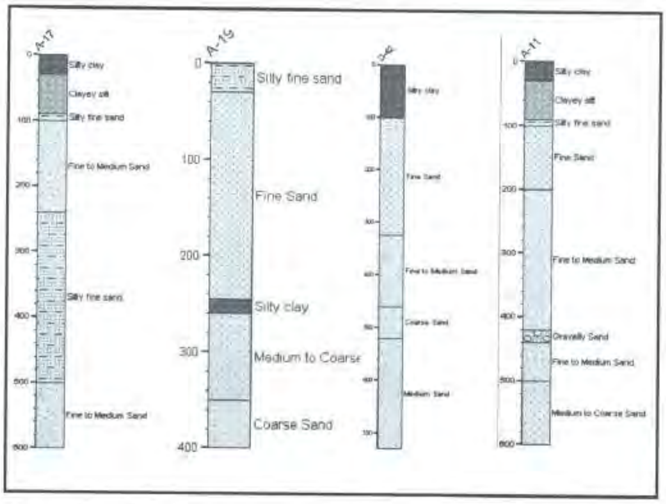

Fig. 5. Lithologs representing Sisuwa deposit

Flooding

Flooding in the Terai region is the common phenomenon during the rainy season. Every year during the monsoon time, the study area had suffered by the flooding normally in the southern part. However, severe type of flooding is not reported.

River bank cutting

River bank cutting is one of the common natural hazards in the study area. It is found both in Budhi khola and Singhiya Khola. The field observation carried out along Budhi Khola showed that bank cutting is occurring mainly near Raitol, Malhatti, Basanpur, Bauraha and Sitapur-3 area. Similar condition is also found in Singhiya Khola near Lakhantari and Gakuwa area.

In the Raitol, near Duhabi, Budhi Khola has cut its right bank and bank cutting process is continuing towards west (Fig. 7). It is learnt from the local people and field observation that the river has been cutting its banks since last few years.

To protect from possible hazard due to river bank cutting some preventive works are also done at few places along the Budhi and Singhiya Kholas. Preventive measures such as gabion walls constructed at few places along the riverbanks are already damaged due to toe scouring of the banks or by heavy flood water (Fig. 8). Retaining structures need regular supervision and maintenance. River bank collapse is caused due to toe cutting by stream. In such cases, prevention of erosion at toe part of river bank is important through the construction of structures like retaining wall, gabion wall etc.

Soil erosion

Soil erosion is taking place in the gully near the Pashchim Nadiyathok-3 of Lakhantari VDC. The area around this gully is becoming vulnerable in terms of huge loss of fertile land due to increase in size of the gully each year during rainy season which ultimately discharged into Singhiya Khola. The local people constructed gabion wall to control further soil erosion.

In the west of Khuniyakatta there is a canal to discharge the excess water during rainy season into the Singhiya Khola. Due to defect in the construction of the canal by gabion wall, the water is leaked from the base of the gabion wall making the foundation very weak. This has resulted tilting and failure of the gabion wall making the flow of

Table-1: Engineering properties of the soil samples derived from laboratory tests

Sample No.	Depth (m)	Fine (%)	Coarse (%)	Water Content W%	Liquid Limit (%)	Plastic Limit (%)	PI (k) m/s	Soil type	Perm (k) m/s	Remarks
SPT-1a	1.0-1.45	62	38	19.45				Sandy silt	2*10^{-6}	Uniform
1b	2.0-2.45	54	46	56.47	39.8	22.2	17.6	Sandy Silt	2.6*10^{-6}	Uniform
1c	3.0-3.45	18	82	16.94				Silty Sand	2.4*10^{-5}	Uniform
1d	4.0-4.45	12	88	16.35				Silty sand	6.2*10^{-5}	Uniform
SPT–2a	2.0-2.45									
2b	3.0-3.45									
2c	4.0-4.45				32	38.4				
2d	5.0-5.45									
SPT-3a	2.0-2.45	85	15	24.87				Sandy silt	1.6*10^{-6}	Uniform
3b	3.0-3.45	78	22	27.47	36	21.25		Sandy silt	1.3*10^{-6}	Uniform
3c	4.0-4.45	46	54	23.37				Silty sand (Few gravel)	3.4*10^{-6}	Uniform
3d	5.0-5.45	32	68	22.09				Silty sand (Few gravel)	7.2*10^{-6}	Uniform
3e	6.0-6.45	23	77	21.79				Silty sand	1.6*10^{-5}	Uniform

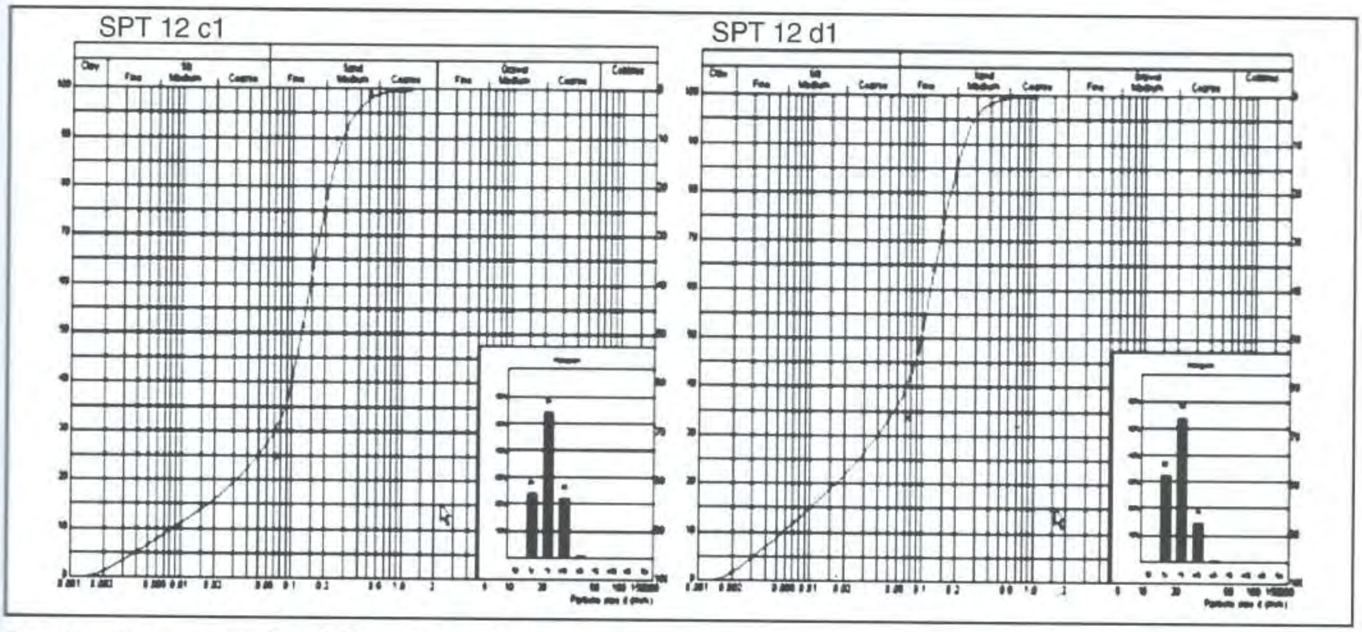

Fig. 6. Sieve charts for different samples

water out of canal. This flow of water accelerated the scouring of the soft ground affecting the agricultural land. While constructing the canal by gabion wall there should be impermeable lining on the side and bottom of the canal.

Haphazard mining

In Budhi Khola near Duhabi sand mining is going on at few places within the 50 meters downstream from the Budhi Khola Bridge (Fig. 10). It is important that the authorities pay a serious concern to the problem immediately. Mining of sand from Budhi river beds and bank near the bridge will cause serious damage to the bridge foundation and ultimately collapse of the bridge will occur if it is not checked in time.

Geo-environment and pollution

Drainage system in the study area is inadequate and need its proper management. Direct connection of sewage drainage from settlement areas to the Budhi Khola and discharge of untreated industrial effluents in the open space, road sides, and streams and improper dumping of solid wastes into the bank of river, road side and in open space has caused pollution to the river water in the study

Fig. 7. River bank cutting of Budhi Khola on its right bank in Raitol near Duhabi

Fig. 8. Failure of gabion wall in the west of Khuniyakatta village (Lakhantari VDC) constructed to divert irrigation water into Singhiya Khola.

Fig. 9. Soil erosion taking place near Pashchim Nadiyathok-3 of Lakhantari VDC that has destroyed agricultural land

Fig. 10. Illegal sand mining from the right bank in Budhi Khola bridge

area. Due to such environment problems, impacts were noticed on human and animal health such as different types of water borne diseases, stomach problem and other types of infectious diseases, which are mainly caused by drinking contaminated water from drainage and open field (Environmental Profile of Duhabi VDC, 2003).

Waste Disposal Sites

The disposal of all types of garbage in the town/ city areas is a common problem that continues to grow with fast expansion due to high rate of population growth together with all types of development activities and industrialization. Waste comes from many sources including agriculture, industry, hospitals, household, market etc.

Biratnagar Sub-Metropolitan city and Duhabi VDC is lacking of its own properly managed permanent sanitary landfill site to manage the safe disposal of the daily waste produced from the urban settlement and industrial sites. Haphazard dumping of the municipal solid wastes in different sites mainly by the side of the roads (Fig. 11), river banks/course and open field should be proibited. There is a need for identifying an appropriate waste disposal site which should be environmentally safe.

The Biratnagar Sub Metropolitan city is planning to establish a new Sanitary landfill site at Karmaiya, Tankisinuwori, 10 Km north of Biratnagar and owned an area of about 10 ha. (Fig. 12) for the purpose. Beside this, Morang District Development Committee (DDC), Sunsari DDC, Dharan, Biratnagar, Itahari and Inaruwa municipalities are also working jointly to construct a regional landfill site.

The area proposed by the municipality in Tankisinuwari seemed to be quite suitable for sanitary landfill site development. The key features of the proposed landfill sites are:

- Presence of thick impermeable clay/silty clay layer on the top
- About 10 Km far from the Biratnagar city.
- About 5 Km aerial distance from Biratnagar airport.
- About 1.5 Km aerial distance from Tankisinuwari (nearest settlement area).

However, the detail investigation is required before making decision.

Landuse

In terms of landuse, the study area is mainly covered by cultivated land where rice in the rainy season and mustard, wheat, vegetables etc. is grown in winter season. Patches of sugarcane fields and bamboo trees are also seen in the area. There is no particular forest land. The side of the Dharan-Biratnagar road is covered by industries.

Fig. 11. Haphazard dumping of solid waste of Duhabi by the side of Budhi Khola near Budhi bridge (Miyatol)

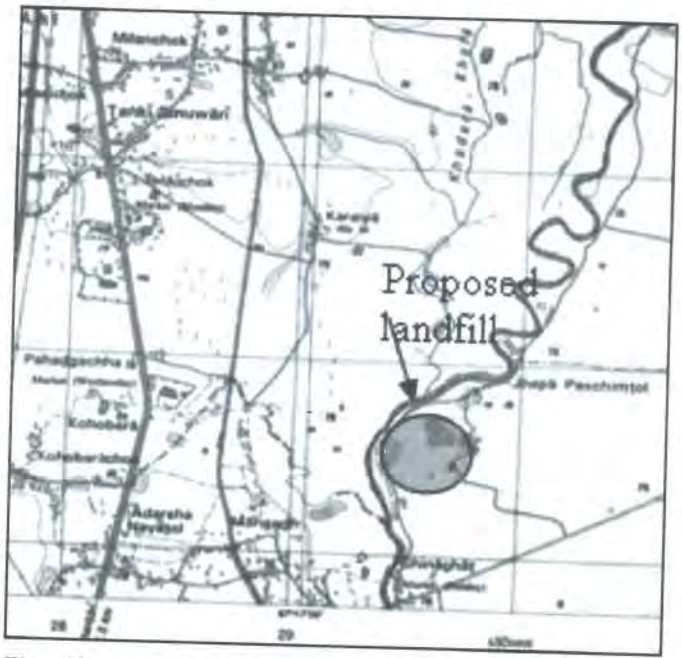

Fig. 12. Location of proposed landfill site near Karnaiya

Natural Resources

The non–metallic minerals resources like construction materials (sand) are found along the riverbeds of Budhi Khola. Since this river is not so big in size the flood plain deposits are also not well developed except at few places.

Few small sand mining are taking place from the river course. Sand deposited along the Budhi Khola is mined near Miyatol and Basanpur village. Mining is done manually from the river bed using bucket (Fig. 13 and 14). In these areas, they are not mining from the flood plain because of presence of clayey siltly sand. The sand extracted from the river course/bed is medium to coarse in grain size. The study area is rich in clay deposits which can be proved by the presence of numbers of abandoned brick factories. Presently clay mining for brick factories is taking place in the western part of the Duhabi near Simarbona and Simariya village.

Bearing capacity and Liquefaction potential

The bearing capacity analysis is carried out in this report according to Peck et al (1974). According to the analysis it is found that the bearing capacity of the study area is medium to very low. The 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 % has moderate and about 1.14% has very low bearing capacity.

The liquefaction analysis in the study area has been carried out taking into account the SPT values, and subsurface soil condition. In this study a qualitative analysis of liquefaction test in the study area is carried out using Juang and Elton (1991) method. The analysis shows that most of the study area is vulnerable to liquefaction hazard incase of strong earthquake. According to this method out of 64 SPT tests performed for liquefaction potential analysis, 35 of them showed high potential, 5 showed moderate, 16 low and 8 of them showed very low potential (Fig. 15). Ohasaki method for the analysis of liquefaction potential was also applied in this study in order to verify Juang and Elton method and the result was found satisfied.

Thus it proves that, most of the areas in Biratnagar lie in high to moderate liquefaction potential. High potential liquefaction is also indicated in the flood plain areas as shown in the Fig. 15. The analysis of liquefaction potential indicates that about 74 percent of the area lies in the moderate liquefaction potential zone, while about 26 percent area lies in the high potential zone and only 0.04 % lies in the low potential zone.

Fig. 13. Sand mining from the Budhi Khola near Basanpur village

Fig. 14. Clay mining by brick factory near Simarbona village

CONCLUSION AND RECOMMENDATION

- Engineering and Environmental Geological Map of Duhabi VDC and the surrounding area has been prepared (Fig. 16). The main town of Biratnagar is situated in the indogangetic alluvial plains consisting mainly of sand, clay, silt and very few fine gravels at few localities. Biratnagar sub metropolitan city and the surrounding area is divided into 4 units based on geological setting and engineering geological properties of soil/rocks. They are Lakhantari deposit, Bhaluwa deposit, Sisawa deposit and the flood plain deposit.

- The ground condition of the study area is dominantly very soft to stiff. Similarly bearing capacity of the ground ranges from extremely low to medium. The liquefaction potential in the study area is moderate to high according to the qualitative analysis carried out on it.

- Flood plain deposits provide source of construction materials like sand in few places of Budhi Khola. The study area is rich in clay which is used by brick factories and other household purposes.

- Duhabi and the entire region is lacking its own permanent sanitary landfill site to manage the safe disposal of the daily waste produced from the urban settlement and industrial sites.

- Haphazard discharge of untreated industrial effluents in open spaces are found in the study area.

- Landfill site proposed by Biratnagar Sub Metropolitan is suitable for the purpose from geological point of view.

- It is recommended to follow proper land use pattern in the study area to agree with the Engineering Geological properties of the soil obtained from present study as far as practicable.

- Most part of the study area lies in very soft to moderate ground condition with considerably low SPT values where some mitigation measures need to be applied while constructing development activities.

- It is recommended to carry out proper site investigation before construction of heavy structures.

- The results of the analysis obtained (liquefaction hazard analysis and the bearing capacity) in this work are not intended to be used as a precise tool for site-specific construction. A more detail investigation with comprehensive merging of geologic, geotechnical and seismological data will be required to carry out precise liquefaction

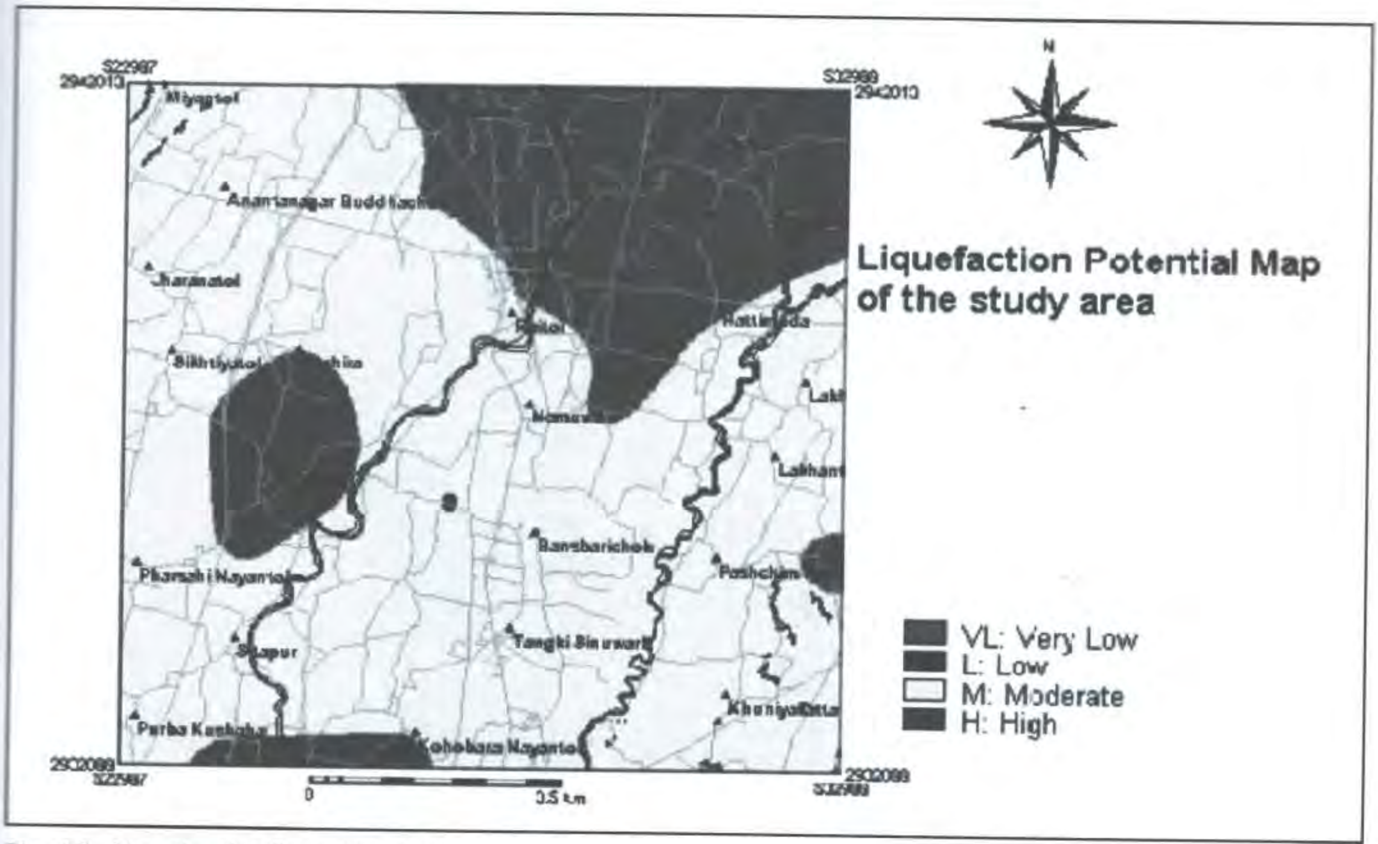

Fig. 15. Liquefaction Potential map

susceptibility mapping as well as bearing capacity for each major development activities. Since the city area lies in moderate to high liquefaction area and with low bearing capacity, a proper mitigation measures should be applied while designing and constructing buildings and other infrastructures.

- The artificial depression or lands left behind by past clay mining should be utilized for temporary sanitary landfill purposes instead of haphazardly dumping wastes along the river and the road side. The extraction of construction materials such as sand should be managed properly.
- Haphazard sand mining from the bank of Budhi and Singhiya Kholas should be stopped to prevent soil erosion and shifting of the river course.
- Natural drains should not be obstructed while constructing new structures like road and canal.
- The new sanitary landfill-sites should be selected as soon as possible for proper management of the wastes.
- River training works should be done for protecting land and settlement adjacent to the river bank against erosion. Human settlements encroaching to the river bank should be discouraged. Sand mining from the river should be carried out only under the supervision of the local authority.
- The proposed dumping site should be implemented after a detailed Environmental Impact Assessment Study on the selected site and should be developed as a sanitary landfill site rather than a simple dumping site.
- Immediate appropriate control works should be needed in the discharge canal near west of Khuniyakatta village (Lakhantari VDC) to protect further loss of fertile land.
- Haphazard discharge of untreated industrial effluents in open space/drainage should be stopped.

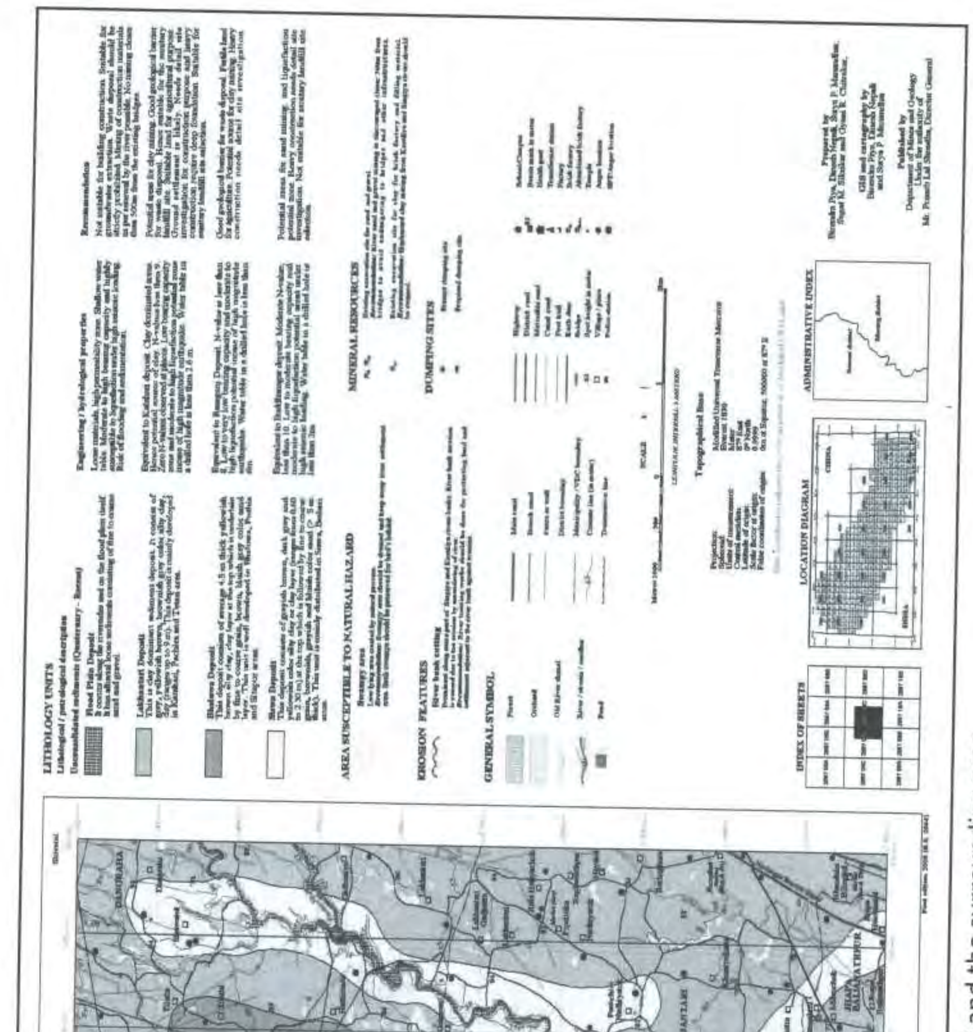

Fig. 16. Engineering and Environmental Geological Map of Duhabi and the surrounding area.

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Landslide Hazard Mapping in Some Parts of Gulmi, Parbat and Baglung Districts, Western Nepal

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INTRODUCTION

Landslide Hazard Mapping was carried out in accordance with the annual program of the Department of Mines and Geology for the fiscal year 2006/2007.The study covered about 650 sq. km area of Toposheet No. 62P/12 in some parts of Gulmi, Parbat and Baglung districts. The area lies between latitudes 28° 00' 00" N to 28° 15' 00" N and longitudes 83° 30' 00" E to 83° 45' 00" E. Kali Gandaki Nadi, one of the major rivers in the Himalaya passes through the middle part of the study area. The major tributaries to the Kali Gandaki are Modi, Theule, Chaur, Bachha, and Galandi Kholas in the area. The lowest elevation in the area is 514m above msl at the east bank of the Kali Gandaki Nadi south of Setibeni and the highest elevation is 2759m at Gajadhurr.

The field survey was focused on verification of erosion features interpreted on aerial photos and satellite images, recording landslides using 'Inventory Forms', mapping of main factors 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 in 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 should be done taking into consideration the information on areas that are prone to such disasters. In this regard, present study is planned for the following objectives:

- To study major landslide and 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 in 1:50,000 scale by optimum utilization of Remote Sensing and GIS techniques.
- To prepare the regional database of landslides.

METHODOLOGY

Desk Study

Aerial photographs of 1996 at 1:50,000 scale acquired from the Survey Department were interpreted to study the landslides, erosion features, tectonic structures, existing landuse pattern and lithological units. Landsat-TM image 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

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], TU[8]	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], TU[8]	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 andgully erosion	VI[6], FC[7] , GIS and image processing
Internal Relief	Topographical map in digital format	Elevation category in meters	DEM

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*
TU[8]: *Tribhuvan University*

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.

GEOLOGY AND STRUCTURE

The investigated area is within the Lesser Himalayan belt. The terrain is represented mainly by meta-sedimentary rocks. Geological studies had been carried out by a number of researchers in the Kali Gandaki Section. Among others, a compiled geological map by Shrestha et. al. is published by the Department of Mines and Geology (DMG) in 2000 A.D. Dhital et.al. (2002), published a geological map of the region between Kushma to the north and Ramdighat to the south. The geological data of the published map of DMG and Dhital et.al had been used as a base for the geological data. Review of existing geological maps suggests that the area is represented by phyllites, quartzites slates, limestone and dolomite rock sequences of Nuwakot Group. Shales and sandstones of the Tansen Group are also exposed around Setibeni (Dhital et.al, 2002). These studies also revealed several thrusts, faults and folds indicating weak zone tectonic belts of regional scales in the area.

Land capability, land utilization and land system maps prepared by Land Resources Mapping Project (LRMP) in 1984 at 1:50,000 scales are the other sources of information used to assess the landslide hazard zones. Landslide Hazard Mapping in Toposheet No. 62P/15 by Tuladhar (2007), was also referred for preparing the final hazard Map. This study program was planned to provide geo-scientific information especially on landslide hazards which shall be beneficial for planning of infrastructure development activities in the 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 landsliding were prepared using GIS system by incorporating the data obtained from desk study and field verification. Slope Map, Aspect Map and Internal Relief Map were generated using a Digital Elevation Model (DEM, Fig. 1b). Relief is expressed as the maximum elevation change within 1 hectare, or within 1 square kilometer (ILWIS 3.3, 2005). In this case 30mx30m pixel size is taken to prepare internal relief map. In the present study, factors such as geology (Fig. 1c), land use (Fig. 1e) slope (Fig. 1g), aspect (Fig. 1i), and internal relief (Fig. 1k) 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 Figs. 1d, f, h, j and i.

ROLE OF REMOTE SENSING DATA AND GIS IN LANDSLIDE 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 of 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

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

Where,
W_i = Weight given to a certain parameter class
Densclass = Landslide density within the parameter class
Densmap = Landslide density within the entire map

such as geology, landuse, slope, slope aspect and internal relief. For the present analysis the following formula was used (after Van Westen, 1993).

INVESTIGATION RESULTS

Meta-sedimentary rocks such as phyllites, quartzites, slates and dolomites of the Nuwakot Group are observed around northern and southernmost part of the study area. Sedimentary rocks such as shale and sandstones of the Tansen Group are also exposed towards east and west of Setibeni village.

Superficial deposits such as residual soil, alluvium and colluvium (including talus) deposits are mapped within the study area. Thick residual soil is developed on the old river terraces around Arbeni, Behadi, Bachha, Karnas, Phalebas, Kushma and Balewa area. River terraces developed in these area form flat geomorphic surface lying on either side of the Kali Gandaki River creating suitable ground for the development of settlement and cultivation. However, these areas still lack proper infrastructures like road, electricity and irrigation. Hill slope and river terraces are cultivated. Improper cultivation practices have often triggered landslides damaging property worth of millions of rupees.

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 are also recorded during field checking. Majority of the slides are soil slides. Rockslides are also triggered in intensely deformed rock mass,

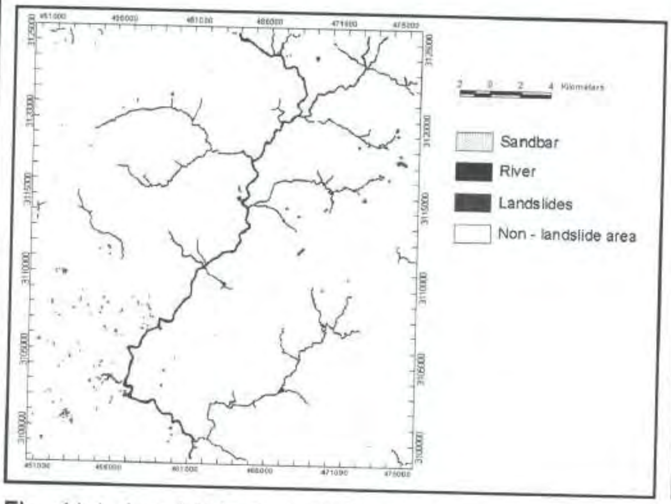


Fig. 1(a). Landslide Distribution Map

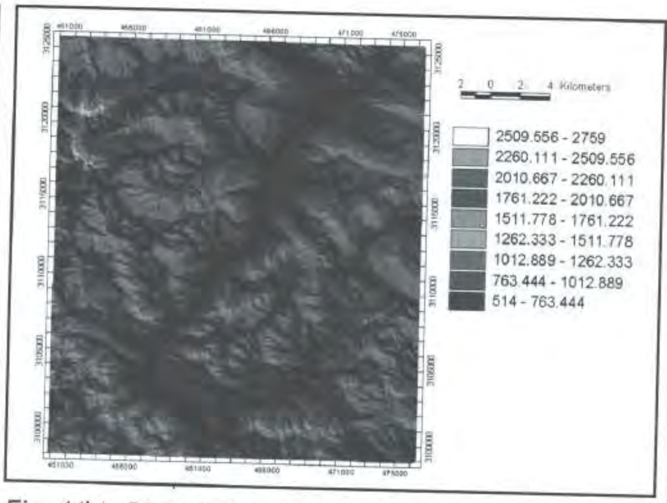


Fig. 1(b). Digital Elevation Model

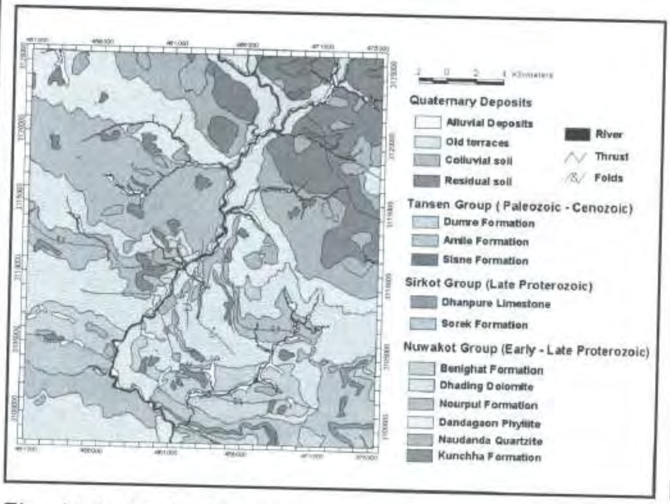


Fig. 1(c). Geological Map

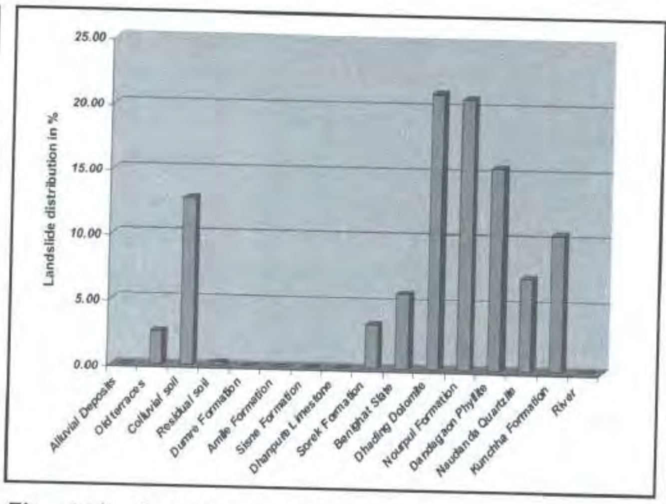


Fig. 1(d). Relation between Geology and Landslide Distribution

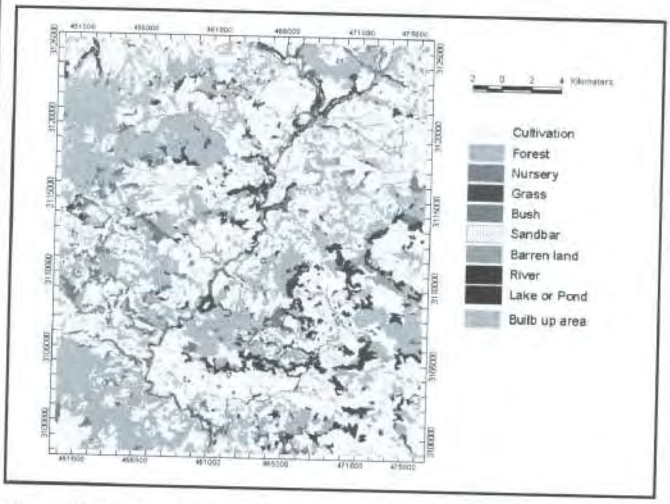


Fig. 1(e). Landuse Map

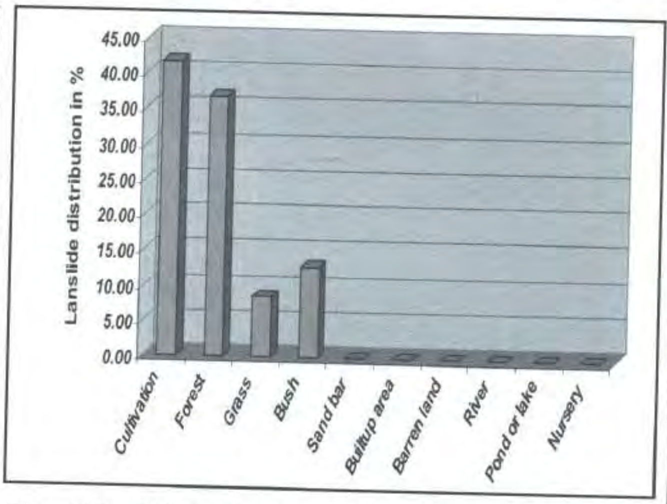


Fig. 1(f). Relation between Landuse and Landslide Distribution

Fig. 1. Various factor maps showing their relation with the landslide distribution

(Fig. 1. contd ......)

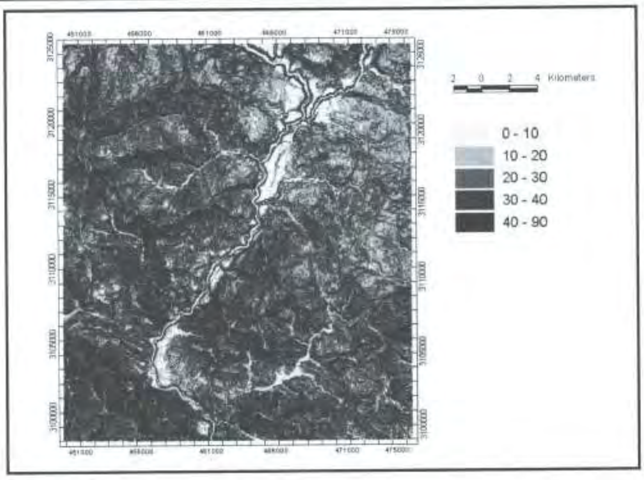


Fig. 1(g). Slope Map

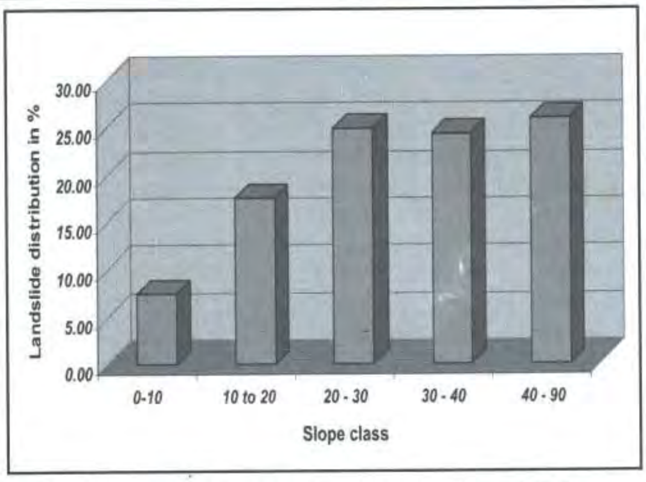


Fig. 1(h). Relation between Slope and Landslide Distribution

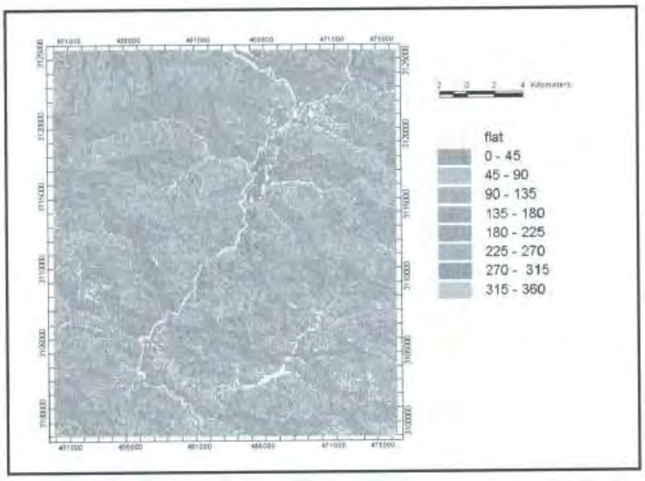


Fig. 1(i). Aspect Map

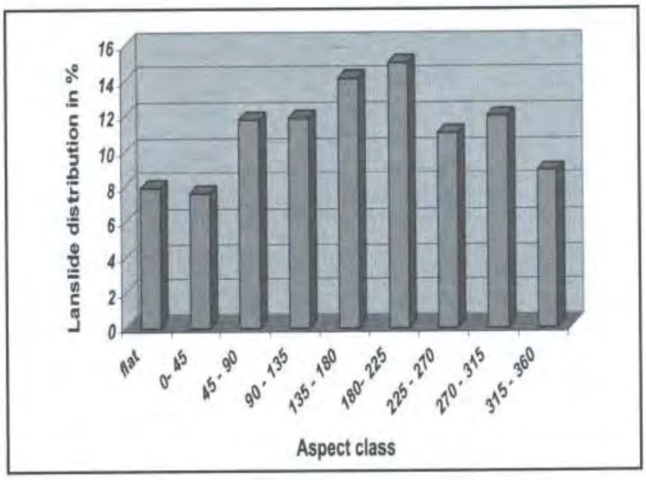


Fig. 1(j). Relation between Aspect and Landslide Distribution

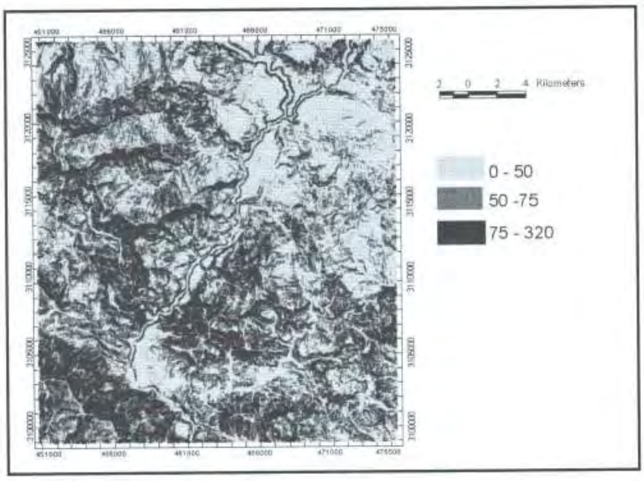


Fig. 1(k). Relief Map

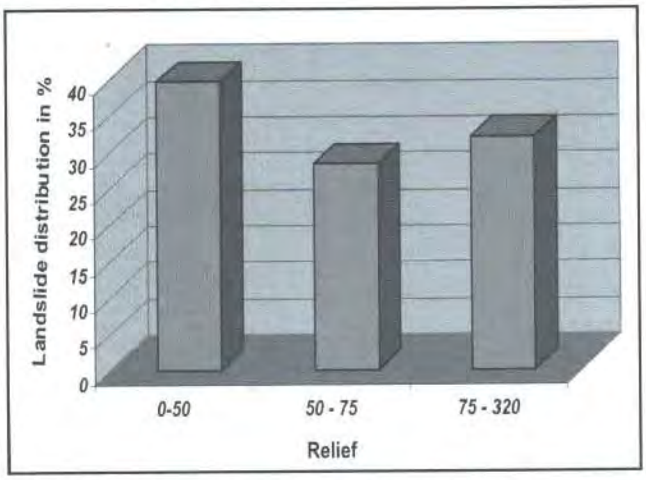


Fig. 1(l). Relation between Relief and Landslide Distribution for example the rockslide of Arbeni. Discontinuities affecting rock mass are joints, bedding planes, foliations, thrusts or faults. Wedge and plane failure are common in rock mass. Block falls and topples are also noted at places of steep slopes. 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.

One large-scale wedge failure has occurred in the headwork area of the irrigation canals constructed for the agriculture land of Arbeni village in Gulmi district. The slide washed away about 50m stretches of three different canals. Part of the lowermost fourth canal was buried and its retaining structure was damaged. Similarly the irrigation canal of Kunadi village was also damaged. Irrigation canals are the most affected structure in the study area.

Based on the field verification, aerial photos and satellite image interpretation and from review of existing maps; soil type distribution map, Landuse map, landslide distribution map and compiled geological map were prepared. Soil units are included in the geological map; slope class map, aspect map and relief map were derived from Digital Elevation Model (DEM). Above mentioned maps were taken as factor maps for causing the landslide. Landslide inventory map was used as a base to calculate the rating values of causative factors to derive the Landslide Hazard Zonation Map using GIS based ArcInfo and Arcview system.

Main causes for the occurrence of landslide in the study area can be attributed to intense fracturing of rock mass, difference in relief, forming steep slopes, improper slope cultivation practices, toe scouring of adjacent slopes of high gradient rivers or streams, high intensity of rainfall and improper mining activities in some cases. Construction of irrigation canals on loose soil mass without proper lining has helped to continuous percolation of water into the soil mass to increase pore water pressure triggering soil slides.

PREPARATION OF LANDSLIDE HAZARD ZONATION MAP

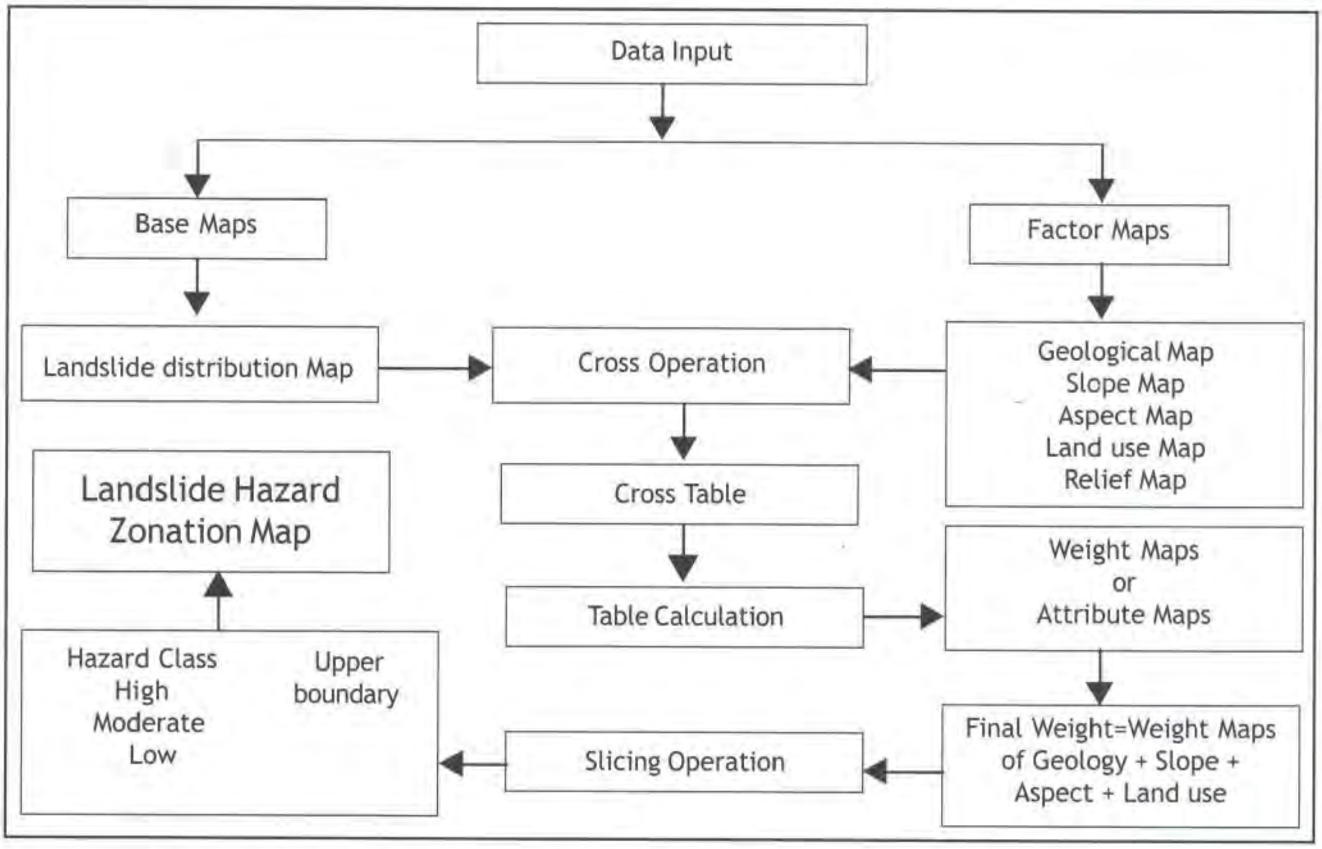
Based on the density of landslide distribution in each class/unit of the causative factors at present situation, a landslide hazard zonation map (Fig. 2) was prepared. The entire study area has been divided into three categories predicting probability of danger from landslide. Since each unit of the 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 classified into three different zones as low, moderate and high hazard. Process of hazard zonation is summarized in the following flow chart.

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 83.91% of the landslides were found to be distributed in high hazard zone; nearly 15.02% in moderate and only 1.05 % 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, d and e) 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.

CONCLUSION AND RECOMMENDATION

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 and rock slides. Irrigation canals passing through loose soil mass are creating unfavorable stability condition on slopes allowing continuous infiltration of water into the soil mass.

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 155 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 -6.4598 to 2.7004. About 83.91% percent of the landslides are found to be located within the high hazard zone, 15.02% percent in moderate hazard zone and only 1.05 % percent in low hazard zone.

Hazard zonation map shows that about 376.89 sq. km is covered by highly unstable zone forming 55.40% of the total study area whereas about 30.57% area are on moderate hazard zone and the rest 13.9141748 % 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 reevaluation because change of a single factor can be sufficient to exceed the threshold for slope instability.

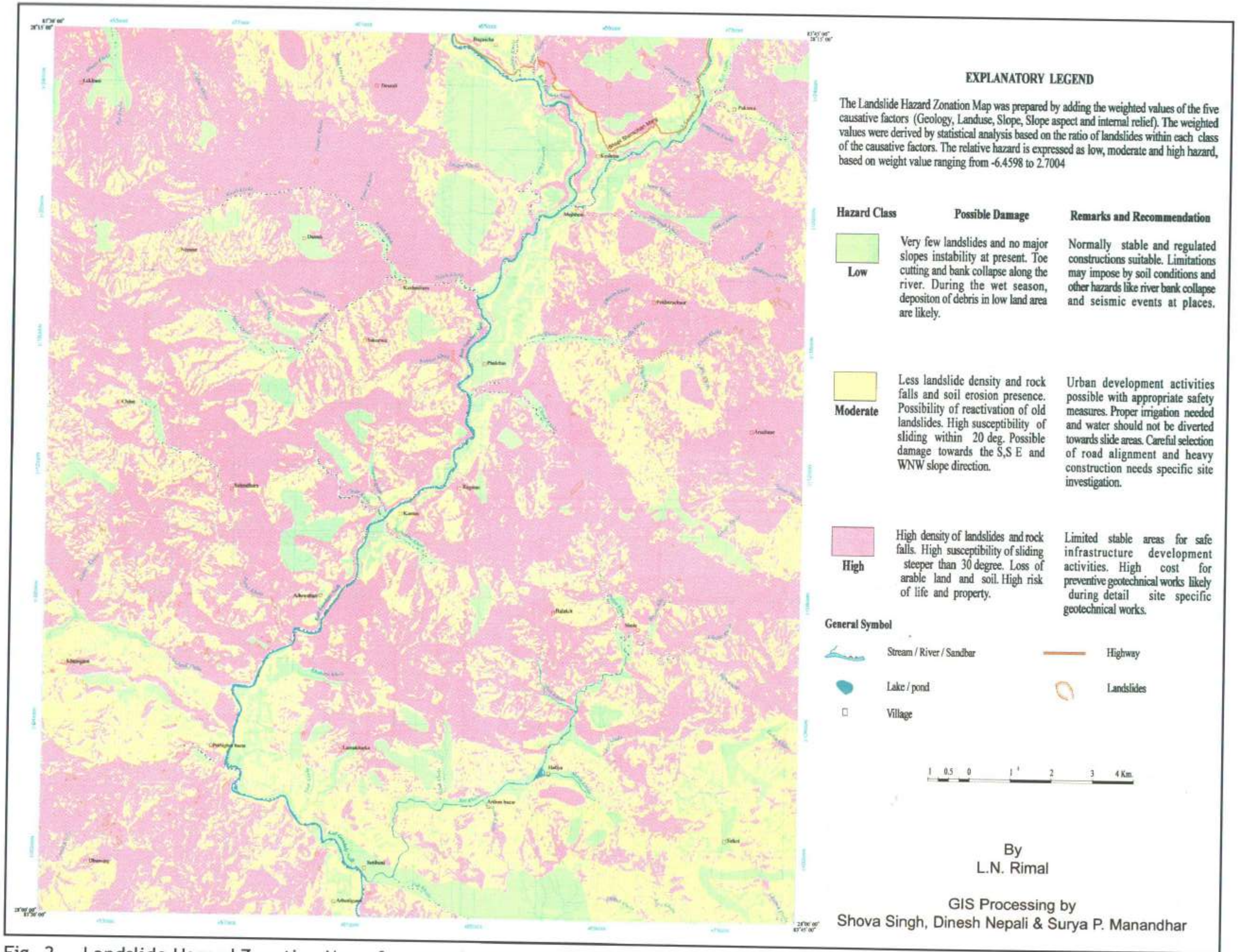


Fig. 2. Landslide Hazard Zonation Map of parts of Gulmi, Parbat and Baglung Districts

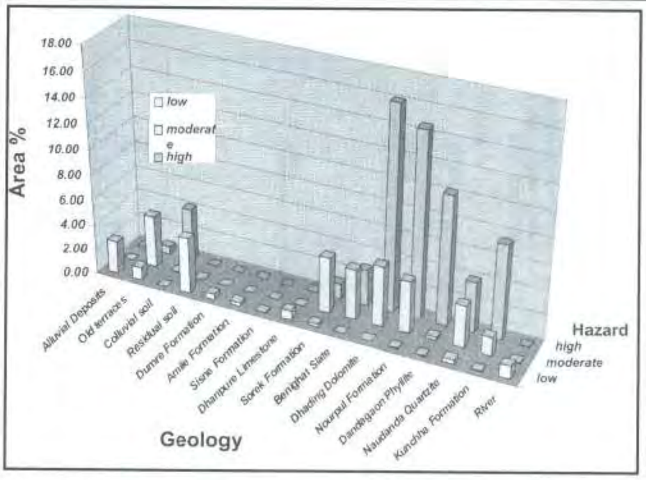


Fig. 3(a). Relation between Hazard and Geology

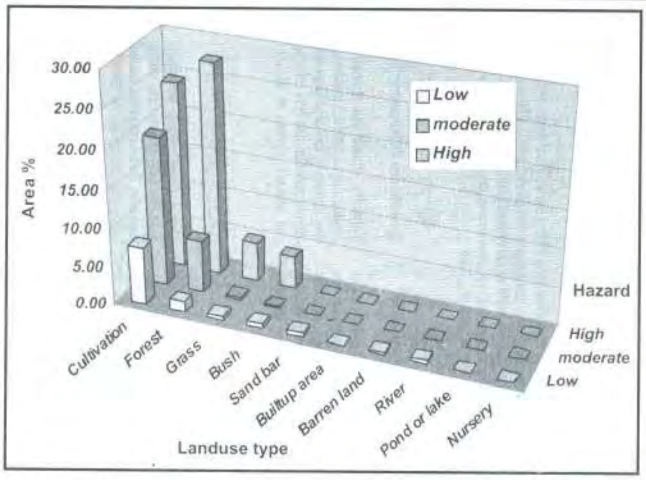


Fig. 3(b). Relation between Hazard and Landuse

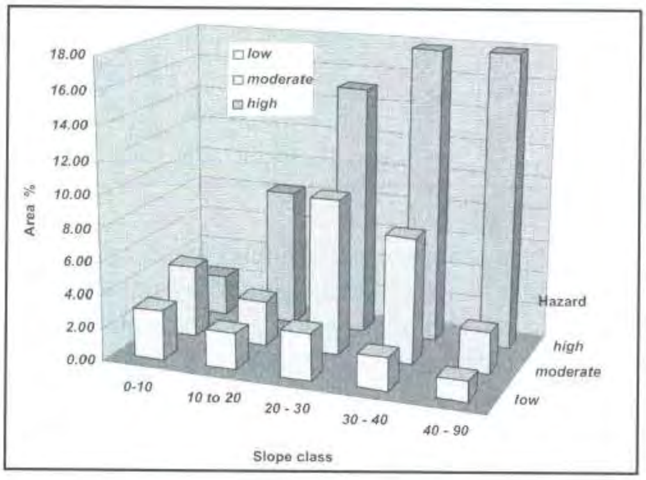


Fig. 3(c). Relation between Hazard and Slope

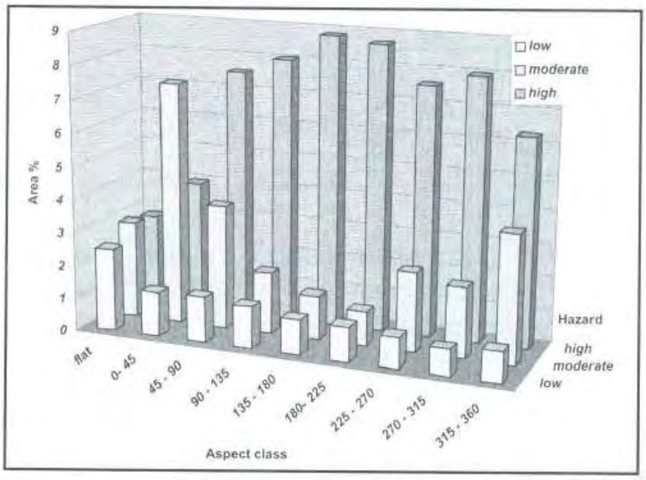


Fig. 3(d). Relation between Hazard and Aspect

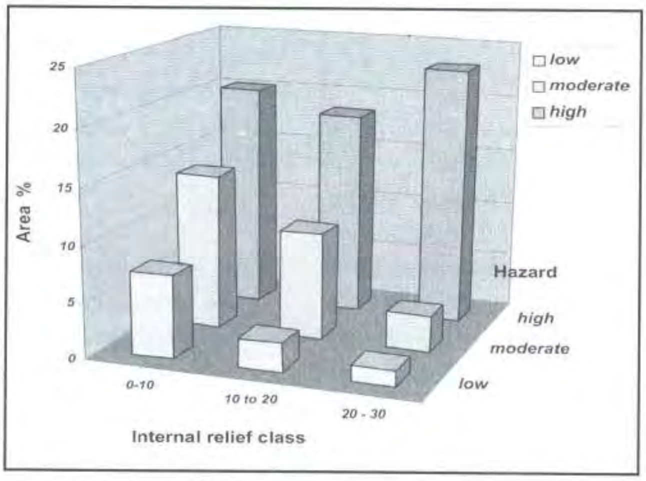


Fig. 3(e). Relation between Hazard and Internal Relief

Fig. 3. Relationship between Hazard Class and Causative Factors

ACKNOWLEDGEMENT

The author is grateful to Mr. N. R. Sthapit, former Director General and Mr. P. L. Shrestha Director General, DMG for supporting the field program and guidance. My sincere gratitude is due to Dr. R. B. Shrestha, Deputy Director General for his keen interest and valuable suggestions. Sincere thanks are also due to Mr. K. P. Kaphle, former Superintendent Geologist for valuable suggestions.

I am thankful to Mrs. Shova Singh, Geologist for the GIS analysis to prepare the map. My sincere thanks are extended to staff members of Remote Sensing Section as well as other sections for fruitful discussion.

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Landslide Hazard Mapping in Some Parts of Syangja, Palpa and Gulmi Districts, Western Nepal

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INTRODUCTION

This report is based on the investigation conducted according to the annual field program of the Department of Mines and Geology (DMG) for the fiscal year 2006/2007. Landslide Hazard Zonation Mapping was carried out by optimum utilization of Remote Sensing and Geographic Information System (GIS) tools in addressing the basic geo-scientific information along with the possibilities of landslide hazards within the study area. This report basically describes the results of the field investigation and 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 study area is bounded by latitudes 27° 45' 00" N to 28° 00' 00" N and longitudes 83° 30' 00" E to 83° 45' 00" E, covering an area of 650 sq. km. in parts of the Syangja, Palpa and Gulmi districts of Gandaki and Lumbini zones. The area lies in Toposheet No.63 M/9. The study area covers a part of Siddhartha Rajmarga from SE to NW corners and also includes some important feeder roads. Two Power Projects namely Kaligandaki-A and Andhi Khola Hydro-electric Power sites are situated within the study area. The results of the present investigation will be basically beneficial for the planning purpose such as infrastructure development, urban and regional planning with the information on possible natural hazards. The duration of the present field investigation was of forty-five days.

OBJECTIVES

Geo-hazards like landslides and debris flows constitute a major risk for communities, infrastructure and lifelines of Nepal. The growing impact of landslide risk on the society and the economic development call for rapid, easy accessible and reliable information for planning purposes. Before planning of any development activities in any area or region the existing stability conditions of the terrain should be assessed to minimize the risk of hazards and environmental degradation and suitable preventive measures could be planned beforehand. Hence, the present investigation aimed at achieving mainly the following objectives:

- to study and register the landslides of the study area in 'Preliminary Landslide Inventory Form'.
- to integrate landslide distribution and geologic information with various slope morphology and existing land use for the preparation of landslide hazard zonation map in 1:50,000 scale by optimum utilization of Remote Sensing and GIS techniques.
- to provide proper geo-scientific information of the area on landslide hazards.
- to prepare the regional data base of landslides.

METHODOLOGY

Desk Study

- Aerial photographs of 1996 at the scale of 1:50,000 were examined to identify the various lithological units, landslides, erosion features, tectonic structures etc.
- LANDSAT-TM Scene of December 1992 at the scale of 1:125,000 were studied for lineament mapping.

* *The author has retired from the Department*

- The topographic maps of 1:25,000 scales from Survey Department had been the base map for the field investigation.
- The Land capability, Land utilization and Land system maps published by the Land Resources Mapping Project (LRMP, 1984) were studied.
- Existing literature and geological maps of the study area were reviewed.

Field Investigation and Data Inputs

Fieldwork and verification of previously interpreted information were carried out using 1:50,000 scale recent aerial photographs in conjunction with 1:25,000 scale topographic maps prepared by Survey Department. Emphasis was given to check the landslides and other areas prone to further soil erosion by closer observation. Some of the major landslides within the area had been studied in details using 'Preliminary Landslide Inventory Form' for regional inventory.

Geological data were obtained from the available geological maps together with simultaneous field mapping within the study area. Structural features were mapped during the fieldwork and verified with the previously interpreted structures from aerial photo- graphs. Erosion and mass movement features were also recorded. The hydro-geological conditions of the area were determined by the observation of type and nature of streams, springs and water seepages. The landslides are grouped as active, old, dormant and reactivated.

The slope and aspect map which is used for preparing the landslide hazard zonation map was directly derived from the digital data with contour interval of the area using ArcView 3D Analyst and further regrouped into five slope classes. Land use map was prepared by integrating field observation data together with the information from the available Land capability, Land utilization and Land system maps published by LRMP. After careful evaluation of the maps during field visit together with aerial photo interpretation, regrouping of each land use map unit was carried out in terms of their presumed slope stability attributes. The regrouping of each factor maps was based on the density and type of vegetation cover, the nature of cultivation, and the land use management system.

The optimum data required for the present investigation were acquired from various sources of information together with fieldwork. All the coverage is stored in the Modified UTM projection. The data overlays, sources, derived parameters and method of generation are given in Table-1.

GEOLOGY AND STRUCTURE

Bedrock influences the landslide occurrence in several ways. Weak and incompetent rock is more likely to fail than strong and competent rock. The strength of a rock mass depends on the type of rock and the nature of discontinuities such as joints and fracture. The more discontinuities present in bedrock, the greater the chance of rock instability.

A number of geo-scientists have investigated the area mainly reconnaissance type of works, whereas a few detailed studies had also been conducted. However, a compiled geological map of the area at a scale of 1:50,000 was published by the Department of Mines and Geology (DMG) in 2000 and it elaborates the regional geological setting including the lithologic, stratigraphic and structural information of the study area. The published geological map from DMG was referred as one of the factor map for the present investigation. Lanslide Hazard Zonation map of DMG (Tuladhar, 2006) was also referred.

In general, the study area is represented by Quaternary to Recent surficial deposits, Upper Miocene to Lower Pleistocene Siwalik Group, Permo-Carboniferous to Oligocene Tansen Group, and Pre-Cambrian Upper Nawakot Group followed by some igneous rock such as Aulis Basalt. Alluvial deposits as silt, sand, gravel are deposited in terrace, flood plain and stream channels whereas, the Middle and Lower Siwalik rocks are exposed merely at southwest corner of the area. Dumre, Bhainsekati, Amile, Taltung and Sisne Formations of Tansen Group of rocks are observed at the central part of the study area along with the Aulis Basalt in the south. Upper Nawakot Group of rocks like Benighat Slate, Dhading

Table-1: Data overlays, sources, parameter derived, 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 Dipslope 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
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 andgully 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*

Dolomite, Nourpul Formation and Dandagaon Phyllite occupies most of the study area.

Structurally, the study area is dominated by Main Boundary Thrust (MBT) between the Siwaliks and Upper Nawakot Group of rocks. A number of thrusts and transverse faults exist within the Tansen and Upper Nawakot Groups. Folds of various generations and scales have affected the rocks of the study area. Most of them were initiated as fault-propagation folds and produce as complex forms.

PREPARATION OF FACTOR MAPS

The factor maps of various parameters such as landslide distribution, geology, slope aspect and land use, which are generally used for the preparation of landslide hazard zonation map at regional scale were prepared after incorporating the available remote sensing and field data into GIS system. The relationship of landslide ratio to various classes of parameter maps was summarized and found to be associated with certain classes of different parameters and presented after statistical analysis.

The Landslide distribution map of the study area was prepared from field mapping with the help of topographical base map, visual interpretation of aerial photographs and by compiling various sources of information and the data finally processed by GIS (Fig. 1a).

Slope Map (Fig. 1g), Aspect Map (Fig. 1i) and Internal Relief 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 Fig. 1d, f, h, i and j.

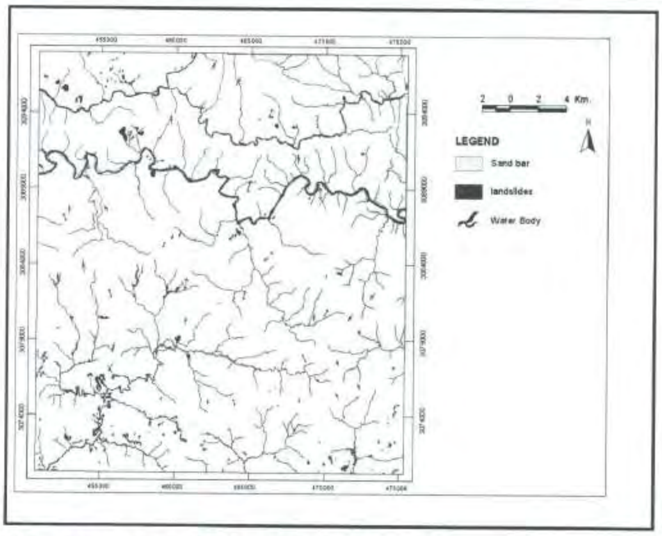


Fig. 1(a). Landslide Distribution Map

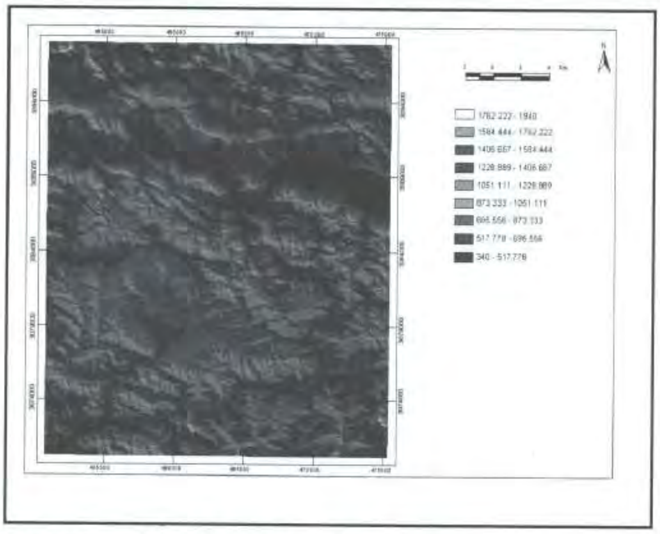


Fig. 1(b). Digital Elevation Model

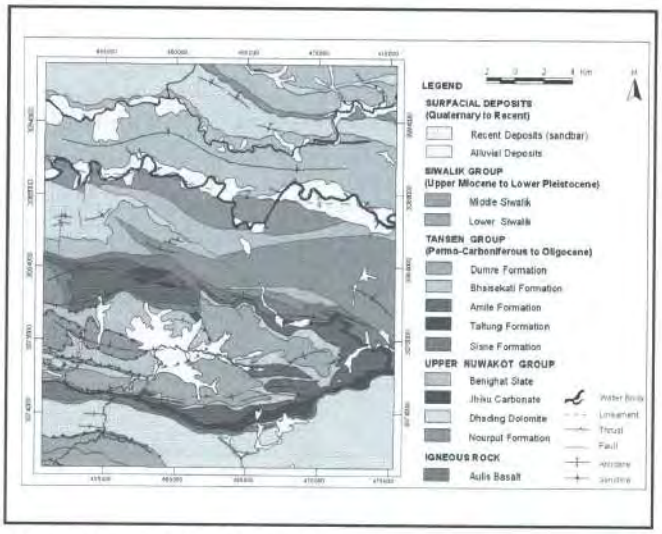


Fig. 1(c). Geological Map

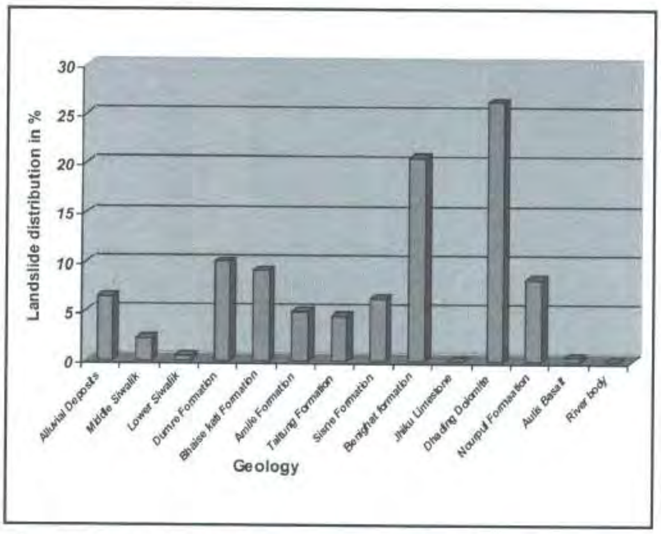


Fig. 1(d). Relation between Landslide Distribution and Geology

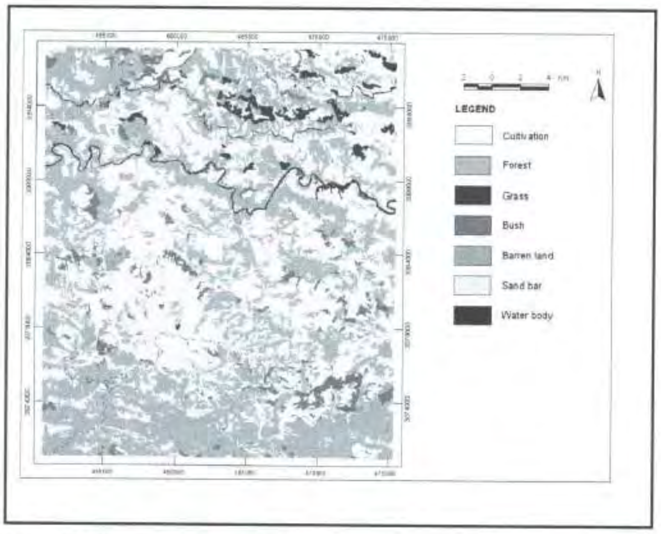


Fig. 1(e). Landuse Map

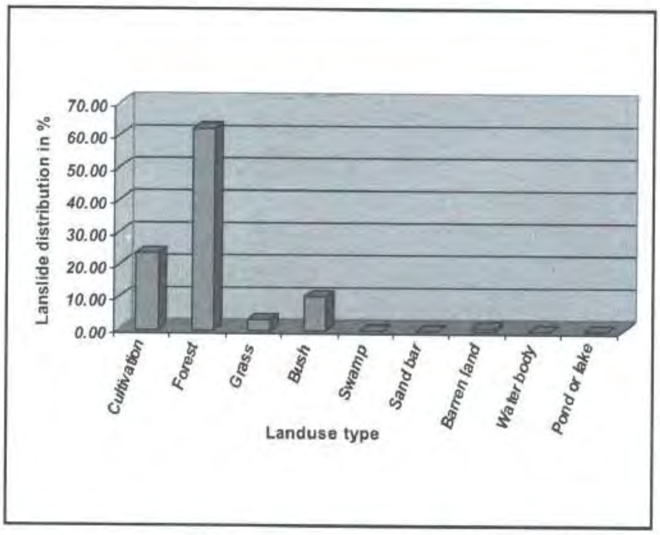


Fig. 1(f). Relation between Landslide Distribution and Landuse

Fig. 1. Various factor maps showing their relation with the landslide distribution

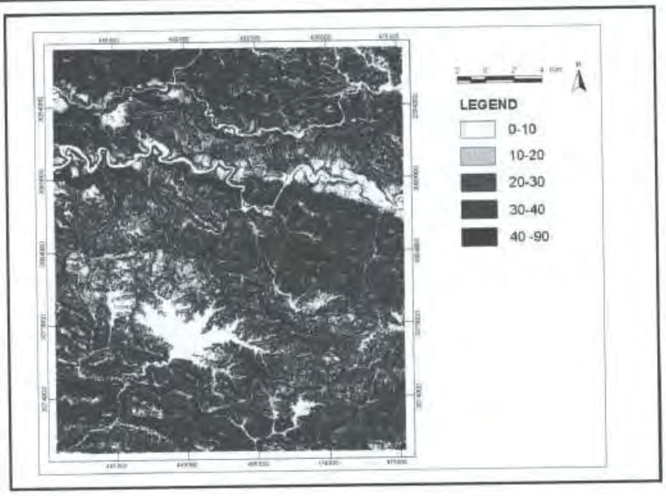


Fig. 1(g). Slope Map

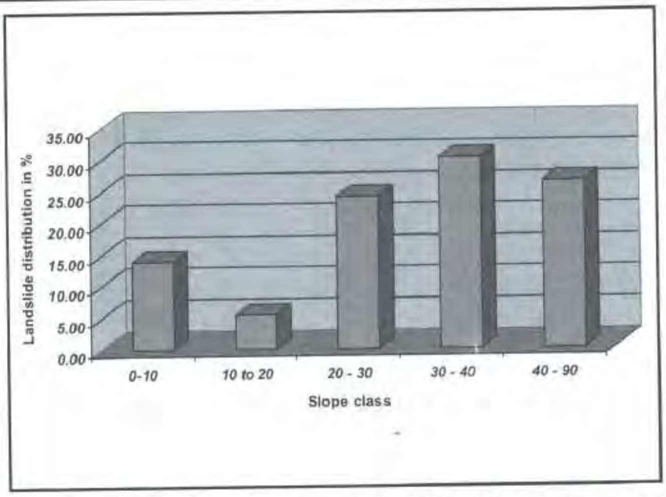


Fig. 1(h). Relation between Landslide Distribution and Slope

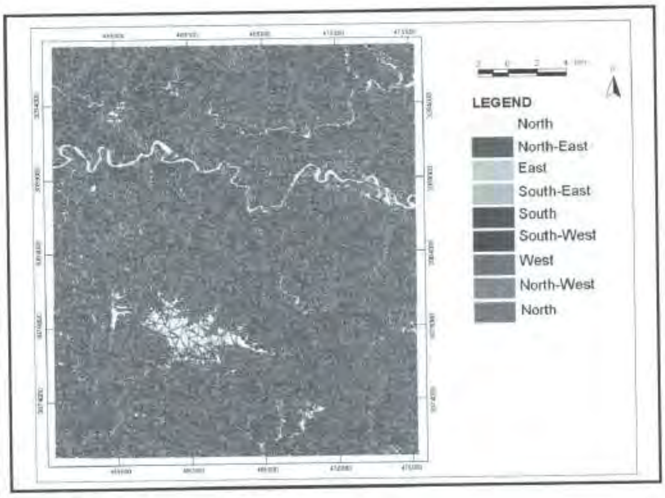


Fig. 1(i). Aspect Map

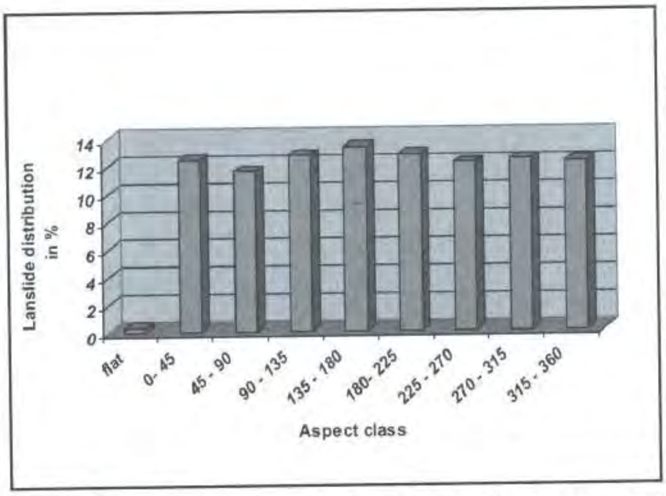


Fig. 1(j). Relation between Landslide Distribution and Aspect

REMOTE SENSING AND GIS APPLICATION IN LANDSLIDE HAZARD STUDY

Remote Sensing Data play a significant role in the evaluation of landslide susceptibility and the analysis of specific landslide events. Similarly, GIS has tremendous application potential and provides the users as a tool for effective and efficient storage of required data. Though the various statistical methods are in use for landslide hazard analysis, 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 aspect. The following formula (after Van Westen, 1993) was used in the present analysis.

Bivariate statistical analysis deals with one dependent variable like landslide occurrence and other independent variables such as factor/ parameter maps. Since, the statistical methods are considered the most appropriate approach for

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

Where,
W_i = Weight given to a certain parameter class
Densclass = Landslide density within the parameter class
Densmap = Landslide density within the entire map

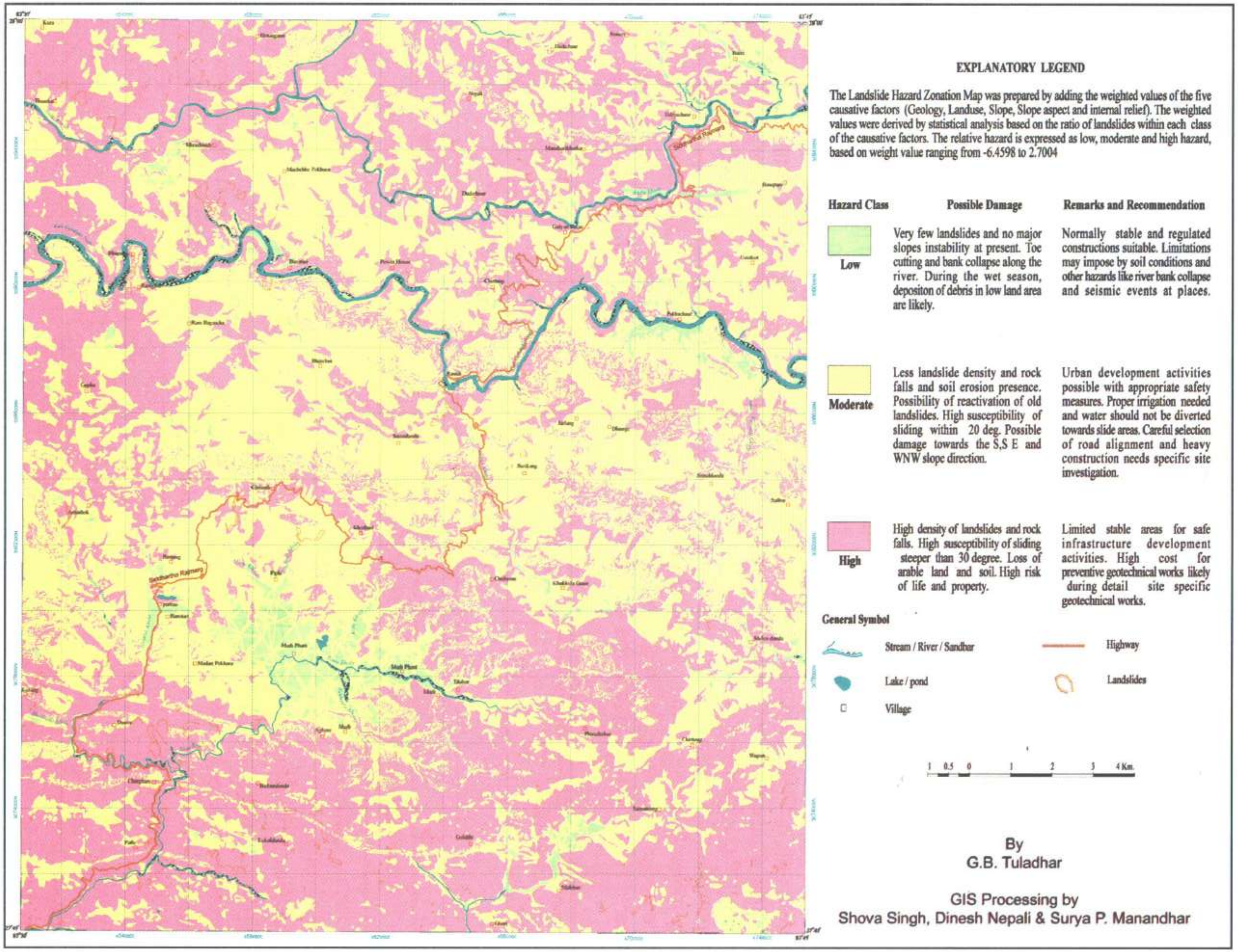


Fig. 2 Landslide Hazard Zonation Map

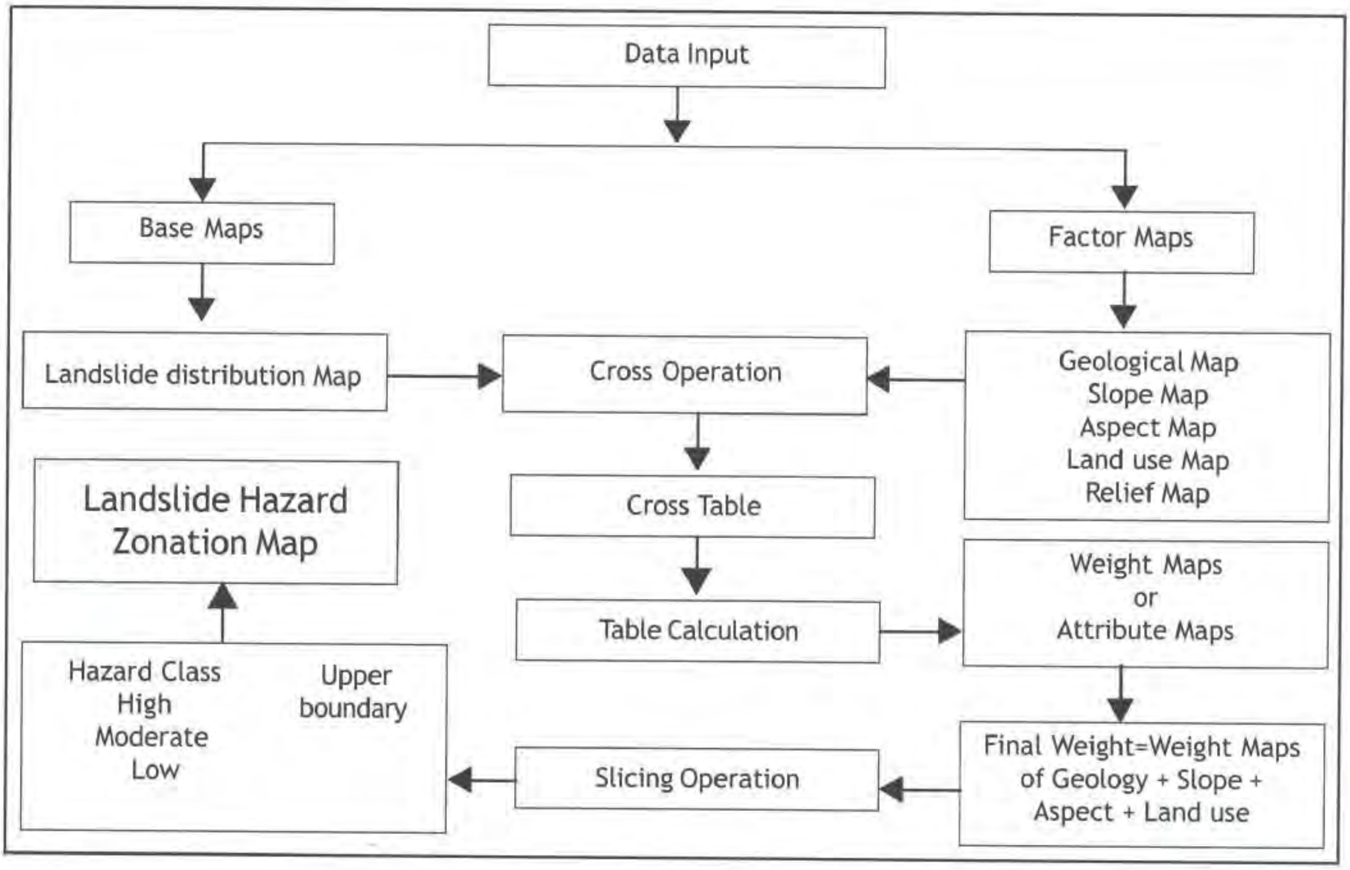
landslide hazard zonation at 1:25,000 to 1:50,000 scale, the landslide distribution map and other parameter maps were prepared in 1:25,000 and 1:50,000 scale.

INVESTIGATION RESULTS

Landslide is a general term used to describe the downslope movement of soil, rock and other organic materials under the influence of gravity, and also the landform that results. The instability of a slope is mainly governed by terrain parameters such as lithology and structural condition of the rocks, properties of overlying soil, slope gradients, vegetation, land use and human intervention acting on the slope conditions. Landslide and soil erosion are often observed throughout the study area caused by both natural as well as human activities like deforestation, improper hillslope cultivation, cultivation on old landslide colluvium deposits, riverbank encroachment, and construction activities. Lithological set up, unfavorable structural discontinuities, increase in pore-water pressure during monsoon season, high intensity rainfall, high degree of weathering, and high gradients with excessive mass of bed loads in the lateral rivers are some of the natural causes of landslides and soil erosion observed in the study area. In the areas with foliated and less competent rocks overlain by jointed quartzite and carbonate rock units, the landslides are very common. The cultivation usually carried out in the unconsolidated debris of old landslide mass has often found to be a major factor for generating new landslides that are observed throughout the study area. The specific impacts of these causative factors can sometime be mixed among themselves making it very complex and difficult to differentiate.

PREPRATION OF LANDSLIDE HAZARD ZONATION MAP

As the main output of the investigation, landslide hazard zonation map (Fig. 2) was prepared by dividing the entire study area into three categories based on the degree of a potential hazard from landslide. Since each class of the factor map has different weight value, the addition of all the weight value for a certain region was carried out during the hazard calculation. After the calculation of total weight for hazard coverage, the hazard zonation was classified into three different zones as low,



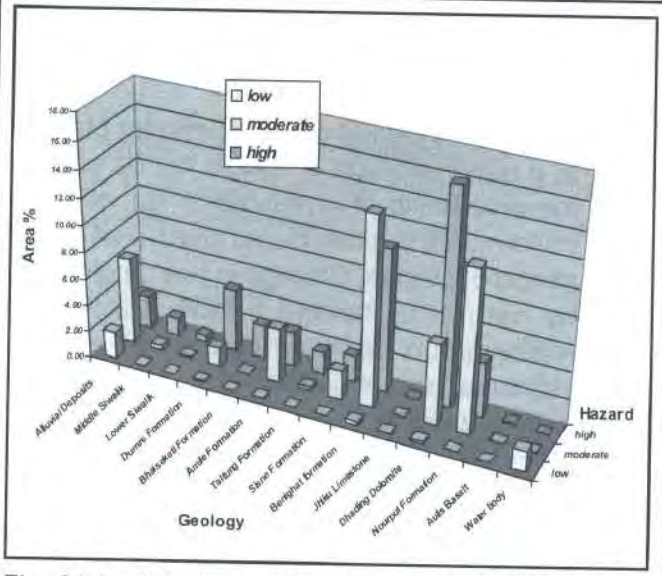


Fig. 3(a). Relation between Geology and Hazard

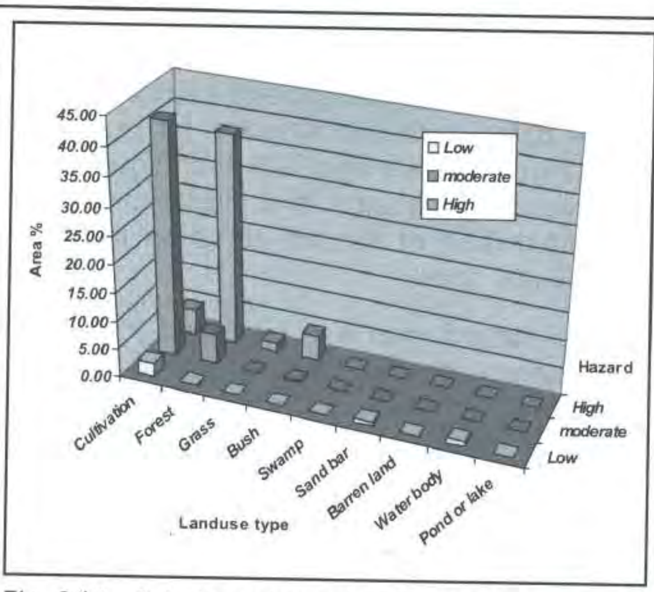


Fig. 3(b). Relation between Landuse and Hazard

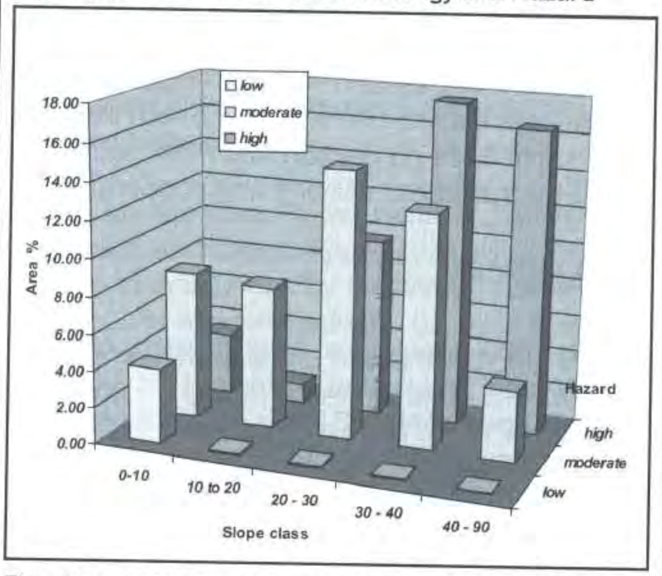


Fig. 3(c). Relation between Slope and Hazard

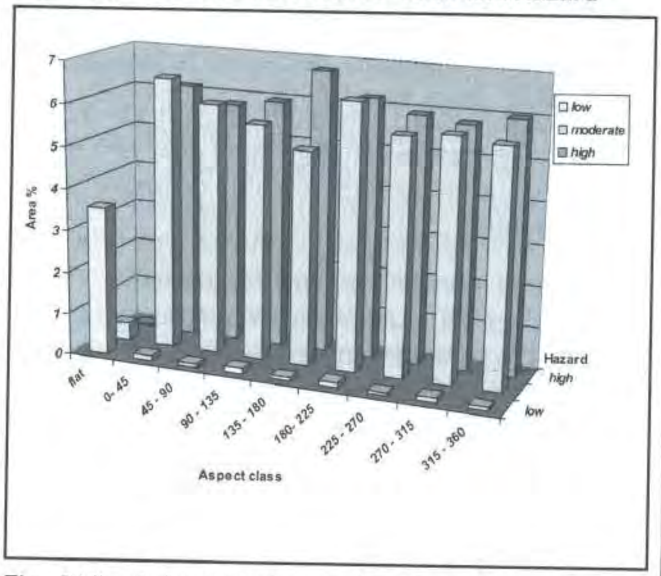


Fig. 3(d). Relation between Aspect and Hazard

Fig. 3. Relationship between the area percentages of various hazard zones and other causative factors

moderate and high hazard. The following Flow Chart illustrates the computation process.

RESULTS OF THE STATISTICAL ANALYSIS

The final landslide hazard zonation map with low, moderate and high hazard zones was overlaid with the landslide distribution map and the landslide densities were calculated in order to checkout how much of the landslide area falls within the three different hazard zones. In this case, almost 83.13 % of the landslides were found to be located within the high hazard zone, about 16.5 % in moderate and 0.3 % in low hazard zone, indicating the satisfactory precision of the adopted statistical method for landslide hazard zonation mapping. Similarly, the relationship between the area percentage of various hazard zones and other causative factors such as landuse, geology, slope and aspect were evaluated to identify the behavior of each factors. The following bar diagrams shows the relation between hazard categories and various causative factors (Fig. 3).

CONCLUSION AND RECOMMENDATION

- The methodology describes the calculation of the Bivariate Statistical model for landslide hazard analysis and GIS techniques for integrating the data in a model and final preparation of hazard zonation map at 1:50,000 scale.
- The hazard map was classified into low, moderate and high hazard zones based on the statistical evaluation of various causative factors related to slope instability and their relationship with landslide distribution.
- Most of the existing old and active landslide falls within the high hazard zone, indicating good reliability and satisfactory precision of Bivariate Statistical Model in landslide hazard zonation mapping.
- Altogether 299 Landslides of various sizes were observed within the study area and they are grouped as active, old, dormant and reactivated.
- The final landslide hazard zonation map (Fig. 2) shows 330 sq. km area covered by highly unstable zone forming almost 50% of the total study area whereas about 49% area is on moderate hazard zone.
- The rapid increase in the population density within the study area and other construction works carried out for various development activities will continuously convert forestland into agriculture land which will be responsible for reduction of stability condition of mountain slopes.
- Before planning of any development activities within the area the existing stability conditions of the terrain should be assessed so that the development activities may be implemented with minimum risk and environmental degradation.
- The landslide hazard zonation map with identification and delineation of landslide prone (unstable) area will be useful to planners in formulating appropriate landuse plans and development activities as well as to reduce the maintenance cost in future in early stage of planning process but it must be realized that it cannot replace detailed site investigation.
- The map is exclusively intended for planning at a regional scale. It should not be used as the only basis of investigation for individual building. It is time dependent and needs periodic revision. Change in any single factor by natural or human intervention needs reevaluation because change of a single factor can be sufficient to exceed the threshold for slope failure.

ACKNOWLEDGEMENT

The author is grateful to Mr. Pranab Lal Shrestha Director General, DMG for supporting the field program and guidance. My sincere gratitude is due to Dr. R. B. Shrestha, Deputy Director General for his keen interest and valuable suggestions. My sincere thanks are extended to the staff members of Remote Sensing Section and other sections of DMG for fruitful discussions and cooperation.

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Geology of Dhangadhi - Jogbudha area of Petroleum Exploration Block-1, Far Western Nepal

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INTRODUCTION

This field program was carried out in accordance with the annual field program of Petroleum Exploration Promotion Project/Department of Mines and Geology (PEPP/DMG) for the fiscal year 2007-2008 A.D. The field program was scheduled to carry out stratigraphy and structural investigation in the area for the preparation of geological map in the scale of 1: 2,50,000. The Investigation area covers 3000 square kilometer within the exploration block 1 (Dhangadhi), Far Western Nepal. (Fig.1).

The study area lies in the parts of Kailali, Doti, Dhangadhi and Kanchanpur district of Far Western Nepal and is bounded by latitude 28° 25' 00"N to 29° 15' 00"N and longitude 80° 03' 00"E to 81° 00' 00"E, in the Topo sheet published by the Survey Department, Government of Nepal and the field investigation data were plotted on 1:25,000 scale Topo maps.

The study area is easily accessible and can be approached via East–West Highway from Attariya. The Dhangadhi – Dandeldhura road connects the East-West Highway at Attariya and can also be approached from Champapur. An unmetalled road connects Budar to Jogbudha from where the area can be easily accessed up to Mahakali River.

OBJECTIVE

The objectives of the present investigation are:

- to prepare a geological map between Dhangadhi- Mahakali area.
- to establish the Stratigraphy and structure of Petroleum Exploration Block–1 Dhangadhi.

METHODOLOGY

Geological mapping is carried out using topographical base maps of 1:25,000 published by Survey Department, Nepal, which are photo reduced to 1:50,000. Geological information derived from unpublished Geological map of Petroleum Exploration Promotion Project and Department of Mines and Geology at the scale of 1:63,360 and other published geological maps are compiled at the scale of 1:50,000 using photo-reduced topographic base map. Sub–surface geological information are based on Report on the Seismic Data Interpretation of the western Terai, Digicon Singapore (1991) and Source and Seal Study Report by Alconsult International Ltd.(1993).

The area has been studied by different Nepalese geologists in connection with the regional geological mapping as well as mineral exploration work. Kayastha (1979) mapped the area in connection with the geological study of Kailali Kanchanpur area, Far Western Nepal. Hunting Geology and Geophysics Ltd. (1980) had carried out Photo-geological work and prepared Photo geological map of Terai-Churia and Lesser Himalaya region of western Nepal.

GEOLOGY

The study area lies in a part of Mahabharat and Churia Ranges. The Churia Range forms an irregular terrain like ridges and valley consisting of sandstone, shale, mudstone and siltstone. The Mahabharat Range consisted of sedimentary and metamorphic rocks. The drainage pattern of the area is mainly dendritic.The study area is drained by a major river called Mahakali river and other rivers like Machheli Nadi , Banda Nadi, Radha Nadi and Rangun Khola. Except Rangun Khola other rivers are flowing almost north south direction

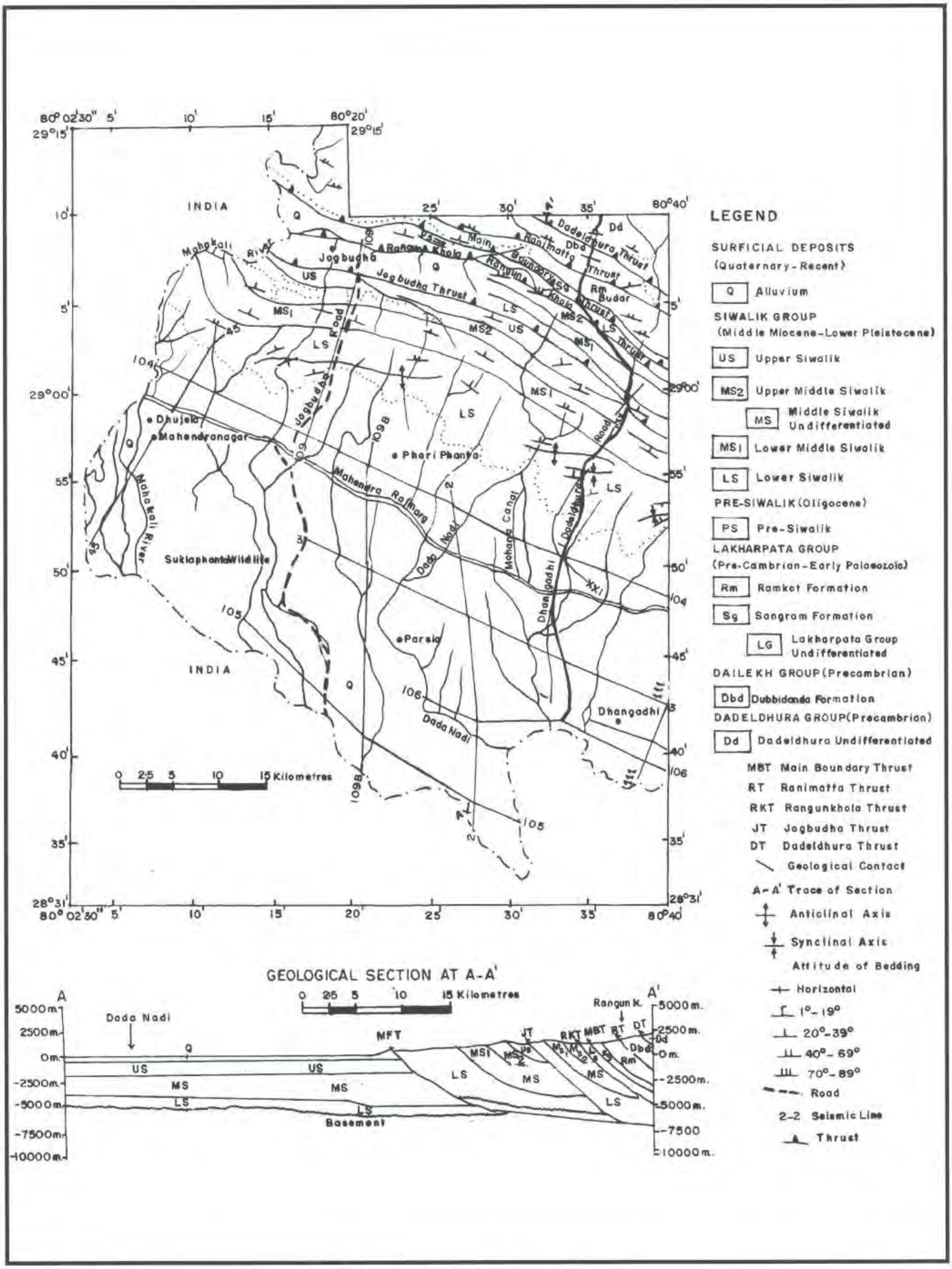

Fig.1. Geological Map of Dhangadhi-Jogbudha Area, Far Western Nepal

where as it is flowing from east to west direction and drain into Mahakali River.

The rocks of Metamorphic Group is exposed in the northern part of the mapped area and is thrusted over the rocks of Siwalik Group along the Main Boundary Thrust (MBT) (Fig.1). The oldest rocks of Metamorphic Group exposed in the study area is Dubbidanda Formation and consists of grey, greenish grey chloritic phyllite, gritty phyllite, white massive quartzite and talcose phyllite The dark gray slaty phyllites are also noted with quartz lenses and veins along the foliation plane. The silicious dolomite and argillaceous limestone are also interlayering within the phyllite and quartzite beds.

The metasedimenrtary rocks exposed in the study area is grouped into Lakharpata Group and this group can be divided into two formations in the present area viz. Sangram Formation and Ramkot Formation. The oldest formation exposed in the study area is Sangram Formation and consists of greenish grey to carbonaceous shale (Fig.2) and massive white grey quartzite (Fig.3) interbedded with greenish grey phyllites.The youngest formation of Lakhrapata group exposed in the area is Ramkot Formation and consists of pink sandstone with ripple marks and purple grey shale exposed along the Dhangadhi-Daduldhura road section (Fig. 4).

North of Rangun Khola section, a small outcrop of Pre- Siwalik rock is noted within the Siwalik Group

Fig. 3. Massive white Budar quartizite of Sangram Formation

which consists of light grey, grey quartzitic sandstone, purple shale, (PEPP/DMG. 2007) and maroon nodular clay. Lower Middle Siwalik Formation (MS1) consists of sandstone, mudstone, claystone, siltstone and shale. Upper Middle Siwalik Formation (MS2) is composed of grey to brownish grey arkosic sandstone, pebbly sandstone and claystone. Upper Siwalik Formation (US) is composed of massive conglomerate, coarse grained micaceous pebbly sandstone and reddish brown clay.

STRUCTURE

The structure of the mapped area is complex. In the study area, there are a number of major and minor folds and faults. The rocks of the Siwalik Group in the mapped area is bounded to the north

Fig. 2. Greenish grey shale of Sangram Formation

Fig. 4. Fine grained jointed sandstone of Ramkot Formation

by the Main Boundary Thrust (MBT) and to the south by the Main Frontal Thrust. Further to the south the Siwalik is concealed under the alluvium. In the mapped area, the Jogbudha Thrust is mapped along the Jogbudha ridge which separates Lower Siwalik Formation from Upper Siwalik Formation. The Rangun Khola Thrust is separating Lower Siwalik (LS) from Lower Middle Siwalik (MS1) along the Rangun Khola. Further west, this fault is concealed under the river beds up to Mahakali River. The Dubbidanda Formation of Dailekh Group is thrusted over the Lakharpata Group along the Ranimatta Thrust. The rocks of Dandeldhura Group is thrusted over the Dailekh Group along the Dandeldhura Thrust. The repetition of Siwalik bed observed in the study area is due to the folding and faulting nature of the formation. The general strike of the rock formation is NW-SE which is parallel to the general trend of the mountain chain and dip towards north east (Fig. 1).

CONCLUSION AND RECOMMENDATION

- Detailed geological mapping for structural and stratigraphic study of the area should be continued.
- Detailed geological work should be carried out to establish the stratigraphy of Far Western Nepal.
- Detailed structural interpretation should be carried out to identify the source, seal and reservoir of the area for hydrocarbon potential.

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The authors are grateful to Mr. Babu Raja Aryal Project Chief, PEPP for providing necessary facilities to conduct the field work and to Dr. R. B. Shrestha, Deputy Director General and Mr. A. K. Duvadi, Senior Divisional Geologist, DMG for going through the manuscript and valuable suggestions for the preparation of this report. Last but not least thanks are due to Mr. Rajan Kumar Thapa, Survey officer for carrying out the cartography work.

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Geological Studies and Section Measurement of Parts of Doti-Kailali Districts, Far Western Nepal

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INTRODUCTION

The field investigation was carried out in accordance with the annual field programme of Petroleum Exploration Promotion Project (PEPP), Department of Mines and Geology for the fiscal year 2063/64 BS. The fieldwork involved in carrying out geological section measurement of 50 km length and geological mapping mainly by geological traverses along major rivers such as Khutia Nala, Thuli Gad, Karmanas Gad, Machhali Khola, and its adjacent areas of Kailali, and Doti Districts of Far Western Nepal.

The study area lies in between latitudes 28° 50' 30"N to 29° 06' 37"N and longitudes 80° 30' 00"E to 80° 45' 00"E (Fig. 1). The study area lies in the parts of toposheets 2880 03A, 2880 03 B, 2880 03 C, 2880 03D, 2980 15 C and 2980 15D prepared by Survey Department, Government of Nepal (Scale 1:25,000) in 1998.

OBJECTIVES

The objectives of the investigation were:

- to carry out geological section measurement along various river sections
- to prepare geological map of the study area
- to collect petrogeochemical samples mainly from shale horizon for source rock investigation

METHODOLOGY

To identify the trace of major structural features such as Main Frontal Thrust (MFT) and Main Boundary Thrust (MBT), satellite images mainly Google earth image and aerial photos were studied. Available literatures on geology of Far Western Development Region were also reviewed before the fieldwork.

The following methods were adopted during the fieldwork:

- Geological mapping and section measurement were carried out using topographic base map in scale of 1:25,000.
- Lithological units and structural features were identified on the basis of field observation. Traverses were made along Godavari Khola, Khutia Nala, Machhali Khola, Kamala Khola, Thuligad and Karmans Gad, parts of the Dhanghadi-Dandeldhura Highway and adjacent accessible areas. 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 (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 investigated area is represented by sedimentary, metasedimentary and metamorphic rocks belonging to Quaternary sediments of Terai,

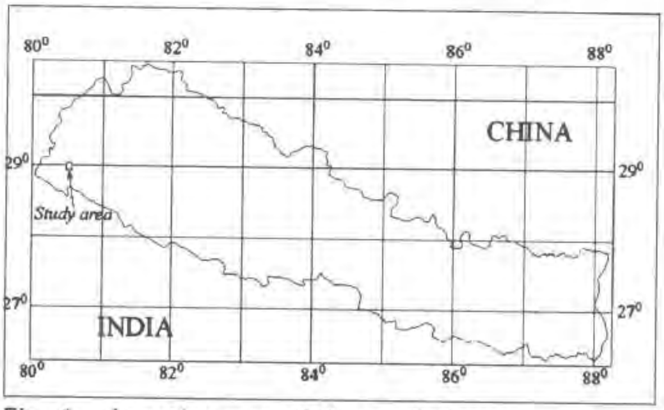

Fig. 1. Location map of the studied area

Siwalik Group of Sub-Himalaya as well as Lakharpata Group and Dailekh Group of Lesser Himalaya from south to north respectively. The Terai is the northern extension of Indo-Gangatic Plain. It consists of Quaternary sediments of different grain size. The rocks of the Siwalik Group consist of claystone, mudstone, siltstone, sandstone and conglomerate. The Mahabharat Range of the Lesser Himalaya constitutes the metasediments to metamorphosed rocks like shale, slate, dolomite, quartzite, phyllite etc (Kayastha, 1978/79; Bashyal, 1981 and Aryal, 1981/82). The geological setting and the stratigraphic sequence of the studied area are shown in Fig. 2 and Table-1 respectively.

In general, the strike of the rock in the area is NW-SE, sometimes NE-SW and the bed dips NE to NW at an angle of 15°- 68°.

Dailekh Group

Dubbidanda Formation

It is the oldest formation in stratigraphic sequence of the studied area. It consists of grey to greenish grey chloritic phyllite and grey quartzites with amphibolites. It is well exposed along the Gadsera Gad and upper part of the Thuli Gad. Garnet bearing phyllite is also observed near the contact of intrusive granite gneiss zones (Kayastha, 1978-79). The amphibolite is also observed within the phyllites and quartzites of this formation.

Lakharpata Group

This Group is exposed to the north of the Main Boundary Thrust. It comprised of pink quartzitic sandstone, purple shale, grey shale and stromatolitic dolomite. In this group, the Sangram,

Table-1: Stratigraphic Sequence (after Kayastha, 1978-79)

Age	Group	Formation	Lithology
Quaternary			Alluvial, gravels, sand, silt, and clay
Middle Miocene - Lower Pleistocene	Siwalik Group	Upper Siwalik (US)	Conglomerates, poorly sorted with irregular bands and lenses of sandstone and minor intercalations of reddish brown, yellow, brown, grey clays and mudstone.
		Upper Middle Siwalik (MS2)	Medium to coarse grained, light grey to grey, arkosic pebbly sandstones interbedded with grey, dark grey, brown mudstone. 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 red coloured mudstone, shale, siltstone and occasional marl.
Precambrian-Early Paleozoic	Lakharpata Group	Gawar Formation (Gw)	Grey stromatolitic dolomite with white grey subordinate sandstone and shales.
		Ramkot Formation (Rm)	Pink quartzitic sandstone with purple grey shales.
		Sangram Formation (Sg)	Greenish grey to gray carbonaceous shale with some light grey quartzites.
Precambrian	Dailekh Group	Dubbidanda Formation (Dbd)	Grey and greenish grey chloritic phyllite, gritty phyllite and white grey quartzites with amphibolites.

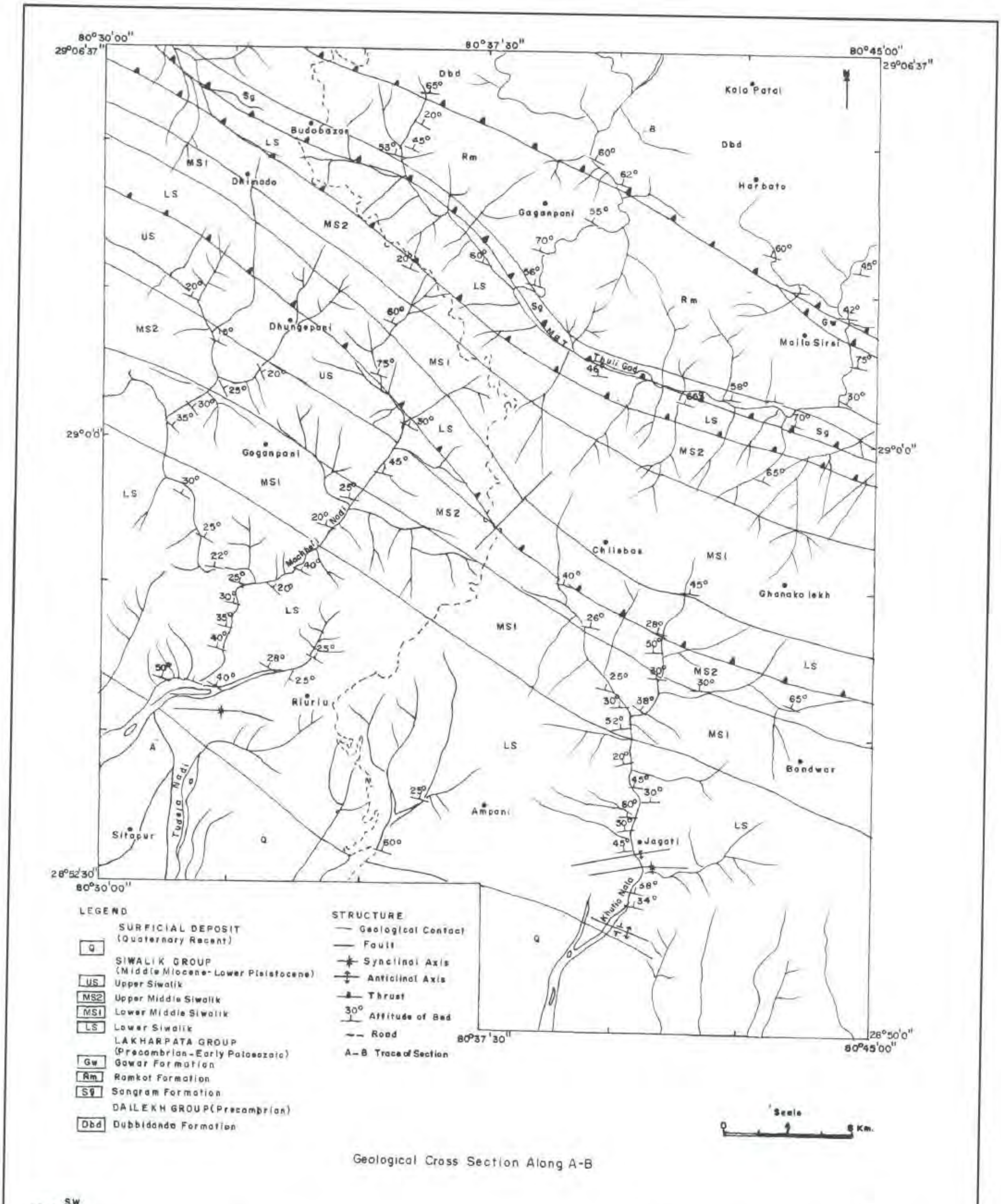

Fig. 2. Geological Map of parts of Doti- Kailali Districts, Far Western Nepal

Ramkot and Gawar formations are present in the studied area. The Sangram Formation is at the base of the Lakarpata Group.

Sangram Formation (Sg)

It is the oldest rock formation of Lakharpata Group in the study area comprising of greenish grey to grey, carbonaceous shales with grey quartzites and occasional bands of dolomites and slates. This formation extends from north of BP Nagar to south of Budar of Doti District. This Formation is clearly exposed along the Thuli Gad Section of the studied area (Fig. 3).

Ramkot Formation (Rm)

The outcrop of this formation comprises mainly pink quartzitic sandstone with purple to grey shales and slates (Fig. 4). Quartzitic sandstones are thick to medium bedded and interbedded with shale and dolomites at some places. Average thickness of the individual bed in this formation ranges from 10 cm to 60 cm. Most of the sandstones are very compact and forms quartzitic appearance. In the west of BP Nagar at Gadsera Gad, pink coloured conglomerate of thickness up to 30 cm is observed.

Shale is very thinly bedded and also found as thin intercalations with sandstones and dolomites. The shale is purple, green and grey colour. Its thickness varies from 35 cm to 75 cm. Dolomites are thinly bedded. Its colour varies from pinkish white to grey. At places very thin algal lamina can be observed in the dolomite.

Gawar Dolomite (Gw)

Grey stromatolitic dolomite with white, grey subordinate sandstone and shale are observed in the Gadsera Khola of Doti district, whereas no Gawar dolomite is observed in the Thuli Gad section (Fig. 5).

Siwalik Group

In the studied area, the Siwalik Group (Middle Miocene-Lower Pleistocene) is composed of sandstone, mudstone, siltstone, shale, clay and conglomerate (Figs. 2 and 6). The Siwalik Group is bounded by Main Frontal Thrust (MFT) to the south and Main Boundary Thrust (MBT) to the north. The sandstone of the Siwalik Group is medium grained, porous, and permeable. It can be considered as the potential 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 subdivided into the Lower Middle Siwalik (MS1) and Upper Middle Siwalik (MS2). All these formations are clearly well exposed in the Machhali Khola section (Fig. 6).

Fig. 3. Greenish grey carbonaceous shale of Sangram Formation in Thuli Gad

Fig. 4. Pink Quartzitic Sandstone with purple Shale observed in the Gadsera Gad

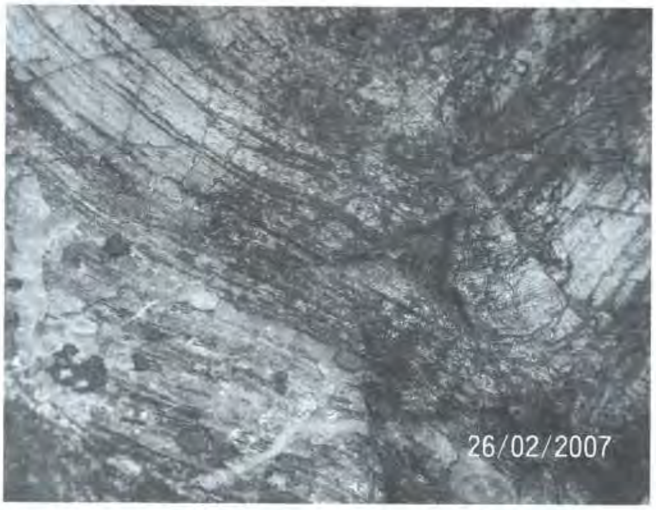

Fig. 5. Grey stromatolitic dolomite observed in the Gadsera Gad section

Lower Siwalik (LS)

It is the oldest formation of the Siwalik Group. It is composed of fine to medium grained light grey to grey sandstone interbedded with purple to variegated clay (Fig. 7). It occupies the southern part of the mapped area just north of Terai plain. It is also repeated at Pallo Basu in the middle part of the Siwalik Range (Fig. 2) and also south of Main Boundary Thrust (MBT).

Thickness of the sandstone increases towards the top. It is comparatively rich in mica mostly biotite. Sandstone beds are very thick and attain unto 2 m. Plant fossils are present at some places. Purple clays are taken as the index horizon in the Lower Siwalk. The thickness of the individual beds of clay and shales vary from 1.3 m to 2.5 m.

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 shales. 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

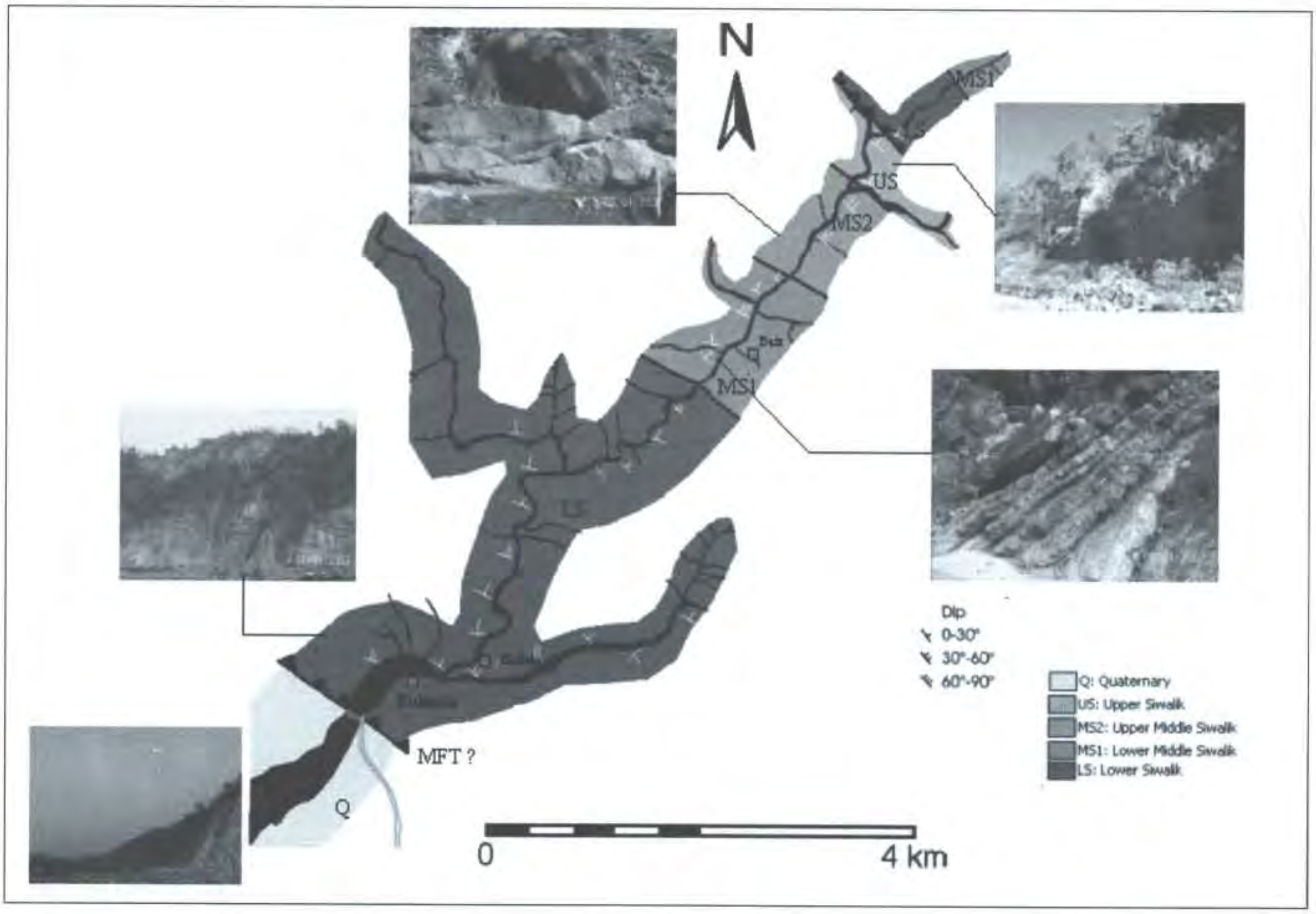

Fig. 6. Geological map along Machhali Khola, Kailali District

sandstone becomes more coarse, gritty and eventually pebbly towards the top. Plant fossils are found in the grey shales and mudstones.

The Middle Siwalik is repeated two times in the mapped area (Fig. 2). 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. Sandstone of MS1 is light grey to grey coloured, medium grained and interbedded with green to greenish grey shale (Fig. 8). It is mainly characterized by arkosic sandstone in the area. It extends from Khutia Nala to west of Machhali Khola with more or less uniform thickness. The Lower Middle Siwalik is also repeated two times in the mapped area due to faulting.

Plant fossils are well preserved in the mudstone, shales along the Khutia Nala and Machhali Khola. The dip direction of the MS1 is NE-SW, sometimes NW-SE and amount of dip is 25°-65°.

Upper Middle Siwalik (MS2)

The Upper Middle Siwalik (MS2) conformably overlies the subunit MS1 with gradational contact. It is mainly composed of gray to grayish white fine to medium grained pebbly sandstone with little intercalation of gray to grayish white shale and clay. Interbands of pebbly conglomeratic horizons along with occasional silty sandstone are very common (Fig. 9).

The individual bed of clay varies from 1.25 m to 3.5 m in thickness. The plant fossils are well preserved in grey clays. The thickness of the individual sandstone bed varies from 2 m to even more than 8 m. The sandstones are often pebbly and at places 1.5 to 3.2 m bands of conglomerate are found. The pebbles of pebbly sandstones are made of mainly white, pink quartzites, sandstone and clay fragments.

Upper Siwalik

The Upper Siwalik consists of poorly sorted homogenous to heterogeneous with irregular bands of sandstones with some intercalations of reddish brown gray sandy clays. It overlies Middle Siwalik with gradational contact. In the study area, one discontinuous band of the Upper Siwalik sediments is exposed in NW- SE direction. Its true thickness is unknown. Conglomerate beds consist of sub rounded pebbles and cobbles of different coloured quartzites, dolomites and older Siwalik rocks (Fig. 10). These are embedded in the calcareous, coarse grained, sandy matrix, sometimes mixed with argillaceous materials. The maximum diameter of the cobble is 40 cm. Sandstones are medium to coarse grained and grey coloured.

Fig. 7. Outcrop of the Lower Siwalik near the Kolmuda in the right bank of Machhali Khola

Fig. 8. Medium grained grey coloured sandstone with grey shale of MS1 observed at Machhali Khola

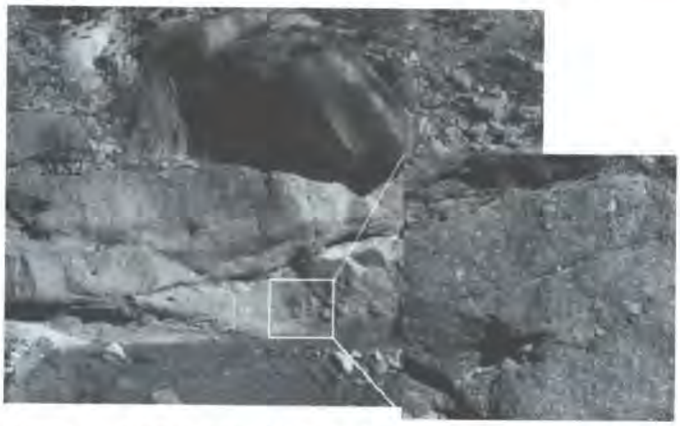

Fig. 9. Pebbly sandstone of Upper Middle Siwalik (MS2) observed in the Machhali Khola

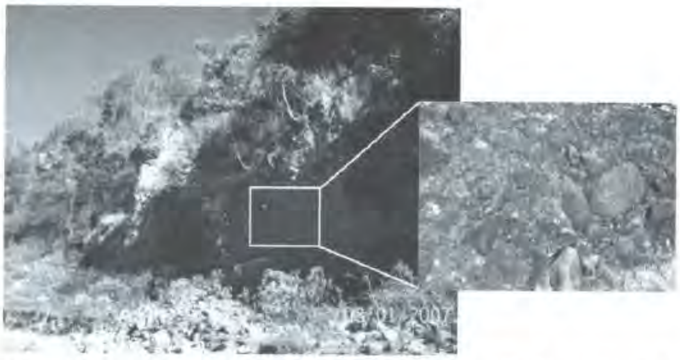

Fig. 10. Conglomerate of Upper Siwalik having sub rounded pebble-boulders exposed in Machhali Khola section

GEOLOGICAL STRUCTURE

The Main Boundary Thrust (MBT) separates Tertiary sedimentary Siwaliks from the earlier Tertiary and the older rocks in the area. The trend of MBT is almost NW to SE direction. This thrust can be distinguished in the field because of strong lithological contrasts across the thrust plane. Many landslides, micro folds, joints, and shearing effect is the strong evidence for thrusting. This fault has sinuous nature which might have been due to the over riding effect of the Pre-Tertiary sediments upon the Siwaliks.

Some of the anticline folds are observed in the Lower Siwalik rocks mainly in Khutia Nala and Machhali Khola. Two distinct anticline folds are observed near lower Hatkoli and upper Hatkoli village along Khutia Nala section (Fig.11). Besides these, many small drag folds are also observed along the MBT.

GEOLOGICAL SECTION MEASUREMENT

Thickness of various rock units and formations were measured in different streams/ kholas in the studied area (Figs. 12 and 13). Upper Siwalik having thickness more than 280m is observed in the Machhali Khola. No Upper Siwalik (US) is observed in the Khutia Nala. Upper Middle Siwalik (MS2), Lower Middle Siwalik (MS1) and Lower Siwalik (LS) were observed in both Machhali Khola and Khutia Nala sections. Thickness of MS2 measured in both sections is similar, whereas MS1 is quite thicker in Machhali Khola section. Similarly, Lower Siwalik (LS) observed in the Machhali Khola is quite thicker than in Khutia Nala section. Thicknesses of different rock units/formations measured in different sections is presented in Tables-2 and 3.

No Gawar Dolomite (Gw) is observed in Thuligad section. Thickness of the Gawar dolomite is 370 m as observed in the Gadsera Gad. Thickness of the Ramkot Formation (Rm) is 1210 m in the Thuligad section but it has only 860 m thickness in Gadsera Gad section. Sangram Formation (Sg) has more or less equal thickness in both sections (Table-3).

Fig. 11. A local anticline fold observed in the Lower Siwalik near the Hitkoli Village in Khutia Khola

CONCLUSION

Sedimentary rocks belonging to the Siwalik Group of Sub-Himalaya and metasedimentary and metamorphic rocks belonging to the Lakharpata Group and Dailekh Group of Lesser Himalaya represent the area. Detail geological sections

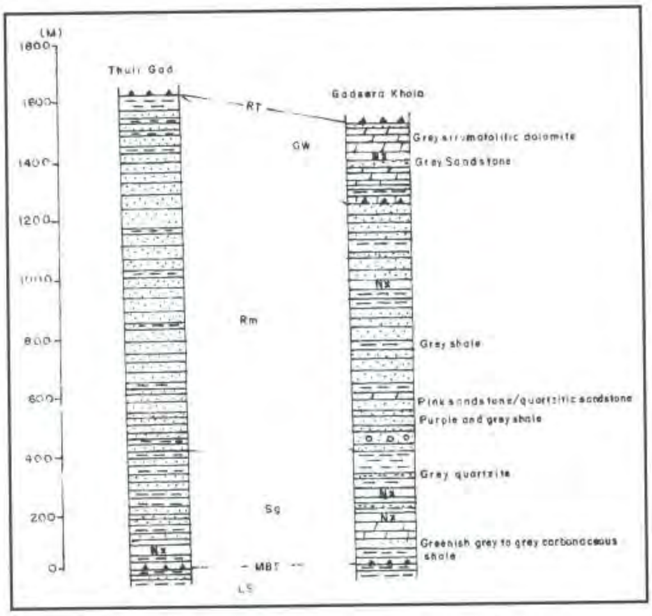

Fig. 12. Lithostratigraphic section measured in Thuligad and Gadsera Khola

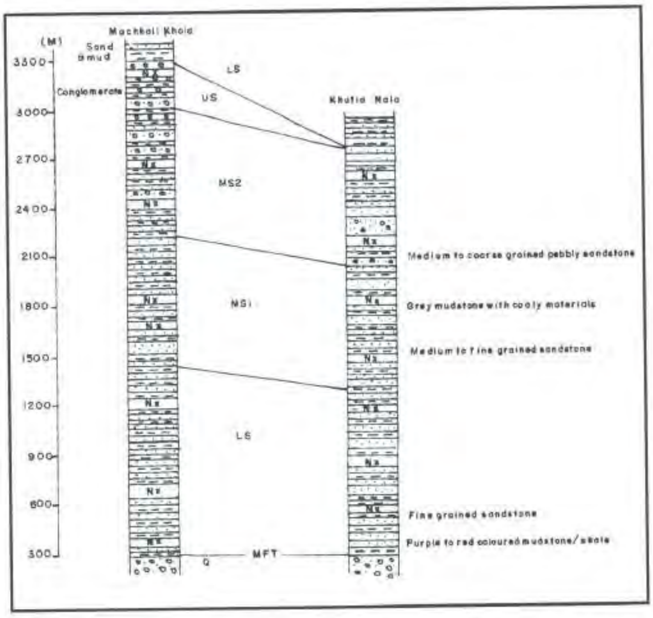

Fig. 13. Lithostratigraphic Section measured in Machhali and Khutia Nala.

Table- 2: Thickness of different geological formations in Machhali Khola and Khutia Nala

Group	Formation	Measured Thickness	
		Machhali Khola	Khutia Khola
Siwalik	Upper Siwalik (US)	+ 280m	-
	Upper Middle Siwalik (MS2)	750 m	750 m
	Lower Middle Siwalik (MS1)	775 m	750 m
	Lower Siwalik (LS)	1460 m	1310 m

Table-3: Thickness of different geological formations in Thuli Gad and Gadsera Khola

Group	Formation	Measured Thickness	
		Thuli Gad	Gadsera Khola
Lakharpata	Gawar (Gw)	-	370 m
	Ramkot (Rm)	1210m	860m
	Sangram (Sg)	380 m	350m
Dailekh	Dubbidanda (Dbd)	-	-

measurement of different rock units / formations along major streams and kholas were carried out in the studied area. Different geological contact and thrusts were identified to trace the lateral extension. More and more satellite images should be used to identify the thrust / faults and geological contact more precisely in the studied area. Furthermore detail geological studies should be carried out to identify the lateral extension of different rock units and formations. More samples should be collected from different rock units to identify the possibility of rock as source or reservoir for the hydrocarbon exploration.

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Inspection and Monitoring of Operating Mines in Different Parts of Nepal

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INTRODUCTION

The Department of Mines and Geology (DMG) is the governmental organization which issues prospecting and mining licenses for minerals. The department has carried out exploration and research work in mineral sector. As per the Mines and Mineral Act 2042, and Regulation 2056, DMG has been regularly inspecting and monitoring the different mines which had been issued license to operate mine in the country. DMG has targeted to inspect and monitor 42 different mines located in different parts of the country in the fiscal year 2063/ 2064. This report covers 17 different mines out of them 4 different mines were followed up in which two mines are of ordinary construction material and related to District Development Committee (DDC), Dhading. This report is based on the inspection and monitoring of different operating mines in Dhading, Gorkha, Arghakhanchi, Tanahu, Kaski, Makawanpur and Palpa districts of Nepal.

OBJECTIVES

The main objectives of the inspection and monitoring of the mines are:

- To inspect and evaluate the exploitation and mining activities carried out by the lease holder for different mines.
- To check whether the direction given during the previous inspection visits were followed or not.
- To check whether the mining work is satisfactory as per the approved mine plan or not.
- To suggest or recommend further actions if the previous suggestion/directives were not followed by the license holders.
- To have the field verification of the mining scheme submitted by the applicant before awarding the mining license.
- To give necessary suggestions and directions to exploit the deposit by applying proper mining methods in an environment friendly manner in compliance with the existing mineral laws and regulations of Government of Nepal.
- To check whether the royalty is paid as per the production and collect production statistics.

METHODOLOGY

Taking into consideration of the technical (mine plan, mining method, mining parameters etc.) environmental (physical, biological and socio-economical) and legal (Mines Rules and Regulations) parameters, the team inspected all those mines, mining activities, monitoring of environmental impact due to mining and gave necessary suggestions and directions to the mine operations/lease holders. For this the inspection team adopted the inspection methodology developed by the Department.

STATUS OF INSPECTED MINES AND DIRECTIVES GIVEN

The regular field inspection report submitted by the team of all the mines/quarries mentioned above are categorized based on the types of mineral commodities and presented below.

ORDINARY CONSTRUCTION MATERIALS

The inspection and monitoring of mines of ordinary construction materials such as raw stone and sand were carried out along the Prithvi Rajmarg (Kathmanu- Malekhu part). The raw stone and sand quarries operating in Dhading District were in operation without forming benches and not in environment friendly manner. Sand quarry running at Baireni in Dhading district is not in safe condition with bench height of 25 m. or so. Raw stone mine at border of Dhading and Kathmandu districts at Khatripauwa is also running in an unsafe condition and labours were not using safety equipment. All these licensees were directed through the concerned DDC to work by making small benches from top to bottom and to follow safety measures by providing safety boots and helmet to the workers.

NON-METALLIC INDUSTRIAL MINERALS

Talc

Three talc mines were inspected and monitored, out of which two mines were in operation and one was not operating due to local disturbance. Local source mentioned that in the Talc mine of Singha Khanij Udyog at Pumdi-Bhumdi in Kaski District, local peoples are demanding more financial support for local development. In the Talc mine of Gautam Khanij at Manapang in Tanahu District, production of talc was about 212 metric ton upto Poush 2063. Dust Nepal Pvt. Ltd. at Phirphire of Tanahu District, had started development work but production was not started until Poush 2063. There was poor waste management and safety measures were not adopted for the labours in the Talc mine of Gautam Khanij Udyog. Instruction was given to have effective waste management system and follow safety measures. At the same time, suggestion was given to work under the direction and supervision of technical experts.

In the mine of Singh Khanij at Pumdi-Bhumdi of Kaski District, suggestion was given to start the mining work as early as possible in close co-ordination with the local organization. In the quarry of Dust Nepal Pvt Ltd, there was construction of gabion wall along the bank of small tributary, which happened to be the implementation of instruction given during the last visit. All of the mine owners were suggested to follow the term s and conditions as mentioned in the mining scheme and to increase the production..

Marble

The marble mine owned by Laxmi Marble Pvt. Ltd. was not in operation during the inspection period. There is no environmental impact in the quarry area. Clearance of approach road was started. The industry is not getting suitable blocks for marble slab. The mine owner is instructed to have production work regularly and follow the terms and condition mentioned in the mining plan. It was recommended that marble produced can also be used as in Chips, Powder and Aggregate as a by-product in case of unsuitability for marble slab production.

Limestone

Eight limestone mines were inspected and monitored. Among them, Annapurna Quarry and Hetauda Cement Industry (HCI) which were mining Jogimara Limestone were followed up for inspection and monitoring purpose. There were local issues in the quarry owned by Hetauda Cement Industry (HCI) in Jogimara area. There was no production in Jogimara side and exploitation work was on the Gorkha side only. A minor landslide had occurred near the Pakhobari area inhabited by Chepang people. They are raising the concern that exploitation work should be stopped in the periphery area of Chepang village. Waste management was poor and there may be debris flow in rainy season if precaution is not taken in Jogimara area. Suggestions were given to adopt better waste management system and to have a detail research work whether the continuation of mining is possible or not. At the same time, local issues should be solved in consultation with the local representatives and other stakeholders. Table-1 summarizes the production of limestone from different quarries in the Fiscal year 2063-064.

In the quarry area of Annapurna Quarry Pvt. Ltd., there was regular production. Waste management is not proper, soil material are dumped in the Jawan Khola causing environmental problem (Fig. 1). Suggestion was given to conserve the top soil instead of dumping in the Khola and have and effective waste management. There is extension of approach road on the upper part of mine area and green plantation is growing in the top area.

These are the implementation of the instruction given during the last visit of the quarry area.

There was development work in the quarry area of Dynasty Industry Nepal Pvt. Ltd. No impact from the mining activity is observed in the water supply intake area. Gabion wall is being constructed near the tributary of water supply area. Local representatives are forcing to the industry that cement plant should be established in Arghakhanchi District itself to have employment opportunities for local people. During the inspection period, there was no supply of limestone to the plant area. Instruction was given to have good waste management and to carry out the mining work in the close co-ordination with the stakeholder.

The limestone mine of Dynasty Industry Nepal Pvt. Ltd. at Narapanai in Arghakhanchi District and two mines of Hetauda Cement Industry Ltd in Makawanpur District were operated with mechanized mining method (Fig. 2). Annapurna Quarries and Hetauda Cement Industry Ltd. (Previous Agriculture Lime Industry) located at Jogimara, Dhading District were operated with semi-mechanized mining method where as the limestone mine of Ajay Raj Sumargi was operated with manual method of extraction.

In the Bhainse and Okhare mines of Hetauda Cement Industry, mining machineries such as excavator, tipper, compressor, drill machine were used. Bench height up-to 7 meter, burden 3 meter, spacing 2.5 m. and the drill holes of 100 mm. diameter was observed during field inspection.

The inspected mines are running in contract basis. The contractor has given priority to increase production rather than to follow safety measures. Concern for the safety of workers was not adequate. In the Majhuwa area of Okhare mine, wastages were kept improperly. In the Bhainse area, there is high rate of erosion and siltation in the tributary. Limestone extracted from this quarry is blended with those having high CaO. Chepang peoples have raised the question in the continuation of mining at Jogimara areas in the mine of Hetauda Cement Industry as there was minor landslide in the private cultivated land near quarry site. Development work was started in the Limestone mine of Ajay Raj Sumargi. Mining is done manually and there is no adverse environmental impact. Proper canalization for drainage is not done in the mine of Annapurna Quarries Pvt. Ltd. Wastages are thrown haphazardly. However, green plantation is being done in the upper part of the quarry area.

Mine development is being continued (at Narapani, Argakhanchi), in the quarry area of Dynasty Industry Nepal Pvt. Ltd. Limestone was stockpiled along the side of the mine development road. It is understood that local people are coordinating in the exploitation of limestone on condition that there should be more employment opportunities to them. No adverse impact is observed in the water supply intake site during the inspection period.

During the inspection visits, the instructions were given to the mine owners of different mines to make environment friendly and to follow safety

Fig. 1. Poor waste management in Annapurna quarry area

Fig. 2. Excavator used in operating mine

Table-1: Production of Limestone from different quarries in FY 2063/064 B.S.

S. No.	Quarry site	Quarry Site	Production in metric tonnes	Remarks
1	Annapurna Quarries Pvt. Ltd.	Jawang Khola, Dhading District	20860	Total production upto Poush 2063
2.	Hetauda Cement Udyog Ltd.	Jogimara, Dhading District	2250	Total production upto Bhadra 2063
3.	Hetauda Cement Udyog Ltd.	Bhainse, Makawanpur District	20007	Total production upto Mangsir 2063
4.	Hetauda Cement Udyog Ltd.	Okhare, Makawanpur District	15020	Total production upto Mangsir 2063
5.	Ajaya Raj Sumargi	Pandrang, Nibuwatar, Makawanpur	-	only development work.
6.	Dynasty Industry Pvt. Ltd.	Narapani, Arghakhanchi District	500	Total production Bhadra 2063

measures. Annapurna Quarries Pvt.Ltd. was directed to have proper waste management, to take sufficient care to prevent erosion and siltation, stopping of throwing wastage in the Jawang khola and to have effective canalization in the quarry.

In case of the mine of Hetauda Cement Udyog at Jogimara, instruction was given to have detail technical study of the quarry area whether the continuation of mining is possible or not. Similarly in the Bhainse mine, instruction was given to construct additional gabion wall on the bank of Rapti khola. In the Majhuwa/Okhare area, direction was given to have effective waste management. For both mines of Hetauda Cement Udyog (in Makawanpur District), instruction was given to supervise and control the activities of mines by the industry itself but not by the contractor.

The mine owner of Dynasty Industry Nepal Pvt. Ltd. was directed to appoint technical personnels of related field to supervise and control the mining activities. In the same time proper attention should be given for waste management and to conserve the water supply system of the local people. In the quarry of Ajay Raj Sumargi, instruction was given to keep the records book properly and increase limestone production.

Fuel Minerals

The coal mine located at Devinagar Village Development Committee (VDC), in Palpa District was inspected during the field visit. Underground mining was done with board and pillar method. Mining was in the initial stage, there was no problem in the lighting system as well as in ventilation. The production up to15 Poush 2063 was about 154 ton of coal. The mine owner was directed to have proper waste management and to work as per mining scheme.

CONCLUSION

Thirteen mines in different part of Nepal were inspected, monitored basically for their mining activities and environmental impact due to mining and these were inspected one to two times a year as per DMG's annual inspection schedule.

Some of the mines were in operation at very low rated capacity and rest were operating but not in full capacity.

Most of mines were not following the directives given by DMG previously. They should be cautioned to follow the same completely.

During the inspection period, it was recorded that safety measures were not dealt in adequate manner.

Published Maps of Department of Mines and Geology

S.No.	Code No.	Title of Map	Scale	Year of Publication
1	GM1	Geological Map of Nepal	1:1,000,000	1994
2	GM2	Geological Map Central Western Nepal	1:250,000	1983
3	GM3	Geological Map of Mid Western Nepal	1:250,000	1987
4	GM4	Geological Map of Eastern Nepal	1:250,000	1984
5	GM5	Geological Map of Far Western Nepal	1:250,000	1987
6	GM6	Geological Map of Central Nepal	1:250,000	-
7	GM7	Geological Map of Kathmandu and Central Mahabharat Range	1:250,000	1980
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9	GM9	Geological Map of Parts of Tanahun Gorkha and Nawalparasi Districts. (72 A/5)	1:50,000	1996
10	GM10	Geological Map of Parts of Tanahun and Kaski Districts. (71 D/4)	1:50,000	1996
11	GM11	Geological Map of Parts of Syangja Kaski and Tanahun Districts. (62 P/16)	1:50,000	1999
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20	GM20	Geological Map of Parts of Myagdi, Baglung and Gulmi Districts. (62 P/7)	1:50,000	2003
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49	PEPP4	Geological Map of Exploration Block-5, Chitwan, Western Central Nepal	1:250,000	1998
50	PEPP5	Geological Map of Petroleum Exploration Block-6, Birganj, Central Nepal	1:250,000	2001
51	PEPP6	Geological Map of Petroleum Exploration Block-7, Malangawa, Central Nepal	1:250,000	2002
52	PEPP7	Geological Map of Petroleum Exploration Block-8, Janakpur, Central Nepal	1:250,000	2004
53	PEPP8	Geological Map of Petroleum Exploration Block-9, Rajbiraj, Eastern Nepal	1:250,000	2005
54	PEPP9	Geological Map of Petroleum Exploration Block-10, Biratnagar, Eastern Nepal	1:250,000	2006
55	PEPP10	Geological Map of Petroleum Exploration Block-1, Dhangadi, Far WesternNepal	1:250,000	2007
56	PEPP11	Geological Map of Parts of Palpa, Nawalparasi and Chitwan Districts, Western Nepal.	1:50,000	2008

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