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Collected By
H. Rahman, DDG, DMG

DEPARTMENT OF MINES AND GEOLOGY

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Publisher

Government of Nepal
Ministry of Industry
Department of Mines and Geology
Lainchaur, Kathmandu, Nepal
Telephone : +977-1-4414740, 4412065
Fax : +977-1-4414806
E-mail : dmgplan@mos.com.np

Collected By
H. Rahman, DDG, DMG

Foreword

The present Annual Report No. 6 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 helpful for the planners, geoscientists, geoscience students, entrepreneurs and others interested in geoscientific study and researches and investors for mineral base industries.

This reports being published as per the approved Annual Program of the Department for the fiscal year B.S.2065/66. 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.

Spmahato

Sarbjit Prasad Mahato
Officiating Director General

Editorial

Department of Mines and Geology is bringing as out this volume of 'Annual Report No. 6, DMG' while giving continuity in its publication as per its annual program for the fiscal year 2008-09. The Department has also given importance to the publication program with the purpose of disseminating the information on geoscientific survey and researches as well as mineral exploration activities annually to the public as well as concerned governmental and non-governmental agencies.

Updating and continuous publication of Geoscientific Reports, Geological Maps, Geohazard Maps and Engineering and Environmental Geological Maps of fast growing urban areas are of utmost importance for Infrastructure Development Planning, Landuse Planning, Hazard Mitigation, Landfill Site Selection etc.

Editorial Board is happy to bring this volume and would like to express its thanks to all the authors and staff of the Department for their contribution and effort in its publication.

Shakya

Rupendra Ratna Shakya
Chief Editor

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Preliminary Exploration of Cement Grade Limestone and Industrial Dolomite in Parts of Nawalparasi District, Western Nepal

Dinesh K. Napit
Department of Mines and Geology, Lainchaur, Kathmandu, Nepal

ABSTRACT

The study was carried out in northeastern part of Nawalparasi district to locate the cement grade limestone and dolomite band of industrial use. Geological mapping and sampling were done in the field. Samples were chemically analyzed. The study shows no cement grade limestone in the area. Dolomite occurs in Devchuli, Badachuli, Kaphaldada, and Kaligandaki areas. Industrial grade dolomite is found in Devchuli area which requires further exploration.

INTRODUCTION

The exploration for cement grade limestone and dolomite was carried out in northeastern part of Nawalparasi district in fiscal year 2064/65. The study area lies in toposheet no 2784 01C and D within latitude of 27°45'00"N to 27°50'00"N and longitude of 84°7'30"E to 84°20'00"E covering an area of 150 sq km. The area lies to the north of Narayangad – Daldale section of East–West Highway. Geological mapping and representative rock sample collection were carried out during the preliminary exploration work.

OBJECTIVES

The main objective of the exploration was to investigate and to locate the cement grade limestone and dolomite band of industrial use, find their extension, thickness and delineate the prospect area and collect the representative samples.

METHODOLOGY

During the field work geological traverses were taken along the roads, rivers and ridges for geological mapping and tracing the extension of limestone/dolomite in topographic base map of 1: 25000. Samples of carbonate rocks were collected by continuous chip and grab sampling method and they were analyzed in the chemical laboratory to determine their chemical grade.

GEOLOGY

Geological study of the area was carried out in the past (Dixit, A. M. 1989 and Pradhananga, U. B., 1994). The geological map of the area has also been published (DMG, 1996, PEPP, 1998 and DMG 1999). The stratigraphy of the area has been described according to DMG, 1996 and 1999.

The study area mainly lies in the Southern Lesser Himalaya and partly in Siwalik comprising of Paleozoic, Mesozoic and Cenozoic formations. The rocks are divided into three major divisions Nawakot Group, Tansen Group and Siwalik Group (Fig.1). The Nawakot Group is divided into Lower Nawakot Group and Upper Nawakot Group separated by an unconformity. Tansen Group of rock is overlying Upper Nawakot Group of rock separated by thrust fault. The Siwalik Group and Tansen Group are separated by Main Boundary Thrust (MBT).

Nourpul Formation

Rocks of Nourpul Formation occur in the southern and northern part of the study area. Lower part of this formation consists of medium grained white to varied colored quartzite with phyllite intercalation. The quartzites are characterized by ripple marks. The basal quartzite is succeeded upward by greenish grey to grey and purple phyllites. The phyllite contain thin layer of pink dolomitic limestone and bands of quartzite.

Dhading Dolomite

Dhading Dolomite are exposed and extended from the area of Dewchuli in the western part to Badachuli and Kaphaldada in the central part and to Kaligandaki River section in the eastern part (Figs. 2 and 3).

The dolomite is light grey to grey in color and fine grained. Intercalations of slates are present in the dolomite. Dome-shaped stromatolites are widely developed. The size of stromatolites varies from 2 to more than 20cm in width. Outcrop of dolomite shows moderate angle of dip and it is exposed mainly in the ridge as cap of the hillock. The Dhading Dolomite in the central and northern part of the study area shows varied thickness.

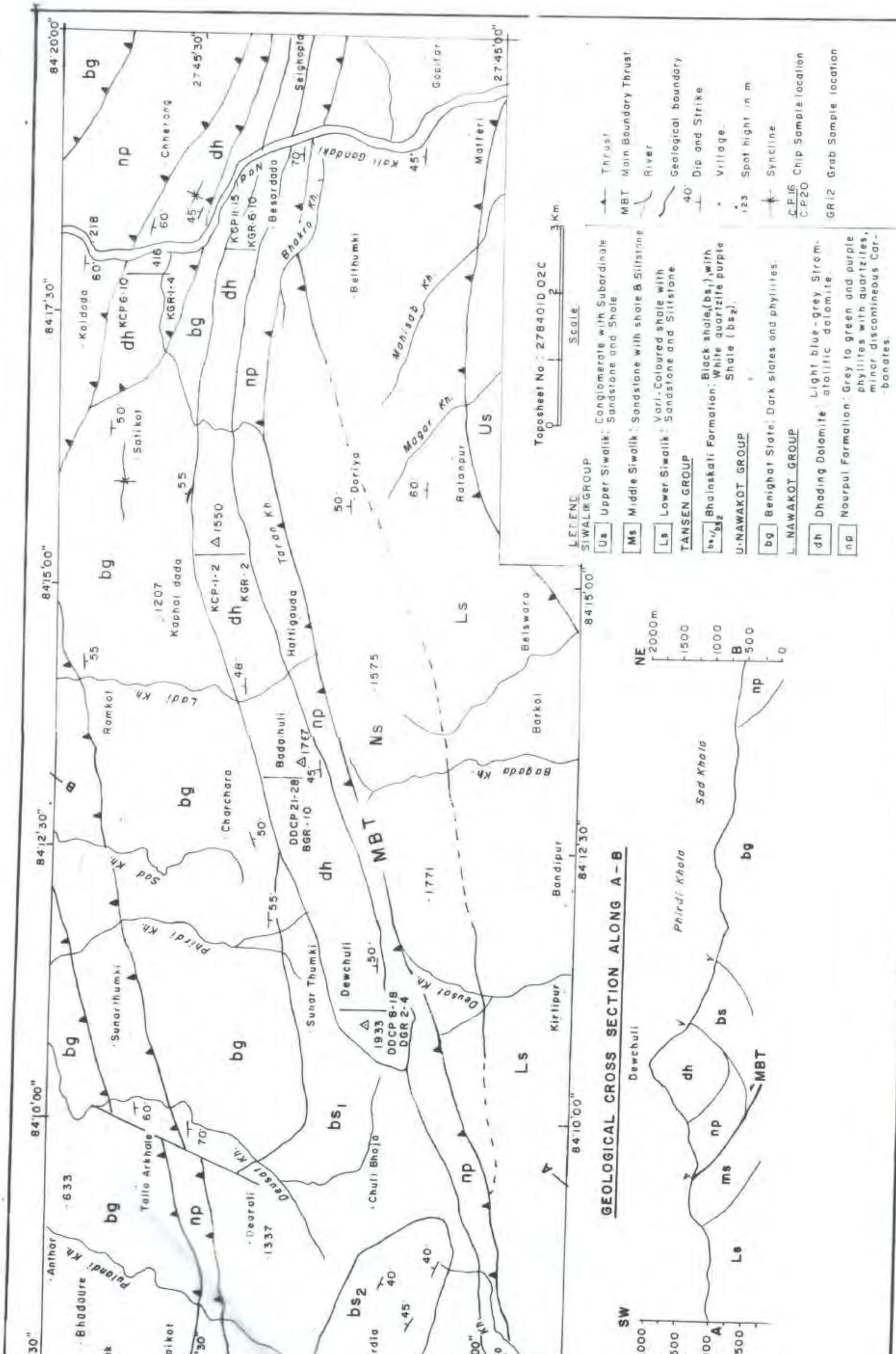

Fig. 1: Geological map of parts of Nawalparsi District

Benighat Slates

Benighat Slates is the major argillaceous unit in the area. This unit is found in northwestern part around Anthar, Bhdaure, Lapak, Raikot, Tallo Arkhale and in central and eastern part around Deustkhola, Charchare, Kaphaldada, Ramkot and Satikot. It consists of shaly slates, carbonaceous slate, slaty phyllites and phyllites. The slates are generally dark grey to black in color but may show different colors ranging from grey, greenish grey, yellow and purplish red in weathered condition. The slates at places are found to contain thin to thick intercalation of sandstones, quartzites and dolomites.

Bhainskatti Formation

The rocks of Bhainskatti Formation are found in the western part of the study area around Hardia, Deurali, Chuli Bhoja and Suarthumki. The formation mainly consists of black and purple shale, medium to fine grained crystalline quartzite and quartzitic sandstone. The formation also consists of dark brown, medium grained, siliceous hematite bed.

Siwalik Group

The rocks of the Siwalik Group are confined to the southern part of the investigated area. The rocks of the Siwalik Group are molasses type of sediments containing sandstone, siltstone, mudstone, marl, and conglomerates.

FINDINGS

Cement grade limestone is not found in the area.

Dolomite Occurrences

Dolomite occurs in the central and eastern part of the area around Dewchuli, Badachuli, Kaphaldada and Kaligandaki. Dolomite of Dewchuli area is monotonous sequence with light grey color, fine grained and fractured. There is no overburden in the area. Thickness of the band is 500m and its extension is about 1100m.The result of the chemical analysis of the dolomite samples of Dewchuli area is given in Table 1.

Fig. 2: Dolomite forming Dewchuli hill (1933m)

Fig. 3: Dolomite boulder on the hill slope of Dewchuli

Table 1: Result of chemical analysis of dolomite of Dewchuli area

	Parameters %						
Sample No	LOI	Acid Insoluble	CaO	MgO	R_2O_3	Fe_2O_3	Al_2O_3
DDCP 8	37.04	4.54	28.74	23.94	4.48	1.31	3.17
DDCP 10	34.11	11.32	28.39	20.16	4.08	0.67	3.40
DDCP 12	34.17	12.88	28.04	20.16	3.18	0.41	2.77
DDCP 14	34.45	12.92	28.04	19.66	3.80	0.35	3.45
DDCP 16	34.35	14.34	29.09	17.14	3.30	0.40	2.90
DDCP 18	27.89	27.46	23.13	16.88	3.35	0.37	2.98
DGR 2	40.12	9.76	22.78	20.66	7.07	0.44	6.63
DGR 4	36.16	16.40	22.43	17.39	7.46	0.55	6.92

The Dolomite of Badachuli area is also monotonous sequence with light grey in color, fine grained, siliceous and often fractured. There is no overburden in the area. The thickness of the dolomite band is 400 m and its extension is 875m. Chemical analysis result of the samples is shown in Table 2.

Table 2: Result of chemical analysis of dolomite of Badachuli area

	Parameters %						
Sample No	LOI	Acid Insoluble	CaO	MgO	R_2O_3	Fe_2O_3	Al_2O_3
DDCP 21	33.23	14.52	26.29	20.92	3.28	0.29	2.99
DDCP 24	26.98	31.31	20.68	16.63	3.2	0.49	2.71
DDCP 26	27.54	30.94	19.98	17.39	2.98	0.42	2.55
DDCP 28	25.68	37.44	19.63	14.87	2.78	0.36	2.41
BGR-10	38.36	13.4	26.28	18.14	3.9	0.34	3.56

Dolomite of Kaphaldada area is more siliceous, light grey in color and fine grained. The thickness of the dolomite band is 350 m and its extension is 700 m. Chemical analysis result of the samples is shown in Table 3.

Table 3: Result of chemical analysis of dolomite of Kaphaldada area

	Parameters %						
Sample No	LOI	Acid Insoluble	CaO	MgO	R_2O_3	Fe_2O_3	Al_2O_3
KCP 2	39.17	10.72	25.24	16.88	8.63	1.24	7.38
KGR 1	41.57	8.4	28.74	18.64	4.43	0.4	3.95
KGR2	36.98	19.3	24.18	15.88	3.5	0.81	2.7

Two bands of dolomite of 350m and 300m thick exposed along Kaligandaki section in the eastern part of the study area is light grey, fine grained, siliceous and weathered. Chemical analysis result of the samples is shown in Table 4.

Table 4: Result of chemical analysis of dolomite of eastern part along Kaligandaki section

	Parameters %						
Sample No	LOI	Acid Insoluble	CaO	MgO	R_2O_3	Fe_2O_3	Al_2O_3
KCP 6	41.01	13.36	24.18	18.65	2.65	0.62	2.03
KCP 9	39.43	9.62	28.74	16.38	4.67	0.61	4.06
KCP 11	38.57	11.1	31.89	16.86	2.18	0.2	1.97
KCP 13	42.37	3.34	32.24	20.16	1.88	0.12	1.75
KCP 15	34.55	13.28	30.14	16.63	4.33	0.5	3.82
KGR 4	36.41	16.36	22.78	16.63	7.68	0.49	7.19
KGR 6	40.75	10.58	26.99	18.14	1.65	0.29	1.36
KGR 10	38.31	16.4	21.38	19.91	3.25	0.39	2.86

CONCLUSION AND RECOMMENDATION

Cement grade limestone is not found in the area. Dolomite occurs in the area of Devchuli, Badachuli, Kaphaldada, and Kaligandaki section. The thickness of dolomite band varies from 350m- 500m. The dolomite of Devchuli area is of industrial grade and thus warrants further exploration.

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Coal Exploration in Mityal-Dharkesin area, Eastern Palpa, Western Nepal

Uttam B. Shrestha and Kushal N. Pokharel
Department of Mines and Geology, Lainchaur, Kathmandu, Nepal

ABSTRACT

Mityal-Dharkesin area in eastern Palpa consists mainly the rocks of Surkhet Group and Lakharpata Group. The rocks in the area are folded into a syncline. Melpani Formation, an important formation of the Surkhet Group for coal exploration point of view, is almost continuous in both the northern and the southern limbs of the syncline. The coaliferous seams of different thickness and extensions are reported from 8 locations from the Melpani Formation. The chemical analysis result of the collected 17 samples showed the fixed carbon content to be in the range of 3.85 to 34.46 by weight percent and accordingly the calorific value in the range of 377.45 to 4667.32 Kcal/kg.

INTRODUCTION

The Department of Mines and Geology (DMG) carried out a 'Preliminary Exploration of Coal Deposit in parts of Palpa District, western Nepal' as per the annual field program of the department for the year 2008. The study area lies west of Kathmandu within the longitudes of 83°52'32" and 84°00'00" E and the latitudes of 27°44'22" and 27°48'58" N. The topographical maps of 1: 25,000 scale of sheet nos. 099 06(RAMPURPHAT) and 099 07 (JHIRUBAS) published by the Government of Nepal, Survey Department include the area. The area stretches for about 12 km and 8.5 km respectively in east-west and north-south directions, covering a total area of about 100 km^2. The area is accessible by three main road routes: the first along Muglin-Narayanghat - Butwal - Aryabhanjyang (Palpa) - Beldada (the northwest part of the study area), the second along Muglin-Pokhara-Waling-Aryabhanjyang-Beldada and the third along Muglin-Narayanghat-Arung-Khola-Bhedabari - Lamedamar (the southern central part of the study area). The Bhedabari-Lamedamar section is under construction.

The DMG has prepared a geological map of parts of Syangja, Palpa and Tanahun Districts (scale-1:50000, 63M/13) that covers the northern part of the study area. Similarly, the geological map-Petroleum Exploration Block-5, Chitwan (Scale- 1:250,000) prepared by Petroleum Exploration and Promotion Project (PEPP) includes the entire present study area. But, there exist no previous studies from coal exploration perspective.

OBJECTIVE

The objectives of the present study were to prepare a geological map of the area in 1: 25,000 scales, to explore coal occurrences in the area, to determine thickness and extension of the explored coal seams, and to collect representative coal samples for quality analysis.

GEOLOGY

The study area belongs mainly to the Lesser Himalayan tectonic unit with only a little part of the Sub-Himalaya (Siwalik) in the southwest part separated by the Main Boundary Thrust (MBT) (Fig. 1). The rocks of Lakharpata Group and Surkhet Group mainly constitute the area and are folded into a syncline with an E-W running fold-axis. These two groups share an unconformable and faulted boundary (Table 1).

Lakharpata Group

Only the Gawar and Ramkot Formations of the Lakharpata Group are mapped. They are present in the southern, northern and western parts of the study area. They share unconformable and faulted contacts with the younger Surkhet Group. Since these formations were found not important from coal exploration point of view, they are mapped as a single unit the Lakharpata Group Undifferentiated.

Ramkot Formation consists mainly of pink and gray quartzite with purple and gray shale/slates intercalations. Mudcracks are present in the quartzite and the shale. The formation also consists of pink and gray limestone and dolomite beds. The Ramkot Formation gives way upward to the Gawar Formation.

Gawar Formation consists of gray dolomite as an essential lithology with subordinate amount of sandstone, shale and limestone. The formation in the study area is more prominent in the northern part than in the southern part. Thin bands of gray to dark gray limestone are also present in the northern part.

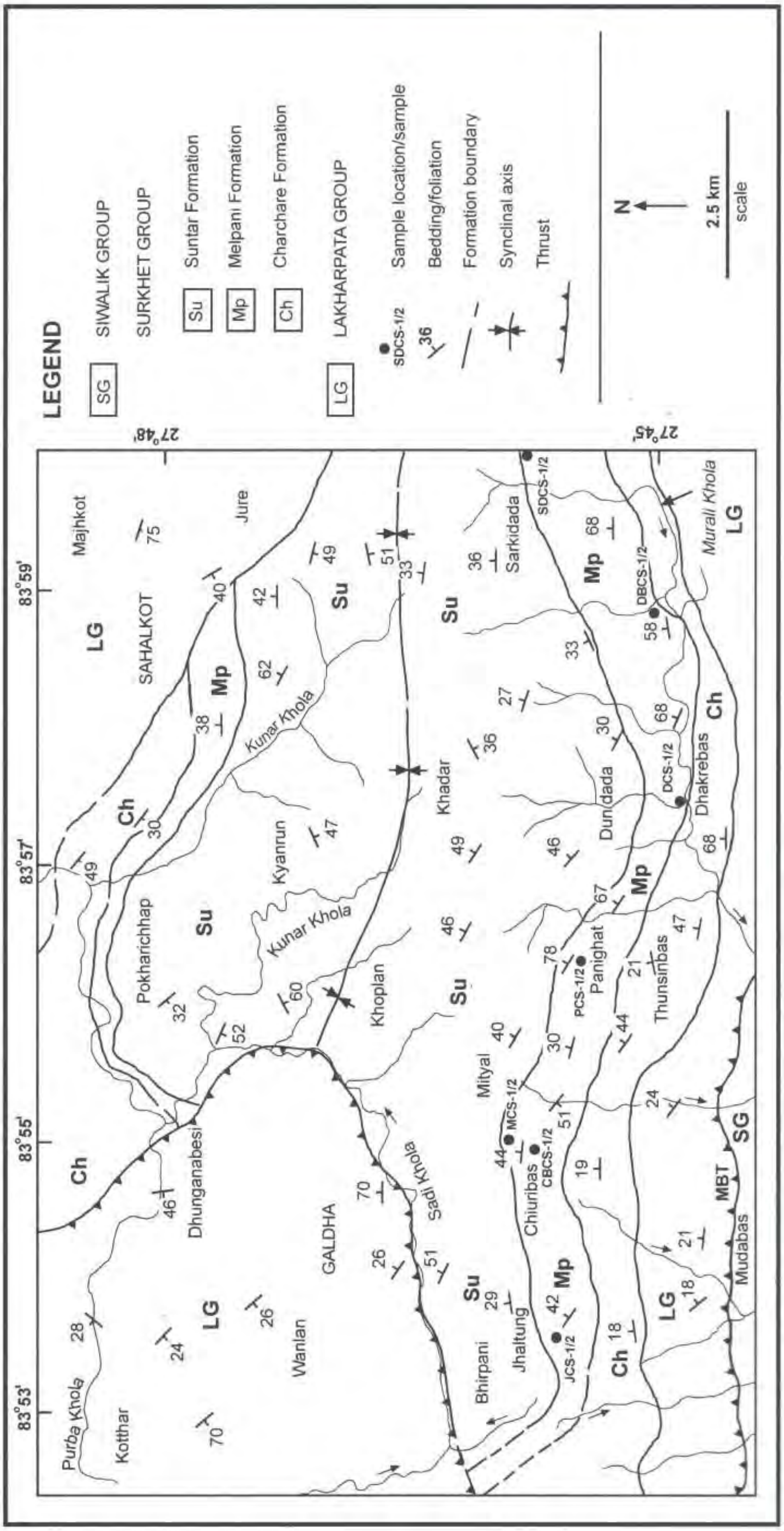

Fig. 1: Geological map of Mityal-Dharkesin area showing location of sample collection

Table 1: Litho-tectonic unit of Mityal-Dharkesin area, eastern Palpa (adopted after Kayastha, 1992)

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

Surkhet Group

Only the three formations- Charchare Formation, Melpani Formation and Suntar Formation of the Surkhet Group are mapped in the area. They are almost continuous from east to west in both the limbs of the syncline. These formations respectively correlate to the Sinse and Taltung Formations (combined), Amile Formation and Dumri Formation of the Tansen Group in western Nepal (Sakai, 1983 and 1984). The Swat Formation (Eocene age) of the Surkhet Group (equivalent Bhainskati Formation of the Tansen Group) which has a stratigraphic position between the Melpani Foramtion and the Suntar Foramtion is missing in the area and thus is not mapped.

Charchare Formation is the oldest formation of the Surkhet Group. It is continuous in the southern limb but is truncated in the eastern part in the northern limb due to a reverse fault (Fig. 1). The formation consists mainly of gray to dark gray slates with diamictite in the lower part. The diamictite consists clast of limestone, dolomite, quartzite, slate etc. The discontinuous conglomerate beds are also present in the upper part. The conglomerate is clast supported.

Melpani Formation rests over the Charchare Formation. It is as the underlying Charchare Formation is continuous in the southern limb but is discontinuous in the eastern part in the northern limb. The formation consists dominantly of white quartzite with subordinate dark gray to carbonaceous slates. The dark gray quartzite, light gray limestone and purple shale also add up to the lithology. The formation at places consists of coaliferous beds and thin coal seams.

Suntar Formation is the youngest formation of the Surkhet Group and forms the core of the syncline. It consists of an alternating fluvial sequence of bluish gray to greenish gray metasandstone and pink to gray shale/slate. The formation consists also of thin bands of marl beds at some places.

Siwalik Group

The thick-bedded, salt and pepper sandstone with mudstone (Middle Siwaliks) representing the Siwalik Group lie only in the southwestern part of the study area. It is separated from the Lakharpata Group by the MBT.

COAL OCCURRENCES AND QUALITY

Stratigraphically, Quaternary lignite of the Kathmandu Valley, Siwalik Coal of the Sub-Himalyas, Eocene and Gondwana coals of the Leseer Himalaya are the four major types of coal occurrences in Nepal (U. N., 1993). But the so claimed Eocene coal could actually be the Cretaceous-Paleocene coal as indicated by their stratigraphic position (Joshi et. al, 2004; Shrestha and Pokharel, 2008). Among these types, the previous studies have shown only the Cretaceous-Paleocene coal to be important from mining point of view (Aryal and Shrestha, 1996 and1997). Therefore the present study is concentrated in the Melpani Formation which consists of Cretaceous-Paleocene coal.

A total of 10 Cretaceous-Paleocene type of coaliferous/coal seams of different thickness and extension have been explored from the Mityal-Dharkesin area (Table 2). All the seams are only in the southern limb of the Melpani Formation.

The coaliferous seams are of swelling and pinching nature. The thickness varies from few centimeters to 1.5 m (Fig. 3). The extensions of the seam is found to be related with its thickness: thicker the seam, its extension is longer. Seams upto the extension of more than 30m are exposed by the escarping at several places during the field work. At the hilly terrain the coal seams are mostly veneered by the colluvial materials. So the actual extension of the seams could be expected several times more than observed one during the field work. The seams are sandwiched within or between the carboniferous slates and quartzites. The host rocks have the general dip direction towards NW to NE with wide range of dip amounts (33° to 78°).The host rock and the seams generally exhibit concordant relationship though they also exhibit discordant relationship in some locations (Fig. 4). The seams are found within the altitudes of 500 to 1300m. Generally, a single seam is seen at a place but in Murali Khola area three consecutive seams are found to exist (Fig. 5).

The coal in general is dark gray to black in color with dull to slightly vitreous luster. They consist of little to considerable amount of carboniferous shale/slate fragments.

The chemical analysis was carried in the DMG laboratory to find out the quality of the collected 17 samples (Table 2). The moisture content, volatile matter, ash, fixed carbon and

Table 2: Proximate chemical analysis results of collected samples

S. N.	Location	Sample	Chemical Analysis					
			Moisture	Ash	Volatile Matter	Fixed Carbon	Calorific Value	Remark
1	Jhaltung	JCS-1	4.49	38.09	23.02	34.46	**4667.32**	Lignite
		JCS-2	2.56	59.95	18.64	18.85	2626.82	-
2	Chiuribas	CBCS-1	5.3	61.86	17.35	15.49	2102.98	-
		CBCS-2	6.5	62.86	19.04	11.6	1465.28	-
3	Mityal-Rupsebhanjyang	MCS-1	1.65	82.46	12.53	3.85	377.45	-
		MCS-2	2.09	57.08	9.18	30.93	**3500.16**	Lignite
4	Panighat	PCS-1	0.37	55.51	9.37	34.31	**3810.62**	Lignite
		PCS-2	0.58	72.29	9.13	17.58	2308.91	-
		PCS-3	0.45	74.89	9.85	14.26	1937.62	-
5	Dundada	DCS-1	2.69	82.45	10.99	3.87	394.27	-
		DCS-2	0.82	81.62	9.17	8.39	1155.65	-
6	Dundada (Magare Khola)	DMCS-1	0.17	86.41	7.11	6.31	872.92	-
7	Dhakrebas (Murali Khola)	DBCS-1	0.56	78.92	13.85	6.67	782.39	-
		DBCS-2	0.75	78.83	14.39	6.03	667.14	-
		DBCS-3	0.58	79.47	14.05	5.90	652.40	-
8	Sarkidada	SDCS-1	0.96	82.89	11.06	5.75	703.76	-
		SDCS-2	1.63	79.32	12.45	7.24	904.93	-

Fig. 2: Coal seam exposed in Mityal-Chiuribas road section near Mityal. Note the folded nature of the seam and the fractured quartzite host rocks.

Fig. 3: The extension of the same coaliferous seam shown in Fig. 2. The seam in this section reaches up to the thickness of about 1.5 m.

Figure 4: A vertical coal seam observed in Mityal area. The seam seen shows a concordant relationship with the host rock. Note the bedding shown by the broken black line. The thin- bedded dark gray quartzite serves as the host rock.

Fig. 5: Three consecutive high angle coal seams in the Murali Khola area. The rocks in between the seams are dark gray slates and thin bedded dark gray quartzite. The thickness of the seam 1 (Sample: DBCS-1), 2 (Sample: DBCS-2) and 3 (Sample: DBCS-3) are respectively 50 cm, 60cm and 40cm.

the calorific value were determined. The proximate chemical analysis showed the moisture content in the range of 0.17 to 6.5, volatile matter in the range of 7.11 to 23.02 and fixed carbon in the range of 3.87 to 34.46, all by weight percent. The calorific value, which depends on fixed carbon, is in the range of 394.27 to 4667.32 Kcal/kg. The coal samples of Jhaltung, Mityal and Panight areas come under the Lignite grade while the other samples show low to very low calorific values. The sample JCS-1 from the Jhaltung area showed the highest carbon content and the calorific value.

CONCLUSION

- The Mityal-Dharkesin area shows occurrences of low grade peat to lignite coal and coaliferous beds within the Melpani Formation.
- The coal samples of Jhaltung, Mityal and Panight areas are of Lignite grade.

ACKNOWLEDGEMENT

We thank Mr. Pranab Lal Shrestha, then director of the DMG for providing all the necessary facilities to carry out this exploration work. We also thank Mr. Sarbjit Prasad Mahato, DDG and Sriram Maharjan, Superitendent Mining Engineer, for fruitful discussion on the topic. Thanks to the DMG laboratory for analyzing the samples and Mr Y.P. Parajuli, assistant sampler, for accompanying in the field.

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Preliminary Exploration of Gold along Kali Gandaki Valley in Some Parts of Myagdi and Mustang Districts, Western Nepal

Hifzur R. Khan
Department of Mines and Geology, Lainchur, Kathmandu, Nepal

ABSTRACT

The present study deals with the result of 'Preliminary Exploration of Gold' along Kali Gandaki Valley in some parts of Myagdi and Mustang districts, Western Nepal. Most of the investigated area contains the rocks of Higher Himalaya and Tibetan Tethys Sediments except southernmost part of the area which contains the rocks of Lesser Himalaya. Heavy mineral concentrate sampling was the main method applied for gold exploration. Samples from riverbed (flood plain) and old river terraces were sieved and panned to know the amount of gold content in them. Some fine to very fine gold colours were observed in the heavy mineral concentrate samples collected from riverbeds and old river terraces of lower parts of Kali Gandaki River (below South Tibetan Detachment System). But not a single visible gold colour was seen in the heavy mineral concentrate samples collected from riverbeds and old river terraces of upper parts of Kali Gandaki Valley (above South Tibetan Detachment System). This observation indicates that gold mineralization occurs within Higher Himalayan rocks and Tibetan Tethys Sediments are barren in gold content. But the presence of gold colours in the heavy mineral concentrate samples collected from lower parts of Kaligandaki River reveals that they could not be of economic interest.

INTRODUCTION

According to the departmental annual field programme of fiscal year 2064/065 a 'Preliminary Exploration of Gold' was conducted along Kali Gandaki Valley in some parts of Myagdi and Mustang districts, Western Nepal. The investigated area lies in between lattitudes 28°32'30" to 28°50'30" N and Longitudes 83°35'00" to 83°50'00" E in Toposheet no. 2883-03, 2883-04 and 2883-07, covering 250 sq. km area (Fig.1).

Recently a gravel road from Beni (headquarter of Myagdi district) to Jomsom (headquarter of Mustang District) and Muktinath has been completed. Beni is connected with Kathmandu by Kathmandu-Muglin-Pokhara-Kushma-Baglung road. The area can be accessed easily by jeep or by bus. A regular air service from Pokhara to Jomsom is also available.

Geological studies of the area were carried out by several Geoscientists such as Gansser (19964), Fuchs (1967), Hagen (1968), Gradstein (1992), Colchen (1999) and Searle (2003). They established stratigraphical and structural framework of the area. Recently, Upreti et.al. (2005) described the geology and natural hazards along Kali Gandaki Valley and Rimal et. al. (2007) conducted geology and natural hazards around Muktinath area. But from the mineral exploration point of view, no work has been conducted before in this area.

Kaphle and Khadka (2000) conducted a 'Preliminary Follow-up Gold Exploration' along Kali Gandaki Valley in some parts of Myagdi, Parbat and Baglung districts, Western Nepal. They conducted preliminary gold exploration along Kali Gandaki Valley from Kusma (Parbat) to Dana (Myagdi) area. They reported alluvial gold in river bed and river terraces along Kali Gandaki Valley, but they could not trace primary gold mineralization in the investigated area. However, they recommended carrying out Preliminary gold exploration along Kali Gandaki Valley further north from Dana to trace the primary source of alluvial gold in this area. Therefore a 'Preliminary Gold Exploration' was conducted in the investigated area.

OBJECTIVE

The main objectives of the fieldwork were:

- To carry out 'Preliminary Exploration' of alluvial gold and trace the possible primary source.
- To prepare geological map (at 1:50,000 scale) of the investigated area.
- To collect heavy mineral concentrate samples with a view to know the concentration of alluvial gold distribution in the riverbeds and old river terraces.
- To conduct geochemical stream sediment survey with a view to know the associated sulphide minerals present in the area.
- To identify the target area for further follow up exploration.

METHODOLOGY

- Available literatures were studied prior to field investigation.
- Topographical maps of 1:50,000 scale were used as base map.

- Heavy mineral concentrate sampling was the main methods for gold exploration. Samples from riverbeds and old river terraces were collected, sieved and panned to know the gold content in them.
- Trenches/pits were excavated in the old river terraces to collect heavy mineral concentrate samples from terrace deposits.
- Stream sediment sampling was carried out in tributary streams to know the associated sulphide ore minerals present in the area.
- Rock samples were collected from outcrops and ore floats with a view to trace the primary source of alluvial gold and other minerals.
- Traverses were made all along the accessible streams, foot tracks, road and hills.

FIELD ACTIVITIES

- 55 heavy mineral concentrate samples were collected from riverbeds of the Kali Gandaki River and its main tributaries to know the gold content in them.
- Likewise 20 heavy mineral concentrate samples were collected from old river terraces with a view to know the concentration of gold in the terrace deposit. Trenching/pitting was carried out (100 cubic meters) in old river terraces to collect heavy mineral concentrate samples.
- 143 Stream sediment samples were collected from various tributary streams of the investigated area to know the associated sulphide ore minerals present in the area. All the samples were analyzed for Cu, Pb and Zn.
- 55 rock chip Samples were collected from the outcrops and floats for petrographic study and chemical analysis for Cu, Au, CaO, MgO and Si.
- Geological map of 250 sq. km area was prepared (in1:50,000 scale) during field investigation.

GENERAL GEOLOGY

The investigated area contains the rocks of Lesser Himalayan, Higher Himalayan and Tibetan Tethyan Sedimentary Groups. Main Central Thrust (MCT) and South Tibetan Detachment System (STDS) are the prominent geological structures which can be traced near Dana and Kokhethati village respectively (Fig.1). Whereas as Higher Himalayan Group lying between MCT and STDS contains high grade metamorphic rocks; Lesser Himalayan Group lying below MCT comprises metasedimentary rocks while Tibetan Tethyan Sedimentary Group situated above STDS consists mainly of sedimentary rocks. Quaternary deposit can be seen all along Kali Gandaki valley of the investigated area. Lithotectonic units of the area are given in the following Table 1.

Lesser Himalayan Group

Benighat Slate (bg)

This unit belongs to Upper Nawakot Group and exposed in southernmost part of the area. It consists of grey to dark grey ph'llite with intercalation of black carbonaceous slate, phyllite and phyllitic slate.

Higher Himalayan Group

This group is exposed in the southern part of area and thrusted over Benighat Slate. It comprises three formations.

Formation I (F I)

This is the lowermost unit of Higher Himalayan Group. It has thrusted contact (MCT) with Benighat Slate. This unit consists mainly of quartz mica-schist and augen gneiss with garnet and kyanite minerals. Mica schist contains more biotite than muscovite. Augens of feldspar are recorded upto 10 cm within gneiss.

Formation II (F II)

This formation overlies Formation I with transitional contact. It mainly contains medium to coarse grained banded gneiss, hornblende gneiss and mica schist. Garnet crystals are seen at places. Hornblende gneiss contains alternate bands and layers of light coloured and dark coloured minerals (Fig. 2). Small intrusions of granite and pegmatite veins are seen within gneiss. Interbeds of marble and calc mica schist are observed at places (Fig. 3).

Fig. 2: Hornblende gneiss showing bands/layers of light coloured and dark coloured minerals within F II.

Formation III (F III)

This formation overlies Formation II and consists of coarse grained, light coloured porphyroblastic augen gneiss. Porphyroblasts of feldspar are recorded upto 4 cm. Small intrusions of pegmatite and aplitic granite are also seen within this formation.

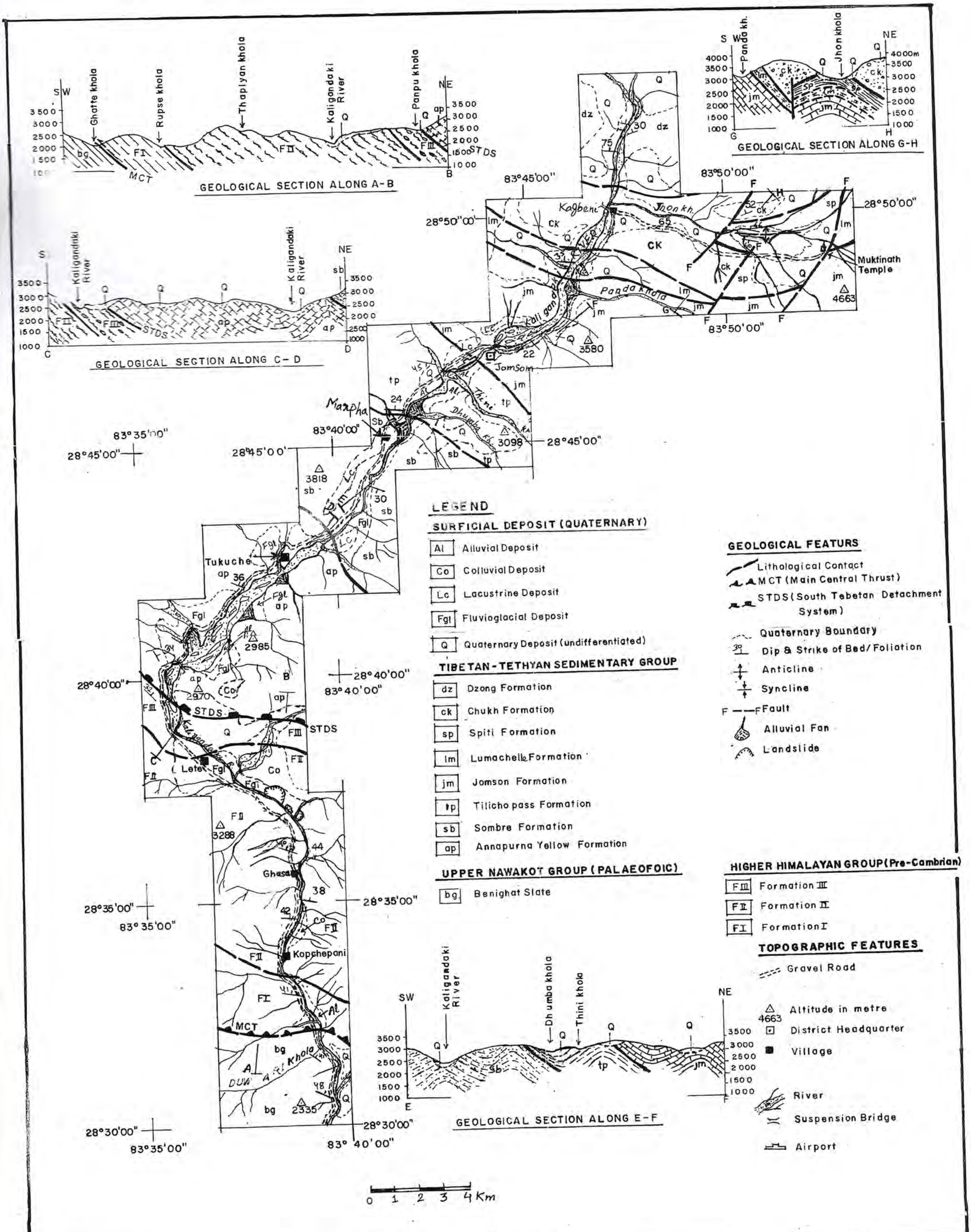

Fig. 1: Geological map of Kaligandaki Valley in some parts of Myagdi and Mustang Districts, Western Nepal

Table 1: Lithotectonic units of the area

Unit	Main Lithology	Age	
SURFICIAL DEPOSIT			
Alluvial Deposit (Al)	Well rounded boulder, pebble, cobble, sand, silt and clay	Quaternary	
Colluvial Deposit (Co)	Angular fragments of loose rock and soil		
Lacustrine Deposit (Lc)	Fine sand, silt and clay		
Fluvioglacial Deposit (Fgl)	Angular to rounded boulder, pebble, cobble, sand, silt and clay		
Glacial Deposit (Gl)	Angular to sub-rounded boulder, pebble, cobble with sandy matrix.		
TIBETAN-TETHYAN SEDIMENTARY GROUP			
Dzong Formation (dz)	Greenish grey glauconitic sandstone and shale with argillaceous limestone.	Lower Cretaceous	Mesozoic
Chukh Formation (ck)	Greenish grey gritty to pebbly sandstone and dark grey shale with ripple marks and plant fossils.	Lower Cretaceous	
Spiti Formation (sp)	Splintery black shale with interbeds of grey limestone and sandstone. Shales are rich in ammonite fossils.	Upper Jurassic	
Lumachelle Formation (lm)	Alternation of grey limestone with shale and sandstone. Limestones are rich in bivalve fossils.	Middle Jurassic	
Jomsom Formation (jm)	Dark grey micritic and oolitic limestone with grey shale and sandstone.	Lower Jurassic	
Tilicho Pass Formation (tp)	Dark grey to black shale and Phyllite with intercalation of sandstone.	Devonian	Paleozoic
Sombre Formation (sb)	Grey to black shale with intercalation of sandstone and limestone.	Silurian	
Annapurna Yellow Formation (ap)	Grey limestone with Phyllite and schist.	Cambrian	
	..............STDS..............		
HIGHER HIMALAYAN GROUP			
Formation III (F III)	Medium to coarse grained augen gneiss and granitic gneiss.	Pre-Cambrian	
Formation II (F II)	Medium to coarse grained banded gneiss with hornblende gneiss and schist.		
Formation I (F I)	Quartz-mica-schist and augen gneiss with garnet and kyanite minerals		
	..............MCT..............		
LESSER HIMALAYAN GROUP			
Benighat Slate (bg)	Dark grey to black slate and Phyllite with carbonate rocks	Paleozoic	

Fig. 3: Thinly laminated calc schist within F II.

Tibetan-Tethyan Sedimentary Group

This group is separated from Higher Himalayan Group with a sharp contact known as South Tibetan Detachment System (STDS). In the investigated area, this group consists of eight folded units.

Annapurna Yellow Formation (ap)

This is the lowermost unit of Tibetan-Tethyan Sedimentary Group and consists mainly of limestone with intercalation of

Phyllite and mica-schist. Limestones are generally laminated. Marble bands and layers are also encountered at places.

Sombre Formation (sb)

This formation overlies Annapurna Yellow Formation with transitional contact. It mainly contains grey to black shale with intercalation of sandstone and limestone. Shales are generally laminated and contain small quartz veins along and across bedding plane.

Tilicho Pass Formation (tp)

This formation overlies Sombre Formation and predominantly composed of dark grey to black shale and phyllite with intercalation of sandstone. In general sandstones are slightly calcareous. Interlayers of quartzite and dolomitic limestone are seen at places.

Jomsom Formation (jm)

This formation is composed predominantly of limestone with grey shale and sandstone alternation. Limestones are generally dark grey coloured and micritic. Oolitic and dolomitic limestones with intercalation of grey shale are also present.

Lumachelle Formation (lm)

This formation consists of dark grey, fine grained micritic limestone with grey shale intercalations. Thin intercalations of reddish sandstone are also observed at places. Generally content of limestone and shale is in equal proportion in this formation. Limestone consists of abundant fossils of bivalves and belemnites (Fig. 4).

Spiti Formation (sp)

This formation is exposed in Muktinath area. It is represented by laminated black shale of splintery nature. Spheroidal, calcareous concretions of light yellow to dark brown colour are very common in black shale. Size of theses concretions is recorded upto 5.0 m in diameter (Figs. 5 and 6). These concretions sometimes contain good ammonite fossils. Spiti Formation is rich in ammonite fossils (Fig. 7).

Chuckh Formation (ck)

This formation mainly composed of greenish grey sandstone and dark grey shale with intercalation of massive quartzite. Interbred of medium to coarse grained gritty to pebbly sandstone and yellowish to purple shale are also seen within this formation. Ripple marks and plant fossils are preserved in the sandstone of the formation (Figs. 8 and 9).

Dzong Formation (dz)

This formation overlies Chuckh Formation and exposed along Kali Gandaki River in northernmost part of the investigated area. It consists mainly of greenish grey glauconitic sandstone and shale with intercalation of argillaceous limestone.

Fig. 4: Bivalves and belemnites are preserved in Limestone of lm Formation.

Fig. 5: Slided outcrop of Spiti Shale with lot of calcareous concretions i Muktinath area.

Fig. 6: A big concretion (5.0 m in diameter) from Spiti Shale

Fig. 7: Ammonite fossils from Spiti Shale

Fig. 8: Wave ripple marks preserved in sandstone of Chuckh Formation.

Fig. 9: Wind ripple marks preserved in sandstone of Chuckh Formation.

SURFICIAL DEPOSIT

This is the Quaternary Deposit that occurs all along Kali Gandaki Valley and also in Muktinath area. This deposit consists of glacial, fluvioglacial, fluvial, colluvial, alluvial and lacustrine deposits (Fig. 10). Lacustrine deposit reveals damming of Kali Gandaki River at several places in the past.

Fig. 10: Lacustrine deposit (west of Jomsom airport)

STRUCTURE

MCT and STDS are the main structural signature in the investigated area. MCT runs between Lesser Himalaya and Higher Himalaya while STDS runs between Higher Himalaya and Tibetan-Tethys Sediments. Rocks of Tibetan Tethys Sediments are highly folded in comparison to Higher Himalayan and Lesser Himalayan rocks. Several micro and mega folds are observed in the investigated area. Some of them can be seen in the following photographs (Figs. 11, 12 and 13). Some transverse faults are recorded in Muktinath area (Fig. 1). Likewise wave ripple marks and wind ripple marks are seen in sandstone of Chuckh Formation (Figs. 8 and 9).

HAZARDS

River bank cutting and debris flow are the main natural hazards in the investigated area. Active landslides are also recorded at places. Active tension cracks can be seen along Jhon Khola near Tongo and Kunjok villages in Muktinath area (Fig. 14). These cracks are developed due to creeping down of rocks and soils of Spiti Formation. Due to creeping of slope wooden bridge of Jhon Khola has been upbulged near Kujok (Fig. 15).

Fig. 11: A small anticline within hornblende gneiss of F II

Fig. 12: Undulations (microfolds) within ap Formation of Tethys Sediments

Fig. 14: Tension cracks developed due to creeping down of hill slope

Fig. 13: A recumbent fold within sb Formation of Tethys Sediments

Fig. 15: Up-bulged wooden bridge of Jhon Khola due to creeping

GEOCHEMISTRY

Heavy Mineral Concentrate Sampling

Heavy Mineral Concentrate Samples were collected from the riverbeds and old river terraces with a view to know the amount of gold content in them. Trenches/pits were excavated in the old river terraces to collect heavy mineral concentrate samples from terrace deposits. Coning and quartering method was applied to reduce the amount of excavated materials. 30 to 40 kg and 50 to 70 kg gravel mixed sand were taken from riverbeds and old river terraces respectively. These gravel mixed sands were sieved through 10 mesh sieve in slow motion of water. Minus 10 mesh fractions were washed and panned for heavy mineral concentrates. During panning precaution was taken for not to lose any gold flakes. As soon as the gold grains become visible, panning was stopped. Some fine to very fine gold colours were recorded in the samples collected from riverbeds and old river terraces of lower part of Kali Gandaki River (below STDS). On the contrary no visible gold colours were recorded in the heavy mineral concentrate samples collected from riverbeds and old river terraces of upper part of Kali Gandaki River (above STDS). This observation reveals that gold mineralization occur within the Higher Himalayan rocks, but the amount of gold content in heavy mineral concentrate samples show that they could not be of economic interest.

Stream Sediment Sampling

Stream sediment samples were collected from various tributaries in the investigated area. Samples were dried and sieved through 80 mesh sieve. Minus 80 mesh fraction of samples were collected. All the samples were analyzed for copper, lead and zinc. Analytical results were treated and calculated statistically to obtain Mean Value, Standard Deviation, Threshold Value and Anomalous Value. On the basis of these parameters anomalous areas are categorized according to a 'Standard Anomaly Category Matrix'. But the anomalous areas are too small and too low in Cu, Pb and Zn content. That is why there is no possibility of finding out of economical ore deposit of Cu, Pb and Zn in the investigated area.

FINDINGS

- Some fine to very fine gold colours were observed in the heavy mineral concentrate samples collected from the river bed in the lower part of Kali Gandaki River of investigated area.
- Likewise few very fine gold colours were recorded in heavy mineral concentrate samples collected from the old river terraces in the lower part of Kali Gandaki River of the surveyed area.
- 50 m thick marble band is recorded within gneiss of Formation II along Kali Gandaki River near Pairothapla village. Thin intercalation of schist and gneiss is present within marble band. Chemical analysis of the samples collected from this band show 47.67 % CaO and 1.41 % MgO. Likewise another marble band is recorded near Kokhethati village.
- Some limestone bands are observed within Annapurna Yellow Formation of Tibetan Tethys Sediments near Koban village. Thickness of these bands is variable. Maximum thickness is recorded more than 400 m. But intercalations of phyllite are seen within limestone bands. Analytical result of the samples reveals 42.34 to 47.94 % CaO and 1.21 to 2.41 % MgO.
- Another limestone band is recorded within Jomsom Formation of Tibetan Tethys Sediments near Jomsom, the headquarter of Mustang district. Exposed thickness is recorded more than 50.0 m. Sample from this band show 51.5 % CaO and 3.22 % MgO.

CONCLUSION AND RECOMMENDATION

- Presence of some fine to very fine gold colours in the heavy mineral concentrate samples collected from riverbed and old river terraces of lower part of Kali Gandaki River (below STDS) indicate that gold mineralization occur within the Higher Himalayan rocks, but the amount of gold content in heavy mineral concentrate samples shows that they could not be of economic interest. Field team was unable to trace the primary source of alluvial gold, but from the observation of gold content in heavy mineral concentrate samples, it is clear that gold mineralization within Higher Himalayan rocks is very poor and could not be of a economic interest.
- Absence of gold colours in the heavy mineral concentrate samples collected from riverbed and old river terraces of upper part of Kali Gandaki River (above STDS) indicate that Tibetan-Tethys Sediments are barren in gold content.
- Presence of marble and limestone bands in the investigated area and analytical result of the samples collected from these bands reveal that the area could be potential for limestone and marble. Therefore a preliminary follow-up work for limestone and marble is recommended in the area.
- Neither stream sediment analysis result nor field observation reveals any potential anomalous zone for base metals (Cu, Pb, Zn) in the area. On the whole the investigated area seems very poor in metallic mineralization. Therefore further follow-up work for gold and other metallic minerals is not recommended in the area.

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Landslide Hazard Mapping in some parts of Syangja, Gulmi and Palpa Districts, Western Nepal

Lila N. Rimal
Department of Mines and Geology, Lainchaur, Kathmandu, Nepal

ABSTRACT

Landslide mapping and inventory was carried out covering 650-sq. km area in parts of Syangja, Gulmi and Palpa Districts of Western Nepal. Data layers on main factors causing landslides such as Landuse pattern, Slope and Aspect were prepared in the map form using the digital topographical database acquired from the Survey Department. Geological Map available at the Department of Mines and Geology was taken as base. Landslide Hazard Zonation Map was prepared by bivariate statistical method using GIS technique in Arcview environment. The Hazard Zonation Map was classified in three zones as Low, Moderate and High indicating chances of occurrence of landslide in the region. The information contained in the map is useful to planning of infrastructure development activities of the area in regional scale.

INTRODUCTION

Landslide Inventory and Hazard Zonation Mapping was conducted in parts of Syangja, Gulmi and Palpa districts in Western Development Region. The survey was carried out in accordance with the annual program of the Department of Mines and Geology for the fiscal year 2007/2008. The study covered 650 sq. km area of Toposheet No.63M/5 in regional scale. The area is located between latitudes 27°45'00" N to 28°00'00" N and longitudes 83°15'00" E to 83°30'00" E. Kali Gandaki Nadi, a major river in the Himalaya passes through the northeast corner of the study area. Badigad, Kurung and Ridi Kholas are the major tributaries to Kali Gandaki Nadi. Kharjyang, Dobhan, Kusum, Sisne, Badahare Kholas are the other streams draining the study area. The lowest elevation in the area is 240m at Northwest of Jamune Phat and the highest elevation is 1996m at south west of Nigali.

Basic geological information at 1:50,000 scales are available at the Department of Mines and Geology. Information on probability of occurrence of natural disasters such as landslides is not available for this area. In this context, present study program was planned to provide geo-scientific information especially on landslide hazards beneficial for planning of infrastructure development activities in the region.

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 government efforts to minimize the risk. Hazard mitigation works and planning of future development activities are done without the information on areas that are prone to such disasters. In this regard, present study was planned with the following objectives:

- To record the landslides of the study area using 'Landslide Inventory Form'. The inventory form is to be included in the technical report.
- 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 1978 and 1979 at 1:50,000 scales acquired from the Survey Department were interpreted to study the landslides, erosion features, tectonic structures, landuse pattern and lithological units. Landsat-TM images of December 1992 were studied as supplement to the aerial photographs for comparing the landuse pattern changes, landslides and tectonic structures of regional significance. The satellite data were used for the preparation of final landslide hazard zonation map of the area. Land capability, land utilization and land system maps (LRMP, 1984) were studied. The topographic maps at 1:25,000 and 1:50,000 scales were acquired and used as a base map for the field data collection together with aerial photographs. Landslide Hazard Zonation Map of Kaski, Myagdi and Parbat district (Tuladhar, 2007) and available geological maps and reports were also referred. Different data and sources are summarized in Table 1.

Table 1: Data overlays, Sources, Parameters and Method of generation

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

DMG[1]: Department of Mines and Geology, Kathmandu. SD[2]: Survey Department, Kathmandu
TU: Tribhuvan University
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

Field Investigation

Field checking and data collection was carried out taking traverses along different routes like main trails, ridges and main roads using landslide inventory form, aerial photos and topographical maps. The field survey was focused on mapping and verification of erosion features interpreted on aerial photos, satellite images, collecting data for landslide inventory and their distribution (Fig. 1a), mapping of various factors that are mostly responsible for triggering landslides. Some of the major landslides were studied in details using 'Preliminary Landslide Inventory Form' for regional inventory.

GEOLOGY AND STRUCTURE

The north part of the investigated area is within the Lesser Himalaya and the southern part is in the Sub-Himalaya. The terrain is represented mainly by meta-sedimentary and the sedimentary rocks. Geological Studies have been carried out by a number of researchers in the Kaligandaki River Section. A compiled geological map by J.N. Shrestha et al is published by the Department of Mines and Geology in 2000 A.D. This map will be used as a base for the geological data. Review of existing geological maps suggests that the area is represented by metasedimentary rock sequences of Pre-Cambrian age belonging to Upper Nuwakot Group, sedimentary rocks of Permo-Carboniferous to Oligocene of Tansen Group and sedimentary Siwalik rocks of Upper Miocene to Lower Pleistocene period. Previous maps show several thrusts, faults and folds of regional scales in the study area indicating weak tectonic belts.

Metasedimentary and sedimentary rocks such as phyllites, quartzites, slates, limestone and dolomites of the Upper Nuwakot Group were observed around northern and southern part. Sedimentary rocks of the Tansen Group such as shale, sandstones and diamictites of Palaeozoic age are also exposed in the central west part. Sedimentary rocks comprising of mudstone, sandstone and conglomerate are developed in the southernmost part.

Superficial deposits such as residual, alluvium and colluviums (including talus) deposits were mapped within the study area. Thick soil is developed on the old river terraces around Aslebchaur, Kotakot and Argeli area (Fig. 1c). 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. Land capability, land utilization and land system maps prepared by Land Resources Mapping Project (LRMP) in 1984 at 1:50,000 scales were also referred as the supplementary information for the landuse pattern of the area. Hill slope and terraces are cultivated. Improper cultivation practices on slopes have often triggered landslides damaging property worth of millions of rupees.

PREPARATION OF FACTOR MAPS

Factors responsible for the cause of landslide in particular area can be of different nature and dimension. In the present study area geology, slope, aspect and landuse were considered the main causative factors. Data collected during field verification and desk level interpretation were incorporated for the preparation of factor maps. A landslide distribution map (Fig. 1a) was prepared based on the information on location of landslides in the area. All collected data were analyzed using GIS technique to produce hazard zonation map. Digital Elevation Model (DEM, Fig. 1b) was created using Arc View GIS from the digital topographical map acquired from the Survey Department. The DEM was used to generate Slope Class and Aspect Maps. Recently published geological map was digitized. Landuse map was created from the digital topographical map and other sources of information. The statistical relation of various factors to landslide distribution is summarized in Figures 1d to 1j.

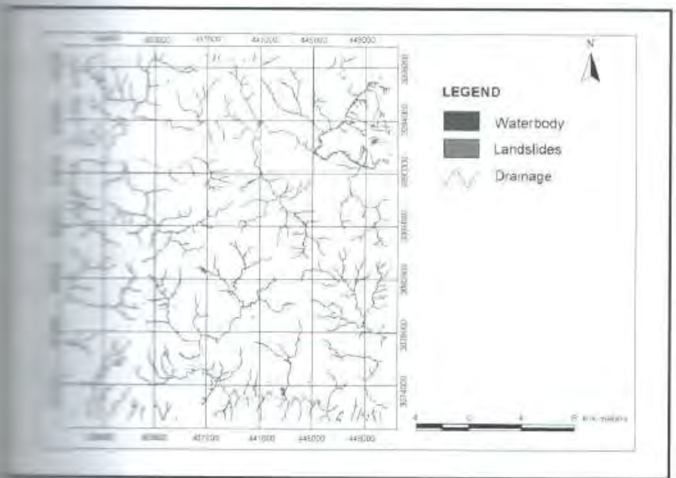


Fig. 1(a): Landslide Distribution Map

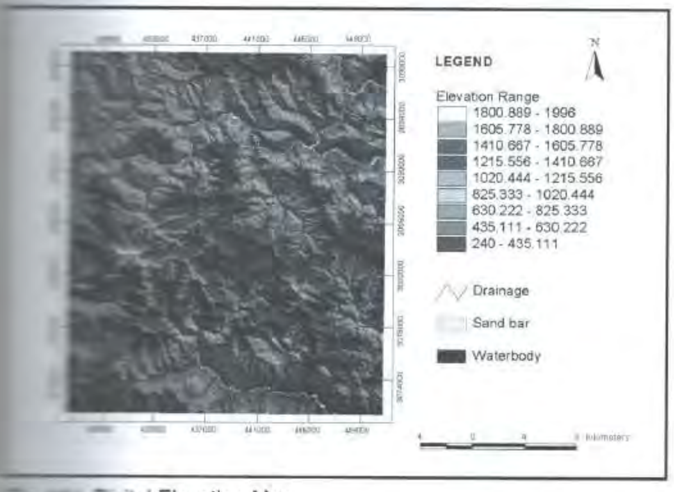


Fig. 1(b): Digital Elevation Map

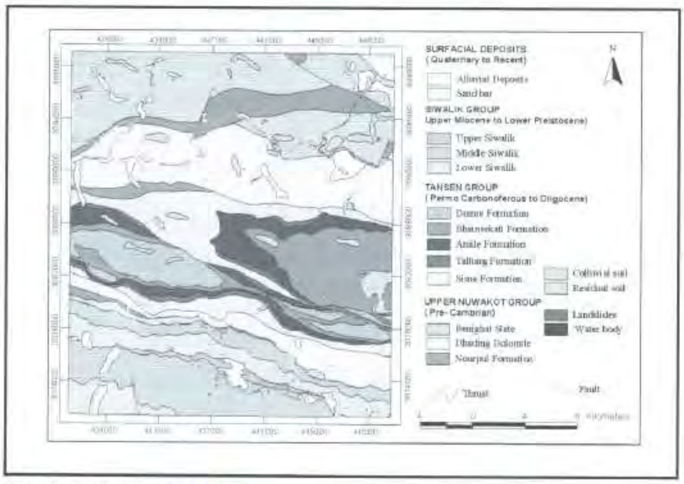


Fig. 1(c): Geological Map

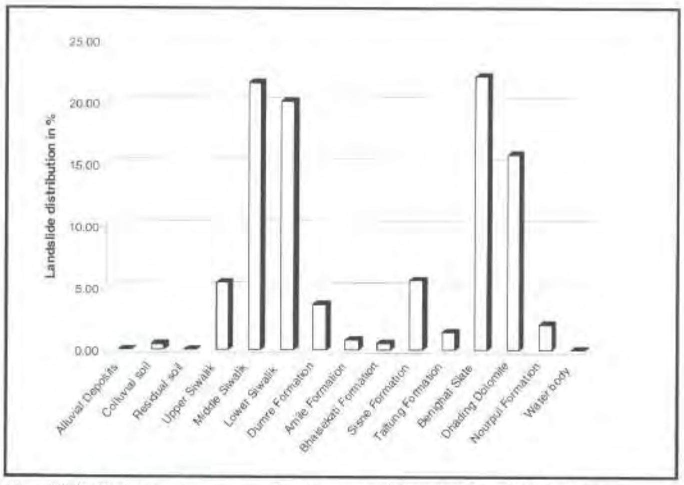


Fig. 1(d): Relation between Geology and Landslide Distribution

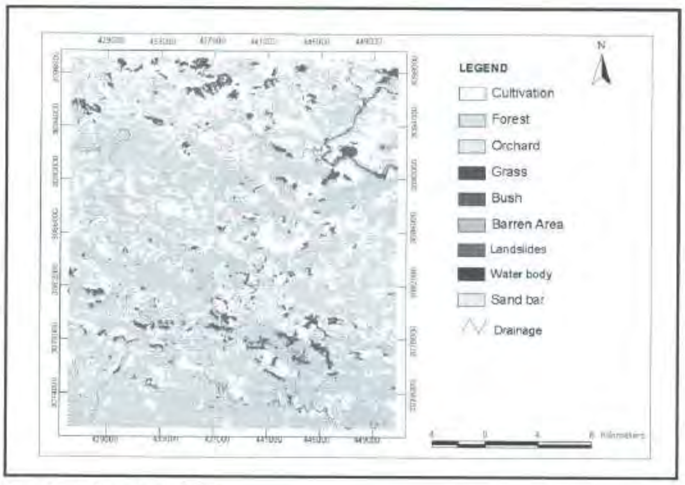


Fig. 1(e): Landuse Map

ROLE OF REMOTE SENSING DATA AND GIS IN LANDSLIDE HAZARD STUDY

Study area is a part of Lesser Himalaya with rugged mountains and remote areas. Satellite images and aerial photographs provide clearly the location of bare soil conditions on slopes except in areas of thick vegetation. Such bare soil conditions were verified and the landslide positions were transferred on the base map to prepare inventory map (Fig. 1a). Recent high-resolution imageries would be more appropriate to be used for this purpose. However the available data such as LANDSAT-TM images (Table 1) was utilized. Data processing was done using Arcview GIS. This program facilitates to produce analytical results in digital form which can be reprocessed and reused for updating purposes in future. In the present analysis bivariate statistical method was used to derive landslide hazard class using following relation (after Van Westen, 1993).

Some flat areas such as hilltops (flat ridges) were found to be grouped into high hazard zone statistically by computer processing considering the similar geological formation on steep slopes with landslides. Landslides were not observed in such flat hilltop areas during field verification therefore those areas were reclassified as low hazard zones.

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

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

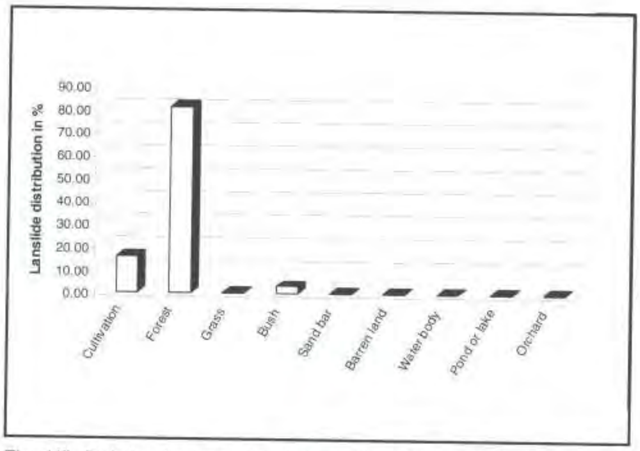


Fig. 1(f): Relation between Landuse and Landslide Distribution

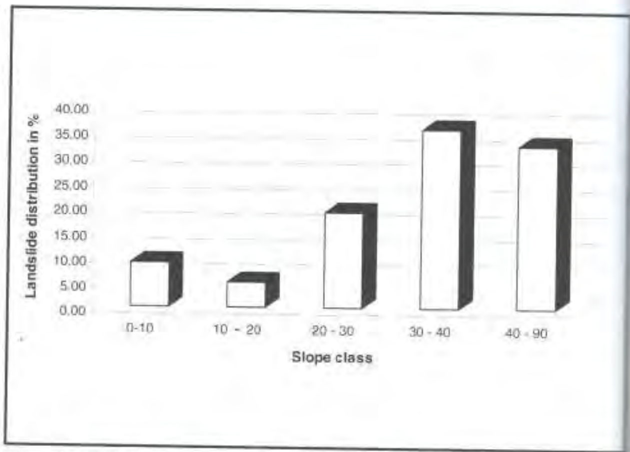


Fig. 1(h): Relation between slope and Landslide Distribution

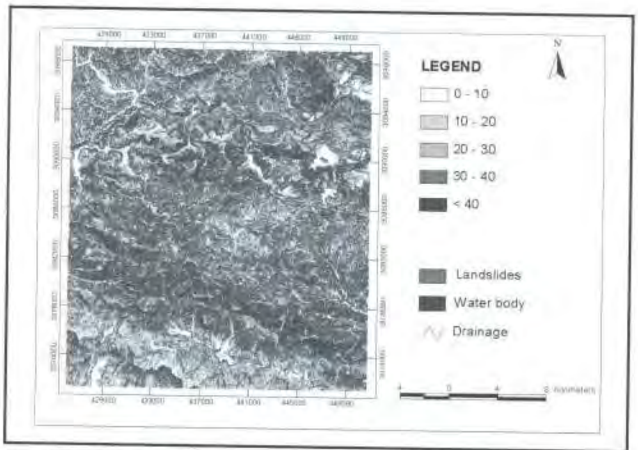


Fig. 1(g): Slope Map

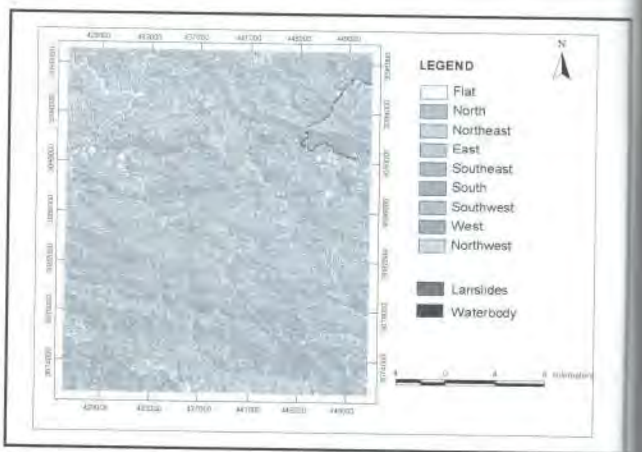


Fig. 1(i): Aspect Map

Fig. 10: Relation between Aspect and Landslide Distribution

INVESTIGATION RESULTS

Slope failure processes noted on satellite image, aerial photographs, topographical maps and geological maps were verified in the field. Areas prone to soil erosion by gully formation and land sliding were also recorded during field checking. Majorities of the slides are developed in loose soil mass and slides are also observed in combination of soil and rock mass. Rockslides are also triggered in intensely fractured rock mass. Discontinuities affecting rock mass are joints, bedding planes, foliations, thrusts or faults. Wedge and planer failures are common in fractured rock mass. Rock falls and topples are also noted at places of steep rocky slopes. Whereas rotational and translation features were observed in the soil mass resulted mainly due to oversaturation and toe scouring of the slope by the rivers.

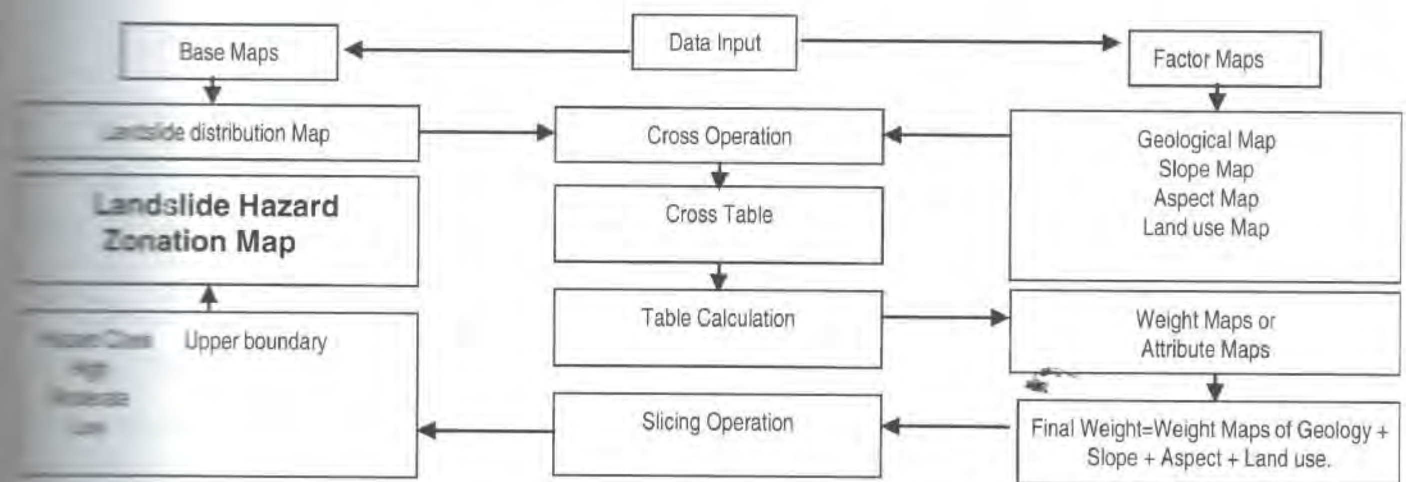
A large-scale slope failure has occurred near Chyami village. The landslide damaged agriculture land of Chyami village of Gulmi district. The slide washed away large mass of soil into the Kali Gandaki River. Alignment of a new road planned through the village was diverted along the riverbank away from the village to avoid the effect of this landslide in future. Another large landslide triggered along the Tansen Baglung road near Laguwa obstructs traffic in the rainy season every year. Landslides also affect new roads being constructed along the banks of the Dobhan Khola. Roads are the most affected structure in the study area.

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

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

PREPARATION OF LANDSLIDE HAZARD ZONATION MAP

Factor maps were subjected to intersection with the landslide distribution map to calculate landslide weight values of each unit of factor maps based on the formula after Van Westeen, 1993. Then weight maps of each factor maps are prepared in the GIS system which are again intersected to calculate total weight values of each units of factor maps creating a total weight map. The total weight map is then converted into grid file by the system with nine class having range of weight values. Finally the grid file is subjectively reclassified into three grid codes having weight value range to denote the area with low, moderate and high landslide hazard zones until the outcome is with the satisfactory result. In this reclassification process approximately 89 percent of landslide are anticipated to lie in the high hazard zone.



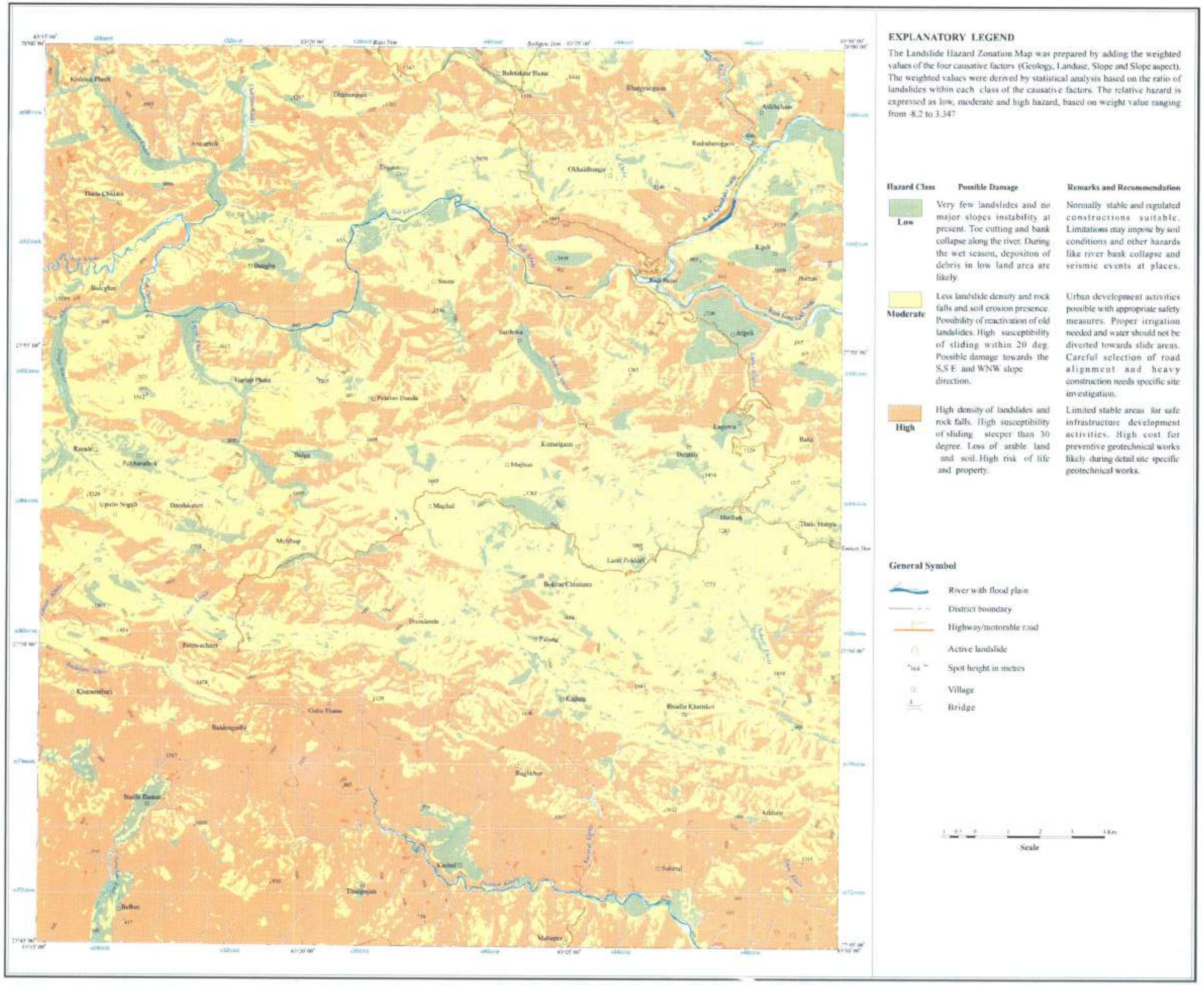


Fig. 2: Landslide hazard zonation map of some parts of Syanja, Gulmi and Palpa Districts

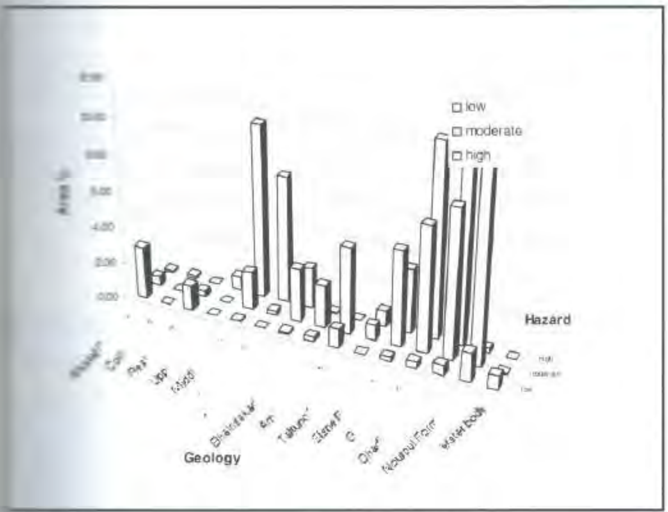


Fig. 3 (a): Relation between Hazard and Geology

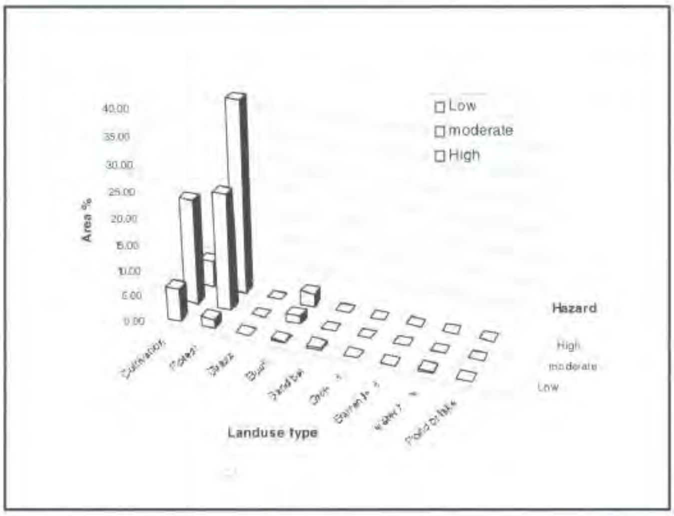


Fig. 3 (c): Relation between Hazard and Slope

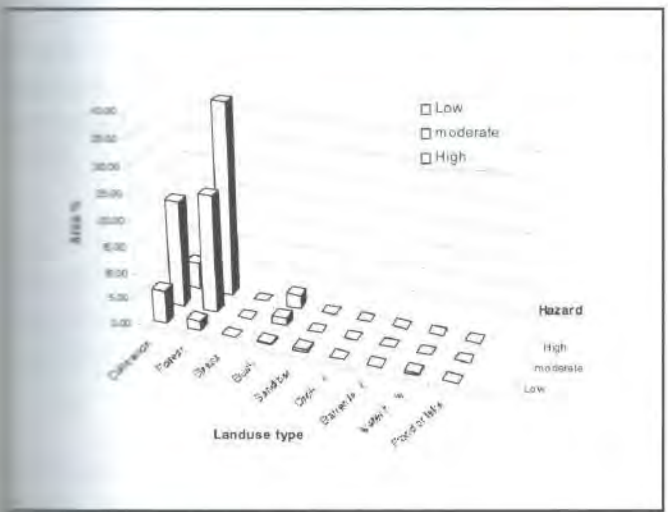


Fig. 3 (b): Relation between Hazard and Landuse

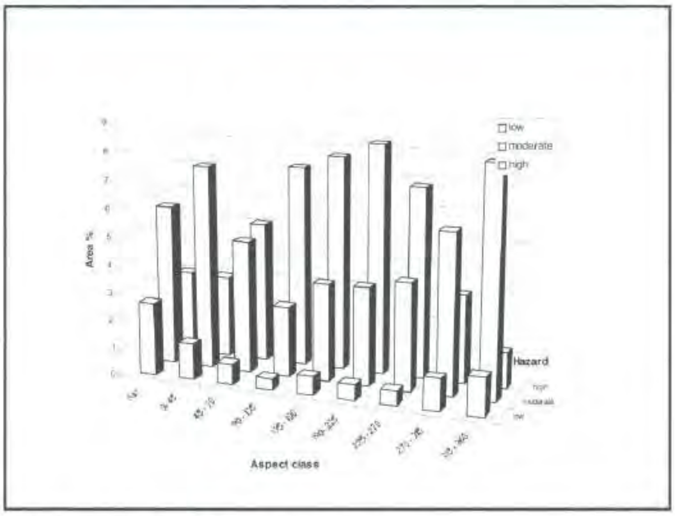


Fig. 3 (d): Relation between Hazard and Aspect

PREPARATION OF LANDSLIDE HAZARD ZONATION MAP

Factor maps were subjected to intersection with the landslide distribution map to calculate landslide weight values of each unit of factor maps based on the formula after Van Westeen, 1993. Then weight maps of each factor maps are prepared in the GIS system which are again intersected to calculate total weight values of each units of factor maps creating a total weight map. The total weight map is then converted into grid file by the system with nine class having range of weight values. Finally the grid file is subjectively reclassified into three grid codes having weight value range to denote the area with low, moderate and high landslide hazard zones until the outcome is with the satisfactory result. In this reclassification process approximately 89 percent of landslide are anticipated to lie in the high hazard zone.

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 88.7% of the landslides were found to be distributed in high hazard zone; nearly 10.8% in moderate and only 0.5 % in low hazard zone suggesting a satisfactory precision of the adopted method for probability of landslide occurrence in this area. The relation between hazard class and causative factors (Fig. 3a, b, c, and d) was also evaluated to assess the affect of various factors for estimating the range of instability in the region in terms of probability of landslide hazard.

CONCLUSION AND RECOMMENDATIONS

1. 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.
2. Slopes with thick soil mass or with highly jointed, deeply weathered soft rocks such as phyllites, mudstone and shale are found to be more

susceptible to land sliding. Steeper slopes with highly jointed rocks such as dolomite, sandstone and quartzite are prone to block falls and rock slides.

3. Newly constructed roads passing through loose soil mass and soft rocks are affected by landslides in the study area.
4. 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.
5. Altogether 230 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.
6. The total weight values were from -8.2 to 3.347. About 88.71% percent of the landslides are found to be located within the high hazard zone, 10.8% percent in moderate hazard zone and only 0.5 % percent in low hazard zone.
7. Hazard zonation map shows that about 310.58 sq. km covered by highly unstable zone forming 45.5% of the total study area whereas about 45.2% area are on moderate hazard zone and the rest 9.3 % in low hazard zone.
8. 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.

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

Achyut Koirala and Dinesh Nepali
Department of Mines and Geology, Lainchaur, Kathmandu Nepal

ABSTRACT

The mountainous terrain of the Nepal Himalayas is generally characterized by steep slopes, high relief, highly weathered and densely jointed rocks with unfavorable hydrogeological conditions with respect to slope stability. 'Landslide inventory and geohazard mapping of some parts of Palpa, Syangja and Tanahun districts' was conducted in accordance with the annual programme of Department of Mines and Geology for the fiscal year 2064/065 in order to acquire first hand information on the landslide hazard condition of the study area. Recently utilization of new methodologies including remote sensing and Geographical Information System are rapidly becoming popular in landslide hazard zonation mapping because of availabilities of appropriate data sets and powerful computer environment. The factors geology, slope angle and landuse all contribute to slope instability. These are analyzed in relation to landslide density and are numerically weighted. Landslide Hazard Map prepared by using bivariate statistical method and field landslide hazard map were considered together to prepare the final Landslide Hazard Map. From this, the study area has been classified into three classes of low, medium and high hazards. The map of this landslide hazard zonation may serve as a base for further study.

INTRODUCTION

Nepal is famous for its rugged mountainous terrain with unstable slope. Combined effect of steep slopes, complex geology, young and fragile mountain and heavy concentrated monsoon rainfall confined within four months of the year (June, July, August and September) has made the mountainous slopes of Nepal one of the most landslide prone areas in the world. Besides causing severe damage to infrastructures, landslides causes loss of human life and properties worth millions of rupees every year resulting disruption to the social and economic development of the country. Landslides can not be stopped because, it is a natural cyclic process of slope building, but efforts can be made to reduce its impact to the human life and properties.

Landslide is downward and outward movement of slope material under the influence of gravity. Normally the movement occurs when the shear stress exceeds the shear strength. Present day landform is the result of past landslide activity in one or other form. The instability of a slope is mainly governed by terrain parameters, lithology, structural condition of the rock, properties of overlying soils/rocks, slope gradient landuse, human intervention, and vegetation cover. Although, the specific impacts of these causative factors sometime so mixed among them make it very complex to differentiate. The landslide hazard is referred to as the probability of occurrence of a potentially damaging landslide within a period of time in certain area. Landslide hazard map is a map to show the interactive and combined result of all the above activities in an area.

The assessment of landslide hazard is a costly and time-consuming activities which requires aerial photographs, field surveys and measurements, and rock / soil property tests in laboratory. Recently, utilization of new methodologies including remote sensing and Geographical Information System (GIS) are rapidly becoming popular in landslide hazard zonation because of availabilities of appropriate data sets and powerful computer environment.

Landslide Hazard Zonation mapping helps to find the ways to mitigate landslide disaster. Department of Mines and Geology (DMG) has been conducting landslide hazard zonation mapping since last few years. Present study 'Landslide inventory and geohazard mapping of some parts of Palpa, Syangja and Tanahun districts' was conducted in accordance with the annual programme of the DMG for the fiscal year 2064/065 in order to acquire the first hand information on the landslide hazard condition of the study area.

The study area is bounded by latitude 27°45'00" N to 28°00'00" N and longitude 83°45'00" E to 84°00'00" E covering 650 sq. km. It comprises inventory and distribution of landslides and other factor maps required for the preparation of Landslide Hazard Zonation map at 1:50,000 scale. The area of investigation falls in sheet No. 2783 04 (63 M/13). Previously landslide hazard mapping of such type was not carried out in this area. The results of present study will be basically beneficial for infrastructure development planning.

OBJECTIVES

Present investigation aimed to achieve the following main objectives:

- To study the major landslides and register them in the Preliminary Landslide Inventory Form
- To map all the landslides observed in the field in 1:25,000 scale topo-sheets as far as the scale permits.
- To prepare landslide distribution map and provide geo-scientific information of the area on natural hazards.
- To integrate landslide distribution and geological information with various slope morphology and existing land-use for the preparation of landslide hazard zonation map at a scale of 1:50,000 by the utilization of suitable Remote Sensing and GIS techniques.
- To identify major causes of landslides and recommend the suitable preventive measures if applicable.
- Finally to prepare a landslide hazard zonation map.

METHODOLOGY

- Topographic maps of 1:25,000 scales from the Survey Department were used as base map for the investigation purpose.
- Aerial photo of 1996 at a nominal scale of 1:50,000 were interpreted to examine morphological character of the ground, various landslides and erosional feature.
- Google image was consulted for the evaluation of overall development of the hill slope processes and man made impact in the nature.
- Existing geological maps and relevant literatures of the study area were reviewed.
- To evaluate the hazard category of an individual slopes, walkover survey was carried out along the valleys and/or ridges whichever was found suitable for better visibility of the slopes with or without landslide.
- Geological reasons were looked for an area whenever an anomalous landslides occurrence was observed.
- Geological observations were made whenever required.
- Landslide inventory forms were filled mainly for old, big and famous landslides.
- In statistical landslide hazard analysis, the combinations of factors that have led to landslides in the past are determined statistically and quantitative predictions are made for landslide free areas with similar conditions.
- Various organizations are using different methods for landslide hazard analysis. The DMG in the past was using mainly bivariate statistical method. Bivariate statistical analyses deal with one dependent variable, which in this case is the occurrence of landslides, and one independent variables, the parameter map.

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

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

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

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

FIELD INVESTIGATION AND PREPARATION OF PARAMETER MAPS

The instability of a slope is mainly governed by terrain parameters such as lithology and structural condition of the rocks, overlaying properties of soils, slope gradient, vegetation, landuse and human activities acting on the slope conditions. However, the specific impacts of these causative factors can sometime be mixed among themselves making it very complex and difficult to differentiate. Therefore, the overall hazard potential of any given area is a combination of subjective rating of that area against each of the above factors.

The data required for the present investigation were obtained from different sources of information together with field work of about one and half month duration, carried out in 2065. Toposheets in a scale of 1:25,000 were used as base maps for plotting the data.

Emphasis was given in checking big landslides and area which were vulnerable to landslide and deep erosion. Maximum amount of data acquisition was done from source maps and field investigation (Fig. 2). The data overlays, sources, derivative parameters and method of generation are given in Table 1.

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

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

DMG[1]: Department of Mines and Geology, Kathmandu SD[2] : Survey Department, Kathmandu, VI[6] : Visual Interpretation, FC[7] : Field Checking

Bedrock influences the landslide occurrence in several ways. Weak, incompetent rock is more likely to fail than strong, competent rock. On slopes where weak rock overlain by strong rock is exposed, the difference in strength increases the potential for landsliding in the stronger rock as well since the weak rock tends to erode and undermine the stronger rock. The strength of a rock mass depends on the type of rock and the presence and nature of discontinuities such as joints or other fractures. The more discontinuities present in bedrock, the greater the likelihood of rock instability. The published geological map of DMG (63 M/13) was used for the purpose of geological data derivation for the preparation of landslide hazard map of this study. According to the published geological map, the study area consist mainly the rocks of Tansen, Upper Nawakot and Lower Nawakot Groups. Major rock types and their probable age of the group of rocks are given in the Table 2.

Table 2: An overview of geology of the study area

Group	Formation	Rock type	Age
Superficial Deposit	Alluvial Deposit	Gravel, Boulder, sand and Silt in terraces, flood plain and stream channel	Quaternary to Recent
Tansen Group	Dumre Formation	Greenish grey sandstone with subordinate purple to dark grey shale and rare carbonates.	Permo-Carboniferous to Oligocene
	Taltung Formation	Grey and purple shale, siltstone, sandstone and conglomerates.	
	Sisne Formation	Grey diamictite with grey and purple shale, sandstone and conglomerates.	
Upper Nawakot Group	Benighat Slates	Dark grey carboniferous slates and phyllites with tongues of Jhiku carbonates	Paleozoic to Pre-cambrian
Lower Nawakot Group	Dhading Dolomite	Grey siliceous dolomite with stromatolites and oolites	Precambrian
	Nourpul Formation	Grey green and purple slates/phyllites arkosic quartzites pink and grey siliceous dolomites and dolomitic quartzites.	
	Dandagaon Phyllite	Greyish green to silver grey phyllites/slates with minor quartzites.	

More than 50% of the study area is covered by the rocks of Lower Nawakot Group mainly by the Dhading Dolomite and Nourpul Formation. Dandagaon Phyllite of the same Group is only appearing in few places and is not playing any significant role in slope formation or slope stability. The rock of Tansen Group is mainly covering southeastern part and a small area in the southwest. Terraces of Kaligandaki River and some of its tributaries are occupied by alluvial deposit. Lastly the rocks of Upper Nawakot Group is covering a wide strip of the map area in the central part map from east to west and also a narrow strip of the same rock is appearing area slightly below the northern boundary of the map. While preparing the landslide hazard map, it was found that relation between the type of rock and the intensity of landslide hazard can be established quite clearly in most of the places. However, slope aspect, the relief and the discontinuity configuration was found to play a leading role when different hazard intensity was found in the area with similar rock type.

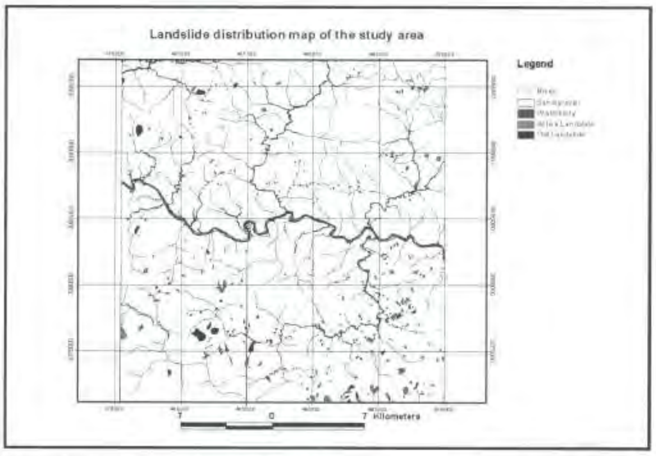

Fig. 1 (a): Landslide Distribution Map

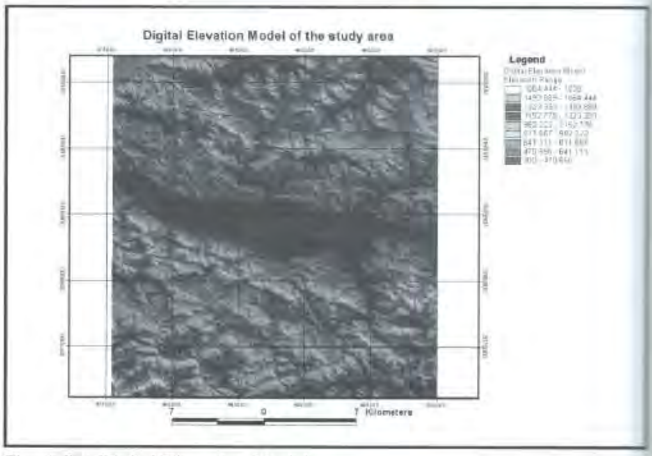

Fig. 1 (b): Digital Elevation Model

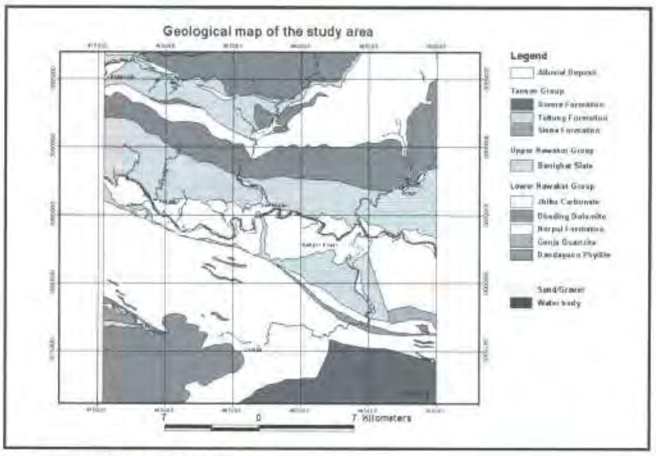

Fig. 1 (c): Geological Map

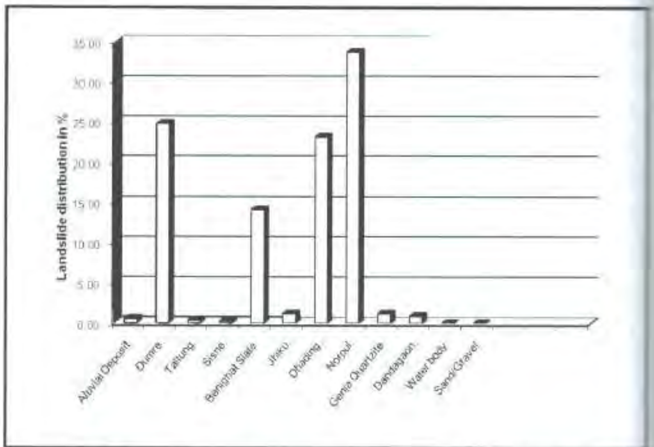

Fig. 1 (d): Relation between Geology and Landslide distribution

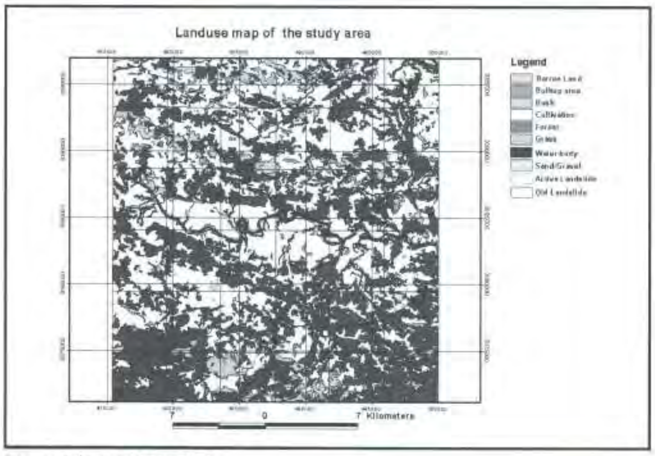

Fig. 1 (e): Landuse Map

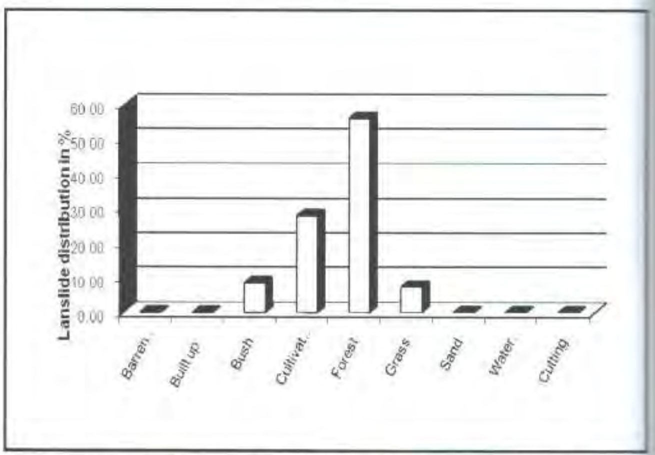

Fig. 1 (f): Relation between Landuse and Landslide distribution

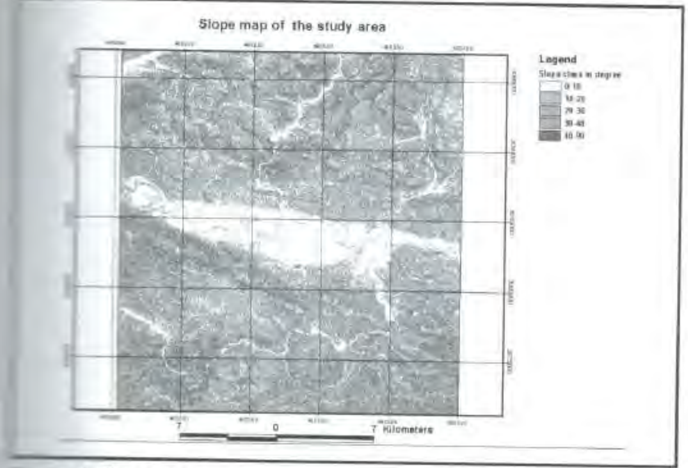

Fig. 1 (g): Slope Map

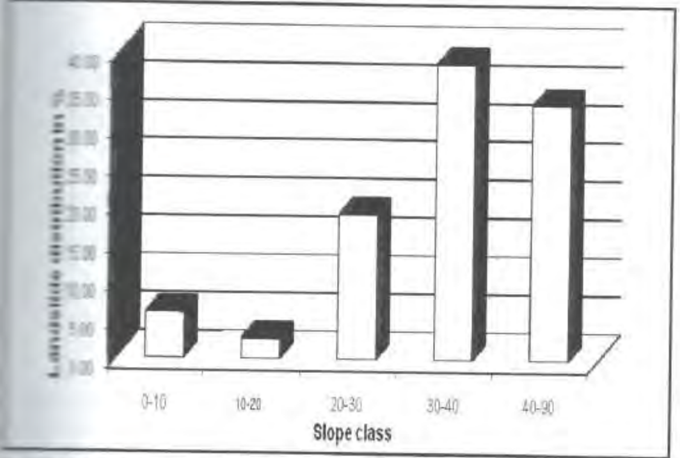

Fig. 1 (h): Relation between Slope and Landslide distribution

The factor maps of various parameters such as landslide distribution, Geology, Slope and Landuse used for the preparation of landslide hazard zonation map were prepared using the GIS. The relationship of landslide ratio to various classes of parameter maps were summarized and found to be associated with certain classes of different parameters and presented after statistical analysis.

Preparation of Landslide Hazard Zonation Map

For the preparation of landslide hazard zonation map, the landslide hazard was evaluated statistically by evaluating those factors that have led to landslides in the past and quantitative predictions are made for landslide free areas with similar conditions. The preparation of the landslide hazard zonation map involved several steps. After having the landslide and all factor maps in coverage/shapefile form, they were intersected utilizing the GIS techniques. Subsequently statistical analysis was carried out in order to derive a bivariate model. The results of this analysis were then transferred back to the GIS for deriving the landslide hazard zones. Landslide hazard map was prepared to identify areas with differing landslide hazard. This map divides the entire study area into sub-areas based on the degree of a potential hazard from landslides. For the calculation of hazard map we have to take consideration on all the weight values of each parameter class.

While preparing the final landslide hazard map besides intensive use of GIS techniques human intelligence was an added factor. In this respect, in the field individual slope unit was evaluated in terms of hazard class, depending upon the morphology of the slope, geological condition, landuse, vegetation cover, human intervention and geohydrology. Hence immediately after the field work a rough landslide hazard map was prepared. However, landslide hazard map prepared using bivariate statistical method and above field hazard map were considered together to prepare the final Landslide hazard map. In most of the cases the hazard category of individual maps from field and the GIS based was matching. Whenever they were different geological causes was found to play a role and hence the suitable hazard class was assigned manually after the proper judgment.

As the main output of the investigation, a landslide hazard zonation map (Fig. 3) was prepared by differentiating the entire study into three hazard classes based on the degree of potential hazard from landslide. For the GIS based map each class of the factor map had different weight value, the addition of all the weight value for a certain region was carried out during the hazard calculation. After assigning the weight for hazard coverage, the hazard zonation was classified into three different zones as low, medium and high hazards.

Result of the statistical analysis

After assigning the hazard classes, an analysis was carried out in order to check how much of the landslide area falls within the high hazard zone. For this Landslide map was overlaid with the final Hazard Map and landslide density for three classes were calculated. In this respect about 85 % of the mapped landslide were located within the high hazard zone, about 14% in medium hazard zone and rest in the low hazard zone. The following figures show the relation between hazard categories and various causative factors (Fig. 4a, 4b and 4c).

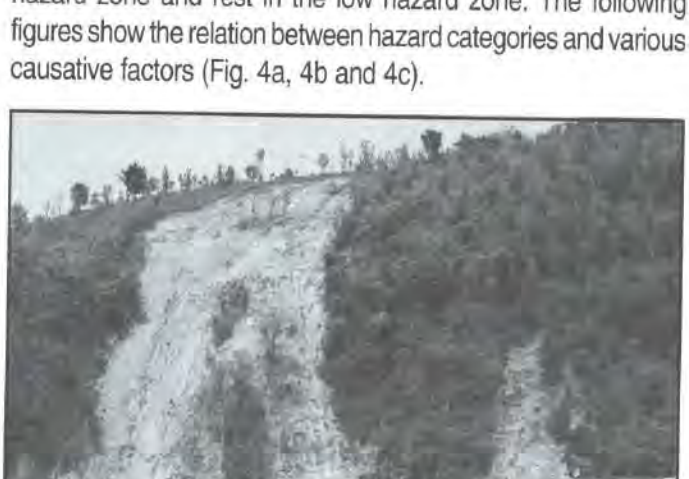

Fig. 2: Landslide on the right side of the Nisdi Khola near Kirtipur village (way to Rampur)

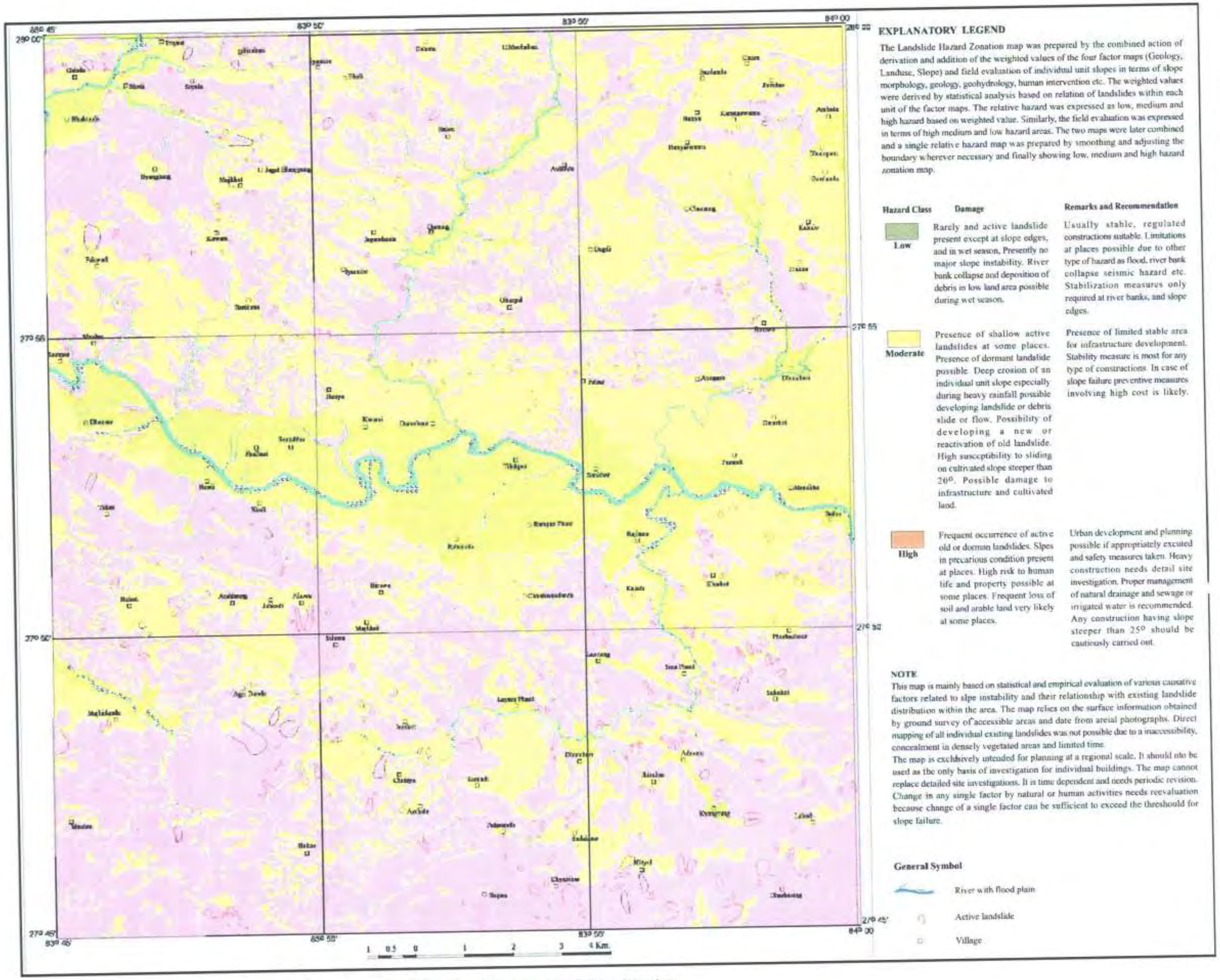

Fig. 3: Landslide hazard zonation map of some parts of Syanja, Palpa and Tanahun Districts

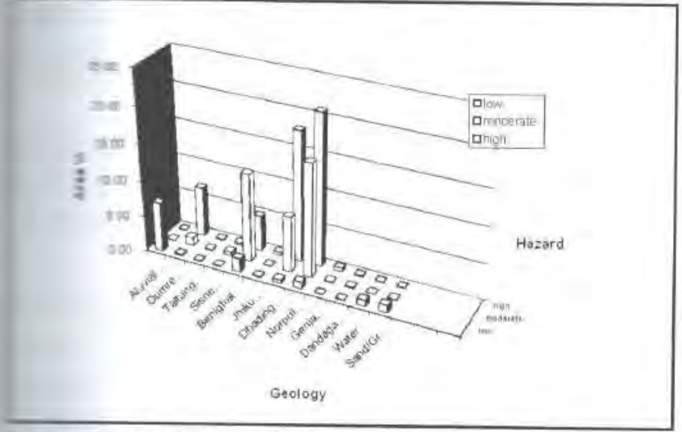

Fig. 4a: Relation between Geology and Hazard

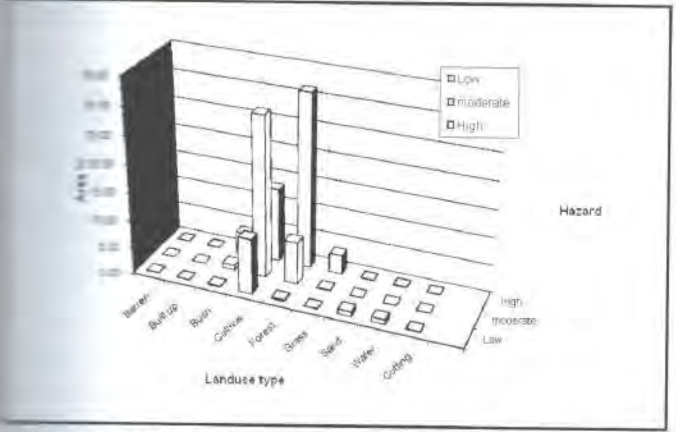

Fig. 4b: Relation between Landuse type and Hazard

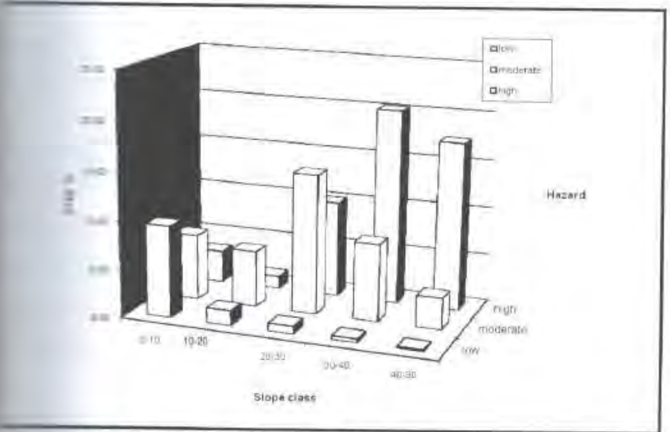

Fig. 4c: Relation between Slope and Hazard

CONCLUSION

- Geographic Information System can be considered as a powerful tool for representation and analysis of spatial information related to geosciences.
- Areas susceptible to landslides can be delineated based on the physical factors associated with landslide activity like past landslide history, geology, slope steepness and landuse.
- The Dumre Formation of the Tansen Group and the Dhading Dolomite and the Nourpul Formation of the Lower Nawakot Group were found to be more vulnerable to landslide than other types of rocks. The landslide in the Dumre Formation can also be attributed to the proximity to Main Boundary Thrust (MBT) whereas the landslides in the Nourpul Formation can be attributed to alternately layered competent and incompetent rock. In case of the Dhading Dolomite the landslides were caused by steepness of the slopes and brittle nature of rock.
- Hence, when compared to the density of landslides to geological formation and hazard class map it was directly correlating. Most of the area occupied by the Dhading Dolomite, the Nourpul Formation and the Dumre Formation were found to be in High Hazard class whereas the majority of the area covered by alluvial deposit was low hazard areas.
- Most of the slope failure that took place in the study area falls in between 30-40 degrees.
- Dip slopes were found to be more vulnerable to landslide development than otherwise.
- Most of the landslides were found to be occurring in cultivated and forest land.
- In most of the cases landslides were occurring due to the natural causes such as toe erosion by river/stream or road construction, steepness of slope, deep weathering in soft nature of rock or unfavorable discontinuity configuration to the slope etc. However, man made causes were also found to play considerable role in the occurrences of landslides mainly in the area occupied by colluvial soil deposit or deeply weathered rock slopes. Mainly the man made causes of landslides were mainly confined to construction of road by toe cutting of vulnerable slopes, deforestation and tilling of marginally stabilized slopes.
- The landslide hazard zonation map provides a good geo-scientific base of the study area for planers policy makers and developers in minimizing the risk of loosing the scarcely available resource of the developing countries like Nepal.
- The final product, landslide hazard map of the study area should be used as the only basis of investigation for major civil structures. It can not replace site specific investigations. It is time dependent and needs periodic revision. Change in any natural factor or any human intervention may change the whole hazard scenario by exceeding the threshold value for the slope stability of the individual unit slope.

ACKNOWLEDGEMENT

The authors are grateful to Dr. R. B. Shrestha the Officiating Director General DMG for supporting the field programme and guidance. Our sincere gratitude is to S. P. Mahoto the Deputy Director General. Sincere thank are expressed to R. R. Shakya and other senior staffs of the Department. The authors also like to express their sincere thank to all those who helped directly or indirectly in course of preparing this report and map.

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Geology of a Part of Sunsari and Morang Districts (Petroleum Explotation Block 10), Eastern Nepal

Devi N. Subedi
Petroleum Exploration Promotion Project / Department of Mines and Geology, Lainchaur, Kathmandu, Nepal

ABSTRACT

The field program was scheduled in accordance with the annual field program of Petroleum Exploration Promotion Project / Department of Mines and Geology for the year 2064-2065. A detailed geological investigation has been carried out in a part of Sunsari-Morang district of Eastern Nepal. The study area consists of metamorphic, metasedimentary and Siwalik Group of rocks. The field investigation was confined to the Siwalik and metasedimentary group of rocks. Fifty kilometer section line were measured along the different khola sections. The Lower Siwalik Formation was studied for identification of shale bed to evaluate the potential source and seal for hydrocarbon generation and few sand samples were collected for the evaluation of potential reservoir rocks. Structurally, the mapped area is complex with presence of major and minor thrust, fault and fold structures. The general trend of the formation is northwest-southeast with dipping towards northeast.

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 B.S. 2064-2065. The field program was scheduled to carry out geological investigation in the area and prepare geological map of a part of Sunsari – Morang district of Eastern Nepal. A 50 line kilometer section measurements had been completed along the different khola section of the assigned area.

The study area lies in Sunsari and Morang districts between 26°44'50" to 26°48'35" N latitudes and 87°25'00" to 87° 35'01" E longitudes, in the topo sheet nos. 2687 – 02D, 03C, 06B and 07A of 1:25,000 scales published by the Survey Department, Nepal. These maps were used as a base map to prepare the geological map.

Geologists from Nepal as well as other countries have visited the area in connection with the regional geological mapping as well as mineral exploration work. Baidya (1968) did the regional geological mapping while Kayastha (1971) concentrated in the tracing of Phosphorite bearing horizon in the area. Yadav (1984) traversed the area in connection with the radioactive minerals exploration in the Siwalik region. Shrestha and Sharma (1997) conducted the geological section measurement in the area.

The study area can be approached via East – West Highway from Kane Pokhari. The Kane Pokhari-Letang gravelled road connects the East-West Highway at Kane Pokhari. The mapped area can also be reached from the various north – south flowing section crossing the East-West highway at places as Teli Khola, Bhaluwa Khola and Chisang Khola.

OBJECTIVES

The objectives of the study are:

- to prepare a detailed geological map between Bhaluwa Khola – Muguwa Khola area within the Siwalik and Metasedimentary Group of rocks.
- to prepare a detailed geological section of selected area so as to cover the total thickness of Siwalik Formation as well as Metasedimentary Group of rocks.
- collection of petro-geochemical samples from the shale horizon of Lower Siwalik Formation and the Metasedimentary Group of rocks to assess potential source, seal and reservoir rocks in the area.

FIELD INVESTIGATION METHODOLOGY

Geological mapping and section measurement were carried out using brunton compass, tape, hammer and topographic base map of 1: 25,000 scale. Traverses were made along the Chisang , Tali and Mugu kholas up to Mahabharat Thrust (MT) to cover the Siwalik as well as to locate the Metasedimentary Group of rocks in the area. The different lithological units within the Siwalik Group has been identified and used for correlation to understand the lithologic variation within the mapped area. The major and minor structural features have been identified in the field. The details of lithological units were measured and mapped to find out the lateral extension and variation of the different rock unit in the formation that helps to understand the source, seal and reservoir character of the formation. Few selective samples were collected from the shale horizon of Lower Siwalik Formation (LS) and sandstone sample from the Middle Siwalik Formation (MS) for source and reservoir analysis.

GEOLOGY

The study area forms a part of Mahabharat Range and Siwalik foot hills. The rock formation within the study area between Bhaluwa khola in the west and Mugu khola in the east was geologically studied and the geological map of the area was prepared. The lower hill (Churia Range) forms an irregular terrain like ridge and valley consisting of sandstone, shale, mudstone and siltstone etc. The higher mountain of the study area is Mahabharat Range of Lesser Himalaya and is composed of metasedimentary and metamorphic rocks. The study area is confined with watersheds of number of major and minor kholas like Bhaluwa khola, Chisang khola, Morang khola, Tali khola Solti khola and Mugu khola etc.The drainage pattern of the river system in the area is mainly dendritic.

The study area consists of rocks of Siwalik Group, Metasedimentary Group and Metamorphic Group of rocks. The Siwalik rocks constitute the foothill Range of Churia Hill of Sub - Himalaya. The metasedimentary rock is exposed along the northeastern part of mapped area. The metamorphic rocks constitute the Mahabharat Range of the Lesser Himalaya and cover almost northern part of the mapped area. The study area falls in the Petroleum Exploration Block 10, Biratnagar (Fig. 1).

Geologically the rock formation occurring in the study area is tectonostratigraphically divisible into two groups. Siwalik Group consisting of molasses sediments occurs in south of Main Boundary Thrust and Midland Group occurs in north of the MT. The metasedimentary rock is exposed at the north eastern part of the mapped area. The rock of Metamorphic Group exposed in the northern part of the mapped area is thrust over the rocks of Siwalik Group along the Main Boundary Thrust (MBT) in the northwestern and central part of the mapped area, where as in the eastern part the metamorphic group of rocks are thrust along the MT. The oldest rocks of Metamorphic Group exposed in the study area consist of white massive quartzite, phylite, gritty phylite and are interbedded with gritty quartzite. Grey massive phylite are also noted with quartz lenses and veins along the foliation plane.

The youngest rock exposed in the study area is the rocks of Siwalik Group. This Group has been classified into three distinct units as LS, MS, and Upper Siwalik (US). Based on lithological character, the MS has been further subdivided into two units as Lower Middle Siwalik (MS1) and Upper Middle Siwalik (MS2). The rocks of Siwalik Group are mainly composed of claystones, mudstones, shale, siltstones, sandstones, pebbly sandstones and conglomerates.

The LS mainly consists of fine to medium grained hard and compact sandstone, which are some time quartzitic in nature. They are grey to light grey in colour. Sandstone intercalated with grey and maroon or purplish grey siltstone is common. The MS1 consists of medium grained sandstone with rhythmic interbands of siltstone mudstone, clay stone and shale. The MS2 is composed of grey to brownish grey arkosic friable sandstone, pebbly sandstone and claystone. In composition MS2 and MS1 are very much similar but only different is in grain size and presence of pebble in sandstone. The US is composed of massive conglomerate, coarse grained micaceous pebbly sandstone and reddish brown clay. The rocks of Siwalik Group are bounded in the north by the MBT and in the south by the Main Frontal Thrust (MFT) followed by Quaternary sediment.

Structurally the study area is complex. There are number of major and minor folds, faults and thrusts. The thrusting has caused the repetition of Siwalik in the southern part of the mapped area, while major thrusts has caused the occurrence of older rocks over the younger rocks in the northern part of the mapped area. The major thrust faults the MBT which has caused the thrusting of the Midland Group of rocks over the Siwalik Group, the MT causing the thrusting of metamorphic unit over the metasedimentary rocks. The repetition of Siwalik rock observed in the southern part of the mapped area is due to the folding and faulting. The general strike of the formation is NW-SE which is parallel to the general trend of the mountain chain and dip towards northeast. At places the dip of the bed shows southwesterly due to folding (Fig. 1).

CONCLUSION AND RECOMMENDATION

Conclusion

The rock formations occurring in the study area have been divided into the Siwalik Group, Midland Group and Metamorphic Group with the boundaries between these groups being the thrust. The older groups of rocks are confined to the upper part of the study area whereas the younger group of rock are confined to the southern part of the mapped area.

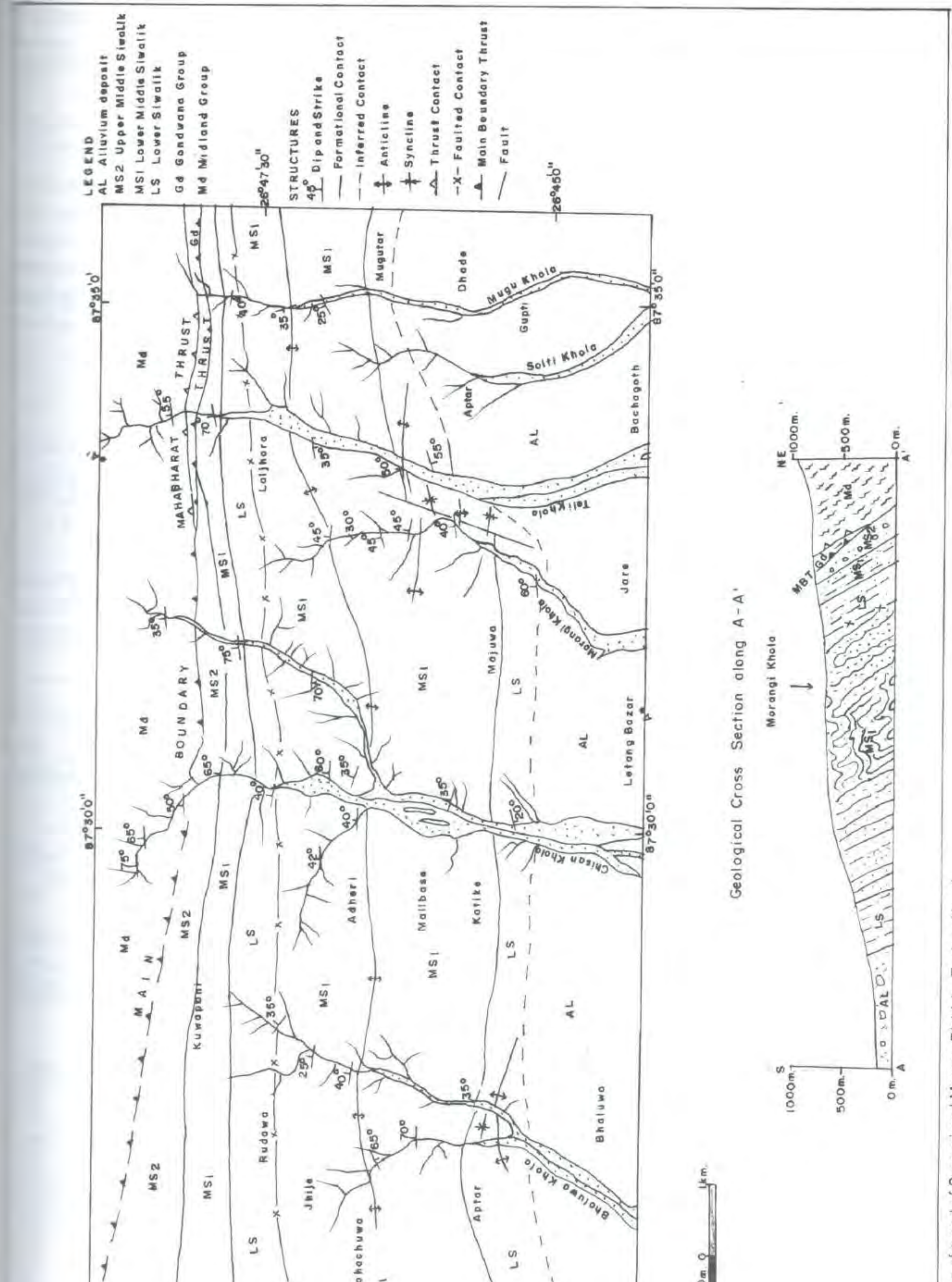

Fig. 1: Geological map of a part of Sunsari and Morang Districts, Eastern Nepal

Geological section measurement and petro-geochemical sampling were carried out along the river section between Bhaluwa khola in the west and Mugu khola in the east within the sedimentary rocks belonging to the Siwalik Group. The sedimentary rocks of Siwalik Group are under the thick alluvium deposit in the south and separated from the rocks of Lesser Himalaya to the north by the MBT. The metasedimentary rocks exposed in the northeastern part of the mapped area are thrust over the Siwalik Group of rocks along the MBT and the metamorphic group of rocks are thrusted over the metasedimentary rocks along the MT in the east and are thrusted over Siwalik Group of rocks along the MBT in the western part of the mapped area.

The Siwalik Group of rock shows the cyclic sedimentation. The sedimentary cycle begins with medium grained sand stone fining upwards to fine grained sandstones grading to sandy siltstone and siltstone and then to silty mudstone to mudstone topped by dark grey carbonaceous to humic clay. Thickness of typical sedimentary cycle is noted few meters along the khola sections.

Samples were collected from the shale horizon of LS and sandstones from the MS to evaluate source and reservoir potential for hydrocarbon generation and accumulation. The shale samples were collected for maturity test and possible source and seal rock analysis. The rock samples from MS were collected to evaluate the possible reservoir rocks analysis.

Recommendation

- Detailed geological mapping and sampling should cover large area to evaluate the lateral variation of the formation and its position in the formation.
- Detailed geological work should be carried out to establish the actual thickness of shale and sandstone beds to assess the sealing and reservoir potential in Siwalik rocks.
- Detailed geochemical and microscopic analysis should be carried out to identify the source, seal and reservoir potential for the sample collected from the Siwalik Group.

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Geological Studies and Section Measurement of Parts of Morang-Sunsari Districts, Eastern Nepal

Rajendra Prasad Khanal
Petroleum Exploration Promotion Project / Department of Mines and Geology, Lainchaur, Kathmandu, Nepal

ABSTRACT

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 2064/65 BS. The present field investigation work is involved in carrying out geological section measurement of 50 km length including geological mapping along major river sections such as Khadam Khola, Seuti Khola, Sehara Khola, Ruduwa Khola, Dharan-Bhedetar Road Section, and its adjacent areas of Morang and Sunsari Districts of Eastern Nepal.

INTRODUCTION

The study area lies within latitudes 26°42'30" N to 26°52'30" N and longitudes 87°15'00" E to 87°28'00" E (Fig. 1). The study area lies in the parts of toposheets 2687 02C, 02D, 06A and 06B prepared by Survey Department, Government of Nepal (Scale 1:25,000).

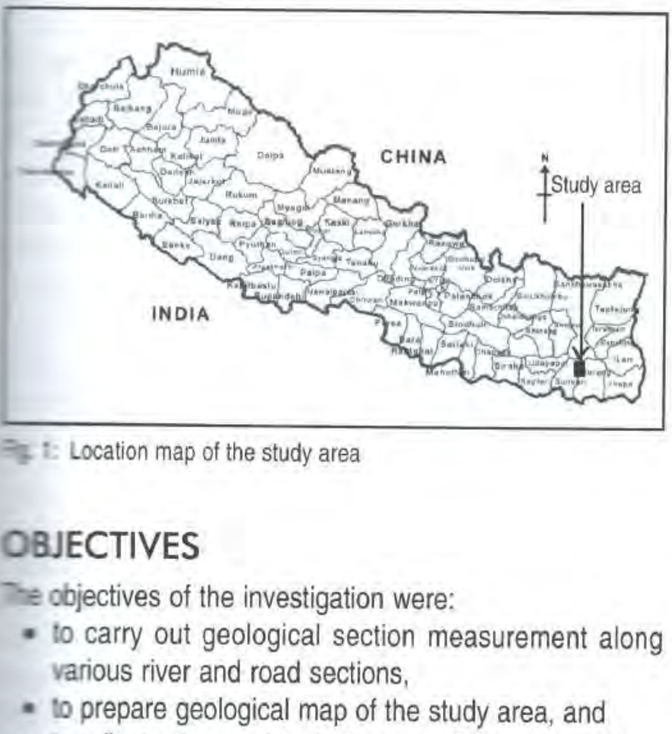

Fig. 1: Location map of the study area

OBJECTIVES

The objectives of the investigation were:

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

METHODOLOGY

To identify the trace of major structural features such as Main Frontal Thrust (MFT), Main Boundary Thrust (MBT), and Mahabharat Thrust (MT) satellite images mainly Google earth image and aerial photos were studied. Available literatures on geology of Eastern Nepal 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 Khadam Khola, Seuti Khola, Ruduwa Khola, Dharan-Bhedetar Road Section, and its adjacent areas of Morang and Sunsari Districts of Eastern Nepal.
- The details of the lithological units were studied and mapped to find out the lateral extension and variation of the different rock types to understand the source, seal, and reservoir potential rocks 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 study area is represented by sedimentary, metasedimentary and metamorphic rocks belonging to Quaternary sediments of Terai, Siwalik Group of Sub-Himalaya as well as Gondwana Group and Midland Group of Lesser Himalaya from south to north respectively (Kayastha, 1971; Bashyal, 1973 and Pradhan et al., 2006). The Terai belt is the northern extension of Indo-Gangatic Plain, which consists of Quaternary sediments of different grain size. The rocks of the Siwalik Group consist of claystone, mudstone, siltstone and sandstone. The Mahabharat Range or the Lesser Himalaya constitutes the sedimentary to metamorphosed rocks like shale, slate, quartzite, dolomite, phyllite, etc (Kayastha 1971, Bashyal, 1973). The geological setting and the stratigraphic sequence of the studied area are shown in Table 1 and Fig. 2, respectively.

In general, the strike of the rock in the area is NE-SW, sometimes NW-SE and the bed dips NE to NW and sometimes SW at an angle of 24°- 78°.

Table 1: Stratigraphic sequence of the study area

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

Dailekh Group

The rocks of the Dailekh Group are clearly exposed in the northern part of the study area. The rocks of this group are thrust over the rocks of the Gondwana Group along the MT (Fig. 2).

Dubbidanada Formation

It is the Precambrian type of exposed rock in the studied area. It consists of grey to greenish grey phyllite and grey to white sericitic quartzites. It is well exposed along Khadam Khola, Sehara Khola and Bhedatar- Dharan Road Section (Kayastha, 1971).

Gondwana Group

Charchare Formation

The outcrop of this formation comprises mainly dark grey to black, carbonaceous silty shale, quartzites with ferrugionous coatings. The rocks of this formation are clearly observed on the north of Dhoban in Khadam Khola (Fig. 4), northwest of Takure village in Sehara Khola Section (Fig. 5), north of Seuti Khola and Dharan-Bhedetar Road Section. Shales are very thinly bedded and also found as thin intercalations with quartzites. The shale contains coal bearing materials (Fig. 5). These are very soft and crushed.

Siwalik Group

The Siwalik Group (Middle Miocene - Lower Pleistocene) is composed of sandstone, mudstone, siltstone, shale, clay and conglomerates in the studied area (Fig. 2). It is bounded by the MFT to the south and the MBT to the north. The sandstone of the Siwalik group is medium grained, porous, and permeable. It can be considered as the good reservoir for hydrocarbon accumulation. The Siwalik group has been divided into three formations: Lower Siwalik, Middle Siwalik and Upper Siwalik on the basis of lithological variations. The Middle Siwalik can be further divided into the Lower Middle Siwalik and Upper Middle Siwalik. Upper Siwalik types of rocks is not exposed in the study area.

Lower Siwalik (LS)

Lower Siwalik is the oldest formation in the Siwalik Group. It is composed of fine to medium grained light grey to grey sandstone, maroon nodular clay and reddish brown marl (Figs. 6 and 7). It occupies the southern part of the mapped area just north of Terai plain mainly in Ruduwa Khola, Sehara Khola, and Sardu Khola Sections. It is repeated in Sehara Khola, Khadam Khola (Fig. 8) and Bhaluwa-Ruduwa Khola Sections in the middle of the Siwalik Range (Fig. 2).

Sandstones are fine to medium grained and grey in colour. Thickness of the sandstone increases towards the top. Sandstone beds are thin to medium bedded and attain up to

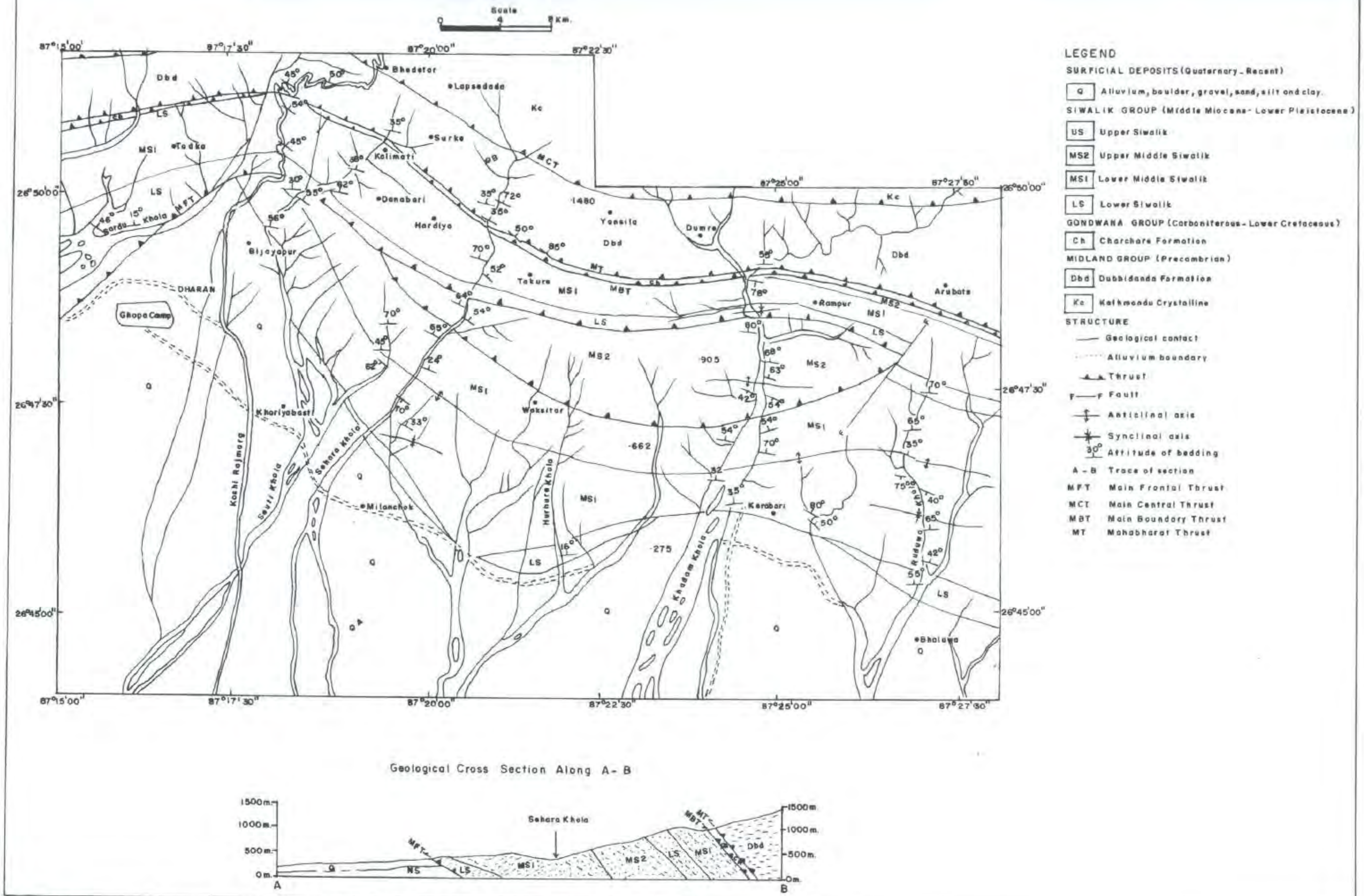

Fig. 2: Geological map of parts of Morang and Sunsari Districts, Eastern Nepal (Petroleum Exploration Block No.: 10)

Fig. 3: Grey phyllite and grey to white sericitic quartzites of Dubbidanda Formation in Khadam Khola

Fig. 4: Grey to dark grey carbonaceous shale of Charchare Formation in Dhoban area along Khadam Khola section

Fig. 5: Dark grey carbonaceous shale with coal bearing materials observed in the confluence of Malba Khola and Sehara Khola, north of Hardiya village

75 cm. Clay layer is medium to very thick bedded and purple to greenish grey in colour. The thickness of the individual beds of clay varies from 1.5 m to 3.5 m.

In general, the strike of the formation is NW-SE with dip amount 35°- 70° towards north and sometimes south. It is conformably overlain by the Middle Siwalik (MS1).

Fig. 6: Outcrop of the mudstone dominated Lower Siwalik along the Bhaluwa-Ruduwa Khola section

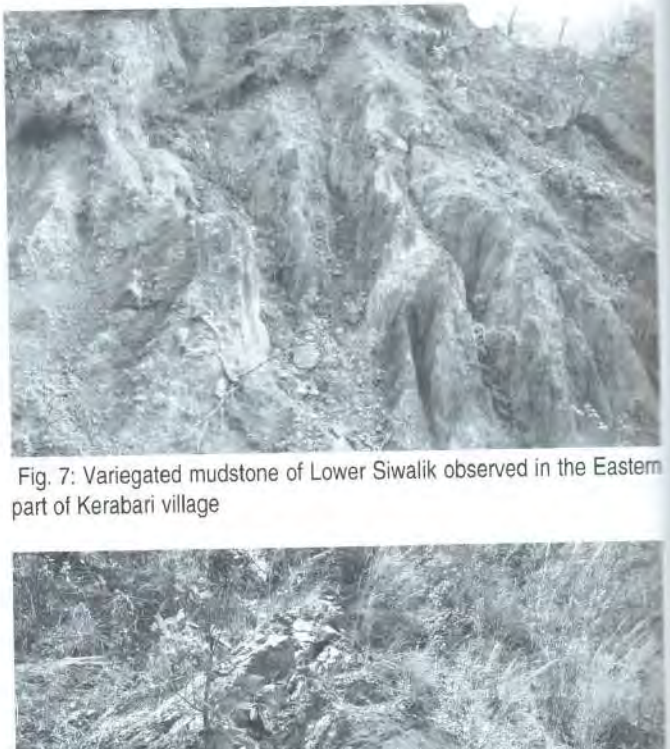

Fig. 7: Variegated mudstone of Lower Siwalik observed in the Eastern part of Kerabari village

Fig. 8: Outcrop of the Lower Siwalik along the Khadam Khola in the middle of the Siwalik Range

Middle Siwalik (MS)

The Middle Siwalik has normal and gradational contact with the underlying Lower Siwalik. It consists of fine to medium and coarse grained sandstones, pebbly sandstones interbedded with greenish grey shale and clay. The lower portion of the Middle

Siwalik contains alternate bands of sandstone, shales and clays. In the upper horizon, the coarseness of the sandstone increases. The sandstone becomes more coarse, and gritty and eventually pebbly towards the top. The Middle Siwaliks are repeated again in the middle of the mapped area. It is also classified into Upper Middle Siwalik (MS2) and Lower Middle Siwalik (MS1) based on the presence of pebbly sandstone horizon and a few conglomerate bands.

Lower Middle Siwalik (MS1)

Lower Middle Siwalik consists of sandstone, mudstone, claystone, siltstone and shale (Fig. 9) Sandstone of MS1 is light grey to grey coloured, medium grained and interbedded with green to greenish gray clay. This sub unit MS1 is repeated again in the eastern parts of the study area. It is mainly characterized by arkosic sandstone in the studied area. It extends from Ruduwa Khola, Khadam Khola and Sehara Khola. It is quite thicker in Ruduwa Khola and Sehara Khola Sections than in Khadam Khola Section. The Lower Middle Siwalik is also repeated in the mapped area due to faulting. The dip direction of the MS1 is NW-SE, sometimes NE-SW and amount of dip is 25°-65°.

Fig. 9: Medium grained grey coloured sandstone with grey shale of MS1 observed at Sehara Khola

Upper Middle Siwalik (MS2)

Upper Middle Siwalik (MS2) is 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 conglomeritic horizons along with occasional silty sandstone are very common (Fig. 10).

The individual bed of clay varies 0.75 m to 3.5 m in thickness. The thickness of the individual sandstone bed varies from 2 m to even more than 5 m. The sandstones are often pebbly and at places 0.5 to 2.0 m bands of conglomerate are found. The pebbles of pebbly sandstones are made of mainly white, pink quartzites and occasional Siwalik sandstone and clay fragments. In general, the strike of the unit is NW-SE, sometimes NE-SW with dipping 25°- 70° towards NE and NW and sometimes SW.

Fig. 10: Pebbly sandstone of Upper Middle Siwalik (MS2) observed in the Sehera Khola

GEOLOGICAL STRUCTURE

The MBT separates Tertiary sedimentary Siwaliks from the earlier Tertiaries and the older rocks in the area. The trend of the MBT is almost NW to SE direction. This thrust can be distinguished in the field mainly in Khadam Khola because of strong lithological contrasts across the thrust plane. Landslides, micro folds, joints, and shearing effect is the strong evidence for thrusting. The trace of MFT is clearly observed in the Sardu Khola. Many active landslides are occurred along the trace of the MFT. The rocks of the Midland Group are thrusted over the rocks of the Gondwana Group along the Mahabharat Thrust (MT). The trend of the MT is almost same as that of the MBT. The Main Central Thrust (MCT) can also be observed in the northern part of the study area, which separates low to high grade metamorphic rock of Dubbidanda Formation from older and high grade metamorphic rocks of Kathmandu Crystalline.

A major anticline fold is observed in the MS1 from Ruduwa Khola to Seuti Khola area. Beside this, a minor syncline and anticline folds are observed on the north-east of Panmara village in Sehara Khola and in Khadam Khola (Fig. 2).

GEOLOGICAL SECTION MEASUREMENT

Thickness of various rock units and formations were measured made along Khadam Khola, Seuti Khola, Ruduwa Khola, Dharan-Bhedetar Road Section, and its adjacent areas of Morang and Sunsari Districts of Eastern Nepal.

Thickness of Gondwana shale has been measured along all sections in the study area. Gondwana shale is quite thicker on either sides of the Dharan-Bhedetar Road Section. The LS is observed in the Sehara Khola and Ruduwa Khola sections. Trace of the MFT cannot be observed in these sections. The MS2 and MS1 are observed in both Khadam Khola and Sehara Khola Sections. Only the MS2 is observed in the Ruduwa Khola and Seuti Khola Sections. the MS2 is quite thicker in Sehara Khola Section. No Upper Siwalik (US) is observed in the study area.

CONCLUSION

Sedimentary rocks belonging to the Siwalik Group of Sub-Himalaya and sedimentary rocks of Gondwana Group as well as metasedimentary to metamorphic rocks belonging to Dailekh Group of Lesser Himalaya represent the area. Detail geological sections measurement of different rock units / formations along major streams and river were carried out in the studied area. Different geological contact and thrusts were identified to trace the lateral extension. More and more satellite images should be used to identify the thrust / faults and geological contact more precisely in the studied area.

ACKNOWLEDGEMENT

The author is grateful to Mr. K.R. Poudyal, Project Chief, Petroleum Exploration Promotion Project, Department of Mines and Geology for providing necessary facilities to conduct the fieldwork. I am very much grateful to Mr. S. B. K.C. (Senior Divisional Geologist) for providing valuable guidance, suggestion and encouragement during the fieldwork. I greatly appreciate to Mr. Rajan Thapa, Survey Officer of Drafting Section for the cartography work and also staffs of Administrative, Planning and Store Sections of Petroleum Exploration Promotion Project, Department of Mines and Geology for providing necessary help to prepare the report.

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Inspection and Monitoring of Operating Mines in Different Parts of Nepal

Som P. Sharma
Department of Mines and Geology, Lainchaur, Kathmandu, Nepal

INTRODUCTION

The Department of Mines and Geology (DMG) is the only governmental organization to regulate the mining activities, geological survey and exploration of mineral work in Nepal. Mines and Mineral Regulation has provided the basic principles to regulate the mining work. District Development Committee (DDC) in different districts is issuing licenses for the ordinary construction materials such as stone, sand and ordinary clay. However, provision is made to take approval from DMG in technical aspect as the DDC does not have technical manpower. Issuing of opening/prospecting licenses is done by the Mining Regulation and Administration Sub-Division of the DMG. For the different mine operations, regular monitoring and inspection and monitoring is carried out by the same sub-division during the F.Y. 2064/65. Inspection and monitoring were carried out in 25 different mines by the different technical team This paper is based on the monitoring and inspection work of 25 different mines in Dhading, Tanahun, Kaski, Palpa, Arghakhanchi, Dang, Rolpa and Gorkha Districts. For this, a team consisted of a mining engineer assisted by a mine-sub inspector and or a surveyor was made.

OBJECTIVES

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

- To inspect and evaluate the exploitation and mining activities carried out by the leaseholder for different mineral commodities.
- To check whether the mining work is satisfactory as per the accepted mine plan or not.
- To check whether the directions given during the past inspection visits were followed or not.
- To check whether the royalty is paid as per the production and also to collect the production data.
- To have the field verification of the mining scheme submitted by the applicant before award of mining license.
- To give necessary suggestions and directions to exploit the deposit by applying proper methods in an environment friendly manner in compliance with the existing Mining and Mineral Rules, 2056 of Government of Nepal.
- To take further actions if the previous suggestions/ directives were not followed by the license holders.

METHODOLOGY

The team considered method developed by DMG to judge over all mining operation. Due care was given in technical (Mining Method, Mine Plan, Mining Parameters etc), legal (Mining Rules and Regulation) and environment (Socio-Economical, Biological and Physical) parameters for mining activities and gave necessary suggestions and directions to the mine operators.

STATUS OF INSPECTED MINES AND DIRECTIVES GIVEN

The field inspection reports of different mines are categorical into three different groups according to the Mineral Commodities.

Ordinary Construction Minerals

The team inspected the different ordinary construction mineral mines along the route of Sidhartha Highway. Two gravel stone mines were in operation at Masyam area of Palpa District. These mines belong to Mr. Pradip Prasad Udaya and M/s Dolomite Limestone Pvt. Ltd. In the gravel mine of Pradip Prasad Udaya, benches are not well developed. Plantation is continued in the bottom part of the quarry of Dolomite Limestone Pvt. Ltd which is the implementation of instruction given previously. During the current visit, instruction to the both mine owner was given to minimize erosion and siltation problem and canalize the drainage through the District Development Committee, Palpa.

Non metallic Industrial Minerals

Limestone

The team inspected four limestone mines. Annapurna Quarries (P). Ltd. and Hetauda Cement Limited were in operation in Dhading District while limestone mine of Pashupati Murarka in Gorkha district was in development stage. Waste management was poor in the mine of Agri limestone. If further attention is not given, debris fall in Prithivi Highway would happen. So the license was directed to do detail study work of quarry area whether the continuation of mining work is possible or not. The mine owned by Annapurna Quarry was mining with semi-mechanized extraction method. Top soil and overburden is thrown in the Jawang Khola. The production of limestone from different quarries is shown in Table 1.

The Limestone Mine of Dynasty Industries (P) Ltd. was mining with semi-mechanized open cast mining method in Arghakhanchi District. In the quarry, machinery such as excavator-1, Dozer-1, Loader-1, Breaker machine were used for development and exploitation work. Run off water was canalized in the southeastern part of the quarry.

In the mines of Annapurna quarries (P) Ltd. suggestion and direction was given to have good waste management system and drainage system. At the same time, attention was drawn to adopt the safety measures properly. The Dynasty Industry Nepal (P) Ltd. was directed to do protection work in the catchment area of drinking water for local people. Due care is necessary to minimize erosion and siltation problem in that area as well. In the quarry owned by Hetauda Cement Ind. Ltd., directions were given to do exploitation work making environment friendly as there is possible of debris fall in the rainy season if necessary precaution is not taken.

Table 1: Production of limestone from different quarries in Fiscal Year 2064/65.

S.No.	Lease Holders	Quarry Site	Production in MT	Remarks
1	Dynasty Ind. Nepal (P) Ltd.	Narapani, Arghakhanchi	16735 MT	Total production upto Magh 2064
2	Annapurna Quarries (P) Ltd.	Jawang Khola , Dhading	14880 MT	Total production upto Magh 2064
3	Hetauda Cement Ind. Ltd	Jogimara, Dhading	2490 MT	Total production upto Magh 2064
4	Pashupati Murarka	Bhumligchok, Gorkha	Development work	During inspection period
5	Limestone Dolomite (P) Ltd	Masyam, Palpa	Development work	During inspection period

Talc

During the inspection period, three Talc Mines were in operation. The production of Dust Nepal Pvt. Ltd. which lies in Tanahu District was about 325 tons in the fiscal year 2064/65 up to inspection period. In the mine of Gautam Khanij Udhyog which lies at Harkapur in Tanahu District, the production of Talc up to inspection period was about 356 tons. Singha Khanij Udhyog was doing development work at Pumdi Bhumdi in Kaski district and collecting the Talc of about 290 tons. Gabion wall is constructed in the lower part of the quarry area in Singha Khanij Udhyog as in the previous inspection period instruction was given for the same. In the quarry area of Gautam Khanij Udhyog waste management system is poor as the waster is dumped roughly in the Pakho bari near the quarry site. Check dam is constructed at the bottom part of the lease area in the mine of Dust Nepal Pvt. Ltd. which is the implementation of last instructions. In the mean time, the mine owners are suggested to take precaution to minimize erosion and siltation problem as well as to have effective waste management system. All the industries are directed to run the mine in full capacity and have a regular production.

Fuel Minerals

Coal

In Dang District, nine coal mines are inspected and monitored. In the mean time two coal mine in Rolpa District and two coal mines in Palpa District are also monitored. The production of coal from the different mines in FY 2064/65 as recorded in the inspection period is shown in Table 2.

Waste management is poor and canalization is not done properly in the working area of Palpa Coal Pvt. Ltd. In the area of Triveni Coal, stock piling of coal is not effective.

Wastages are not properly managed in the working area of Dinesh Kumar Dangi, Bageswari Coal and Basu Dev Pandey. Drainage system is poor in the working area of Rishi Khanij Udhyog, Bibek Coal Pvt. Ltd, Himalaya Coal Pvt. Ltd. There is no production work at Dubring area in Rolpa District in the mine of Balaram Shrestha, Bibek Coal Pvt. Ltd.

The mine owners of Palpa Coal, Triveni Coal, Dinesh Kumar Dangi, Bageswari Coal, Basu Dev Pandey are directed to have good waste management system and to minimize

Table 2: Production of coal from different quarries in Fiscal Year 2064/65.

S.No.	Lease Holders	Mine area	Production (MT)	Remarks
1	Dinesh Kumar Dangi	Agimara, Tulsipur, Dang	114 MT	Total production upto Magh 2064
2	Bageswari Coal Pvt. Ltd.	Chisapani, Tulsipur, Dang	NA	Mine development continued
3	Rishi Khanij Udhyog Pvt. Ltd.	Siuja, Dang	84 MT	Total production upto Magh 2064
4	Palpa Coal Pvt. Ltd	Devinagar, Palpa	23 MT	Total production upto Magh 2064
5	Bibek Coal Udhyog Pvt. Ltd.	Siuja, Dang	279 MT	Total production upto Magh 2064
6	Kanchan Coal Pvt. Ltd.	Saigha, Tosh, Dang	18 MT	Total production upto Magh 2064
7	Triveni Coal Pvt. Ltd.	Devinagar, Palpa	150 MT	Total production upto Magh 2064
8	Himalaya Coal Udhyog Pvt. Ltd.	Saigha, Tosh, Dang	808 MT	Total production upto Magh 2064
9	Basu Dev Pandey	Thara, Kavre, Dang	127 MT	Total production upto Magh 2064
10	Subham Khanij Udhyog Pvt. Ltd.	Murkuti, Dang	203 MT	Total production upto Magh 2064
11	Balaram Shestha	Dubring, Rolpa	NA	Development work continued
12	Bibek Coal Pvt. Ltd.	Loharpani, Dang	100 MT	Total production upto Magh 2064
13	Bibek Coal Pvt. Ltd.	Dubring, Rolpa	NA	No mining work

NA= Not available

erosion and siltation problem. In the same time leases as Rishi Coal, Bibek Coal and Himalaya Coal are instructed to have effective canalization in the mine area.

CONCLUSION AND RECOMMENDATION

Conclusion

- 25 mines in different parts of Nepal are inspected and monitoring was done for mining activities and environment impact due to mining.
- It was recorded that safety aspect in general is found poor during the inspection period.
- It is found that the suggestions and directions given in the previous inspected period is followed only partially. Thus, frequency of the monitoring should be increased.
- Almost all of the operating mines are not doing production in full capacity. So leaseholders should be directed to run the mine in optimal capacity.

Recommendation

- DMG should force to the leaseholder to operate the mine in optimal capacity to meet the goal of Mineral production with minimum environmental impact.
- Frequency of inspection and environmental monitoring should be increased and should be done effectively.
- All the leaseholders should be directed to employ technical person in full time basis.

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म्याग्दी जिल्लाको औल गाऊँको पहिरोको अध्ययन

बीरेन्द्र पिया र दिनेश नेपाली
खानी तथा भूगर्भ विभाग, लैनचौर, काठमाडौं

१. परिचय

औल गाऊँ म्याग्दी जिल्लाको हिस्तान मण्डली गा.वि.स. को वडा नं. ७ र ८ मा पर्ने एउटा सुन्दर बस्ती हो (चित्र नं. १)। यो गाऊं समुन्द्रको सतहदेखि करिब १५५० मिटरको उचाईमा अवस्थित छ। यो गाऊँको पूर्वतिरबाट पूर्व पश्चिम भई औला खोला बगेको छ। यस गाऊँका चारैतिर अग्ला अग्ला भिराला पहाडहरु छन्। यस गाऊँमा हाल करिब १४३ घरधुरी छन् र करिब ८०० जनाको जनसंख्या छ (साभार : कान्तिपुर दैनिक, मिति २०६४ असार ४ गते)। स्थानीय व्यक्तिहरुको भनाई अनुसार बि.सं. १७९२ तिर यहाँका बासिन्दाहरु नजिकका पहिरो गाऊँबाट बसाई सरी यहाँ बसोवास गर्दै आएका हुन्। यहाँ अत्याधिक पुन थर भएका मगर जातिहरुको बसोवास छ। यस क्षेत्रका बासिन्दाहरुको मुख्य पेशा खेती तथा पशुपालन नै हो। यहाँ समशितोष्ण प्रकार (Temperate type) को हावापानी पाईन्छ। गाऊँदेखि पूर्व र दक्षिण भागमा खेतियोग्य जमिन रहेको छ, जसमा धान, मकै, कोदो तथा बिभिन्न प्रकारका तरकारीहरु मौसम अनुसार उत्पादन गरिन्छ।

यस गाऊंका बासिन्दाहरुको भनाई अनुसार यस गाऊंदेखि उत्तर सिधा माथि करिब ७०० मिटरको उचाईमा रहेको (३० मि. X २० मि. X १६ मि.) अर्थात ९,६०० घन मिटरको बिशाल चट्टान आफ्नो ठाउंबाट घिस्रिई अप्ठ्यारो अवस्थामा रहेको एवं त्यस स्थानबाट समय समयमा साना ठूला चट्टानका टुक्राहरु फुटी तल गाऊँतिर खस्ने गरेको र यसले गाऊँमा रहेको १४३ घर धुरीका करिब ८०० बासिन्दालाई जोखिमपूर्ण अवस्थामा जीवन बिताउन बाध्य पारेको कारण उक्त चट्टानलाई बिष्फोटन गरी व्यवस्थापन गर्नु पर्ने भनिएकोमा त्यहां स्थित जिल्ला प्रशासन कार्यालयबाट उक्त बिष्फोटनको कार्य गर्नु भन्दा पहिला, सम्बन्धित भूगर्भविदबाट सो ठाऊंको भौगर्भिक अध्ययन तथा अनुसन्धान गराउनु पर्ने र सो को लागि भूगर्भविद्हरुको टोली उक्त स्थानमा पठाउनको लागि जिल्ला प्रशासन कार्यलय म्याग्दीको प.स.नं. ०६३।०६४ च.नं. मिति २०६४।२।७ मा गृह मन्त्रालयमा पत्र पठाएको थियो। यसै सम्बन्धमा उक्त क्षेत्रको भूस्थिति अध्ययन गरी उक्त स्थानमा बिष्फोटनको कार्यबाट पर्न सक्ने नकारात्मक असरबारे अध्ययन अनुसन्धान गर्न दैवी प्रकोप व्यबस्थापन शाखा, गृह मन्त्रालयबाट यस खानी तथा भूगर्भ बिभागमा अनुरोध भई आएकोमा यस बिभागबाट २ जना भूगर्भबिद् संलग्न भएको एक प्राविधिक टोली उक्त प्रभावित क्षेत्रको स्थलगत निरीक्षण तथा अध्ययन गर्न मिति २०६४।२।२३ देखि जम्मा ५ दिनको फिल्ड कार्यमा खटीई गएको र उक्त क्षेत्रको भूबनौट तथा भौगर्भिक अवस्था बारे अध्ययन गर्ने कार्य पुरा गरी यो प्रतिवेदन तयार पारिएको छ।

२. उद्देश्य

यस अध्ययनको मुख्य उद्देश्य निम्न बमोजिम छन् :

(क) औल गाऊं तथा बिशाल चट्टान रहेको स्थान वरिपरीको भौगर्भिक अध्ययन गर्ने।

(ख) गाऊं देखि माथि करिब ७०० मिटरको उचाईमा रहेको बिशाल चट्टानलाई बिष्फोटक पदार्थ प्रयोग गरी फुटाएको खण्डमा पर्न सक्ने नकारात्मक असरको अध्ययन तथा अनुसन्धान गर्ने।

(ग) त्यस ठाऊंमा पहिरो जानुको कारण पत्ता लगाउने।

(घ) पहिरोको रोकथाम तथा खस्न सक्ने चट्टानका टुक्राहरु बाट गाऊंबस्ति बचाउन सक्ने सुरक्षाका उपायहरु बारे अध्ययन गरी उपयुक्त सूझाव पेश गर्ने।

३. बर्तमान स्थिति

म्याग्दी जिल्ला हिस्तान मण्डली गा.बि.स. वडा नं. ७ र ८ मा पर्ने औल गाऊंदेखि करिब ७०० मिटरको उचाईमा एउटा (३० मि. X २० मि. X १६ मि.) अर्थात ९,६०० घन मिटर आकारको बिशाल चट्टान आफ्नो ठाऊंबाट छुट्टिएर झर्न सक्ने अवस्थामा रहेको छ। उक्त बिशाल चट्टानसंगै पश्चिमपट्टि एउटा पहिरो छ, जुन स्थानिय बासिन्दाहरुको भनाई अनुसार २०६३ साल भाद्र महीनाको दोश्रो हप्तामा गएको थियो। उक्त पहिरोले गाऊँलाई कुनै क्षति नपुर्‍याए पनि त्यसको केहि दिनमा (भाद्र

१५ गते) (२.९० मि. X १.७५ मि. X १.३० मि.) अर्थात ६.६ घन मिटरको एउटा चट्टानको टुक्रा उक्त गाऊँ नजिक खसेको थियो (चित्र नं. २) । भाग्यवश उक्त चट्टानले पनि गाऊँलाई कुनै क्षति पुऱ्याएन । हाल पनि उक्त स्थानमा पहिरोको कारण बिकसित भएका असंख्य चिराहरु तथा पानीको प्रक्रियाबाट क्षयिकरण भई रहेका चट्टानका टुक्राहरु कुनै पनि बेला छुट्टिई तल गाऊंमा खस्न सक्ने संभावना रहेको छ । मुख्यतया भारी बर्षा भएको समयमा अथवा भूकम्प गएको समयमा उक्त स्थानमा अस्थिर रुपमा रहेका चट्टानहरु खसी गाऊँमा धनजनको क्षति हुने सक्ने बढि संभावना रहेको छ ।

हाल पहिरोको दुबै तिर दायाँ तथा बायाँ क्षेत्रको चट्टानहरुमा चिराहरु (Cracks and fissures) परी अस्थिर अवस्थामा रहेका छन् (चित्र नं. ३ र ४) । बर्षायाममा पानीको भल पहिरोको बाटो भई बग्ने हुंदा यसले Debris flow को रुप पनि लिन सक्ने संभावना छ । बिशाल चट्टानको माथिल्लो तहमा रहेको Quartzite को २ देखि ३ मिटर सम्मका मोटाई भएका चट्टानका तीन चिरा भई उक्त ठाउँमा अडि बसेका छन् । बिशाल चट्टान रहेको भित्ता पट्टि उक्त चट्टान तल तिर खस्किरहेको (Vertical displacement) चिन्हहरु (Mark) देख्न सकिन्छ (चित्र नं. ५) गाऊंलेको अनुसार १ बर्ष भित्रमा उक्त चट्टान करिब ५६ से.मि. जति तल (Vertically) खस्किसकेको छ । त्यस्तै गरी उक्त चट्टान Horizontally १५ से.मि. जति सरी सकेको छ । यसले उक्त स्थान भौगर्भिक हिसाबले अस्थिर अवस्थामा रहेको देखाउँदछ (चित्र नं. ६) ।

हाल उक्त स्थानमा स्थानीय बासिन्दाहरुले खस्न सक्ने चट्टानहरुबाट गाऊँलाई बचाउनका लागि बिभिन्न संघ संस्थाहरुको सहयोगमा ४५ मिटर लामो तथा १ मिटर चौडा २ मिटर अग्ला पक्की ग्याबियन पर्खाल (Gabbion wall) बनाएका छन् (चित्र नं. ७) । त्यस ग्याबियन पर्खाल को चट्टान तिर करिब ३० मिटर दुरीमा अर्को अस्थाई ग्याबियन पर्खाल (Gabbion wall) पनि बनाएको छ । यसरी बनाएको ग्याबियन पर्खालले पनि टुक्रि झरेका चट्टानहरुलाई रोक्न मद्दत पुऱ्याउँदछ (चित्र नं. ८) । त्यस्तै गरी चट्टान भन्दा माथि तिर (Slope) मा बर्षाको पानी पहिरो तिर आउन बाट बचाउन दुबै दिशा तिर (देब्रे, दाहिने) पानी जाने कुलोहरुको निर्माण गरिएको छ (चित्र नं.९) । यसरी प्रकोपबाट गाऊँलाई धनजनको क्षति हुनबाट बचाउन स्थानीय बासिन्दाहरुले आफ्नो प्रयास जारी राखेका छन् ।

स्थानिय बासिन्दाहरुको चाहना अनुसार सम्भव भएसम्म उक्त चट्टानलाई बिष्फोटन गरी फुटाउने रहेको छ । यस कार्यको लागि म्याग्दी जिल्ला स्थित नेपाली सेनाले जिल्ला प्रशासनको अनुरोधमा, स्थानिय बासिन्दाहरु तथा सम्बन्धित बिज्ञहरुको समेत सहमति प्राप्त भएमा उक्त कार्य सम्पन्न गर्ने आश्वासन दिएको स्थानीय बासिन्दाहरु बताउँदछन् । हाल स्थानीय बासिन्दाहरु पानी परेको बेला माथिको उक्त ठूलो तथा अन्य चट्टानहरु खसी जीउधनको नोक्सान पुऱ्याउन सक्ने डरले गाऊँ देखि केहि पर रहेको खेतबारीहरुमा अस्थाई रुपमा गोठ, टहरा बनाई बस्ने गरेका छन् (चित्र नं.१० र ११) (साभार : कान्तिपुर दैनिक, २०६४ असार ५ गते) ।

४. भौगर्भिक अवस्था

औल गाऊँ भौगर्भिक हिसाबले महाभारत पर्वत क्षेत्रमा (Lesser Himalayan Zone) पर्दछ । खानी तथा भूभर्ग बिभागबाट प्रकाशित भौगर्भिक नक्शा Toposheet No. 2883 11 (62 P/11), 2002 अनुसार यो क्षेत्र Kunchha Formation मा पर्दछ । यस Formation का चट्टानहरु Light-greenish grey to dark grey sericitic, chloritic phyllite / yellowish green gritty phylite interbedded with several quartzite प्रकारका छन्।

सम्बन्धित ठाऊंमा गरेको भौगर्भिक अध्ययन अनुसार यस ठाऊंका चट्टानहरु (Phyllites) धेरै नै मकिएका (highly weathered) छन् भने quartzite चट्टानहरु मा चिरा परेका (jointed) छन् ।

४.१. उक्त स्थानको बिभिन्न ठाऊँमा गरेको भौगर्भिक नाप (Geological measurement) निम्न अनुसारको छ ।

उक्त स्थानका चट्टानहरुको attitude: strike N12°W, dip direction 78°NE तथा dip amount 10° देखि 15° (Variation) रहेको छ । खानी तथा भूभर्ग बिभागबाट प्रकाशित यस क्षेत्रको जियोलोजिकल नक्शा अनुसार यो ठाऊँ भएर एउटा Thrust गएको छ (चित्र नं. १२) भने उक्त क्षेत्रमा बिशाल चट्टानको केहि पर एउटा Normal fault पनि देखिएको छ (चित्र नं. ५) यहि fault line भएर उक्त बिशाल चट्टान आफ्नो ठाऊंबाट छुट्टिई dip direction संग perpendicular भई slope direction तिर सरिरहेको देखिन्छ (चित्र नं. १३) र यो प्रक्रिया निरन्तर चलि रहेको छ । यस्तो किसिमको भौगर्भिक प्रक्रियाको कारणले गर्दा उक्त स्थान स्थिर नभएको देखिन्छ ।

GPS बाट लिइएको पहिरोको Location

Northing (अक्षांश) (28°25.17'

Easting (देशान्तर) (83° 37.028'

Slope direction towards south

४.२. उक्त क्षेत्रमा पहिरो जानु तथा जमिन अस्थिर रहनुको कारणहरु:

४.२.१. भौगर्भिक स्थिति तथा भिरालो जमिनः

भौगर्भिक हिसाबले उक्त स्थान निकै भिरालो जमिनमा अवस्थित छ। त्यस ठाउँको भिरालो सतहको slope झण्डै ५०° देखि लिएर ८५° सम्मको छ। यस्तो भिरालो जमिनमा ढुङ्गा माटोहरु अडिई रहन सक्दैनन् र कुनै बाह्य बल जस्तै भूकम्प (Earthquake) तथा बर्षाको पानीको चाप बढ्न गएमा पहिरो जाने तथा Rock fall हुने संभावना बढि रहन्छ। फेरि उक्त ठाउंमा क्षयिकरण भई रहेको कमजोर चट्टानहरु (Weathered Phyllite Rocks) रहेको छ। त्यस्तै गरी उक्त स्थानमा रहेको चट्टानहरुमा असंख्य रुपमा चिराहरु (Cracks र fractures) को बिकसित भएको छ। यसले गर्दा उक्त स्थानमा पहिरो गएको हो र पछि पनि जाने संभावना बढी देखिन्छ। त्यस्तै गरी उक्त स्थानमा भौगर्भिक संरचनाहरु (Structures) fault तथा joints हरु रहेको देखिन्छ। यसले गर्दा पनि उक्त स्थानलाई बढी अस्थिर बनाएको छ।

४.२.२. अत्याधिक बर्षा:

नेपालमा धेरै पानी पर्ने जिल्ला मध्ये म्याग्दी जिल्ला पनि एक हो। बर्षाको पानी भिरालो जमिन भई बग्ने हुंदा यसले पहिरो जानलाई मद्दत पुऱ्याउँदछ। अत्याधिक बर्षाको कारण पानी जमिन भित्र पस्न गई जमिनको भार बढ्न जान्छ र उक्त भारलाई जमिनको सतहले थाम्न सक्दैन, त्यसै गरी पानीको चापले गर्दा ढुङ्गा माटोहरु आफ्नो स्थानमा अडिन सक्दैन र तलतिर खस्किन गई पहिरोको रुप लिन्छ। यहि कारणले गर्दा उक्त स्थानमा पहिरो गएको हो।

५. निष्कर्ष

५.१. औल गाउँ माथि करिब ७०० मिटरको उचाईमा अस्थिर अवस्थामा रहेको बिशाल चट्टानलाई बिष्फोटक पदार्थ प्रयोग गरी तह लगाउने र गाउँलाई सुरक्षित पार्ने स्थानिय बासिन्दाहरुको मनसाय भएता पनि त्यस ठाउंको भौगर्भिक जटिल स्थितिका कारण ठुलो खालको बिष्फोटक पदार्थ प्रयोग गरी चट्टान फुटाउन उपयुक्त नहुने देखिन्छ। किनभने बिष्फोटकको प्रयोगबाट उत्पन्न हुने कम्पन तथा अत्यधिक आवाजले पनि वरिपरीका चट्टानहरुलाई दखल दिन सक्ने र virgin condition मा स्थिर भई रहेका चट्टानहरुलाई समेत कमजोर गर्न सक्न र साथै कमजोर अवस्थामा रहेका चट्टानहरुलाई पहिरोमा बदल्न सक्ने हुन सक्छ। तसर्थ बिष्फोटक पर्दाथको बैकल्पिक उपायहरु अपनाउनु उपयुक्त देखिन्छ।

५.२. औल गाउँ माथि रहेको उक्त चट्टान तथा अन्य वरिपरी कमजोर अवस्थामा रहेका चट्टानहरुबाट गाऊं असुरक्षित रहेको देखिन्छ र त्यसलाई जति सक्दो चाँडो न्यूनिकरणका उपायहरु अवलम्वन गरी गाऊंलाई पहिरोबाट बचाउन आवश्यक देखिन्छ।

५.३. उक्त स्थान भौगर्भिक हिसाबले निकै जटिल अवस्थामा रहेको छ।

५.४. यस स्थानको भौगर्भिक जटिलताले गर्दा स्थायी रुपमा यो समस्यालाई समाधान गर्न नसकिएता पनि अस्थाई रुपमा यो क्षेत्रको समस्याको हल गर्न सकिने अवस्था देखिन्छ। यस कार्यको लागि तल दिइएका अनुसारको न्यूनिकरणका उपायहरु अवलम्वन गर्नु जरुरी छ।

६. समस्या समाधानको उपाय

औल गाऊँमा भबिष्यमा जान सक्ने पहिरो, खस्न सक्ने चट्टान तथा चट्टानमा देखा परेका चिराहरुलाई बिचार गरी स्थाई रुपमा रोकथाम गर्न भौगर्भिक स्थिति तथा भिरालो जमिन भएको कारण कम संभव देखिएता पनि यसको असरबाट जन धनको क्षति रोक्न वा कम गर्न निम्न अनुसारको रोकथामका उपायहरु अपनाउनु अत्यावश्यक देखिन्छ। Rock fall र Slides तथा पहिरो बाट गाऊंलाई सुरक्षित राख्न दुई प्रकारका उपायहरुलाई अवलम्वन गर्नु पर्ने देखिन्छ।

६.१. तत्कालिन गर्नु पर्ने उपाय (Immediate solution)

६.२. दीर्घकालिन उपाय (Long term solution)

६.१. तत्कालिन गर्नु पर्ने उपाय (Immediate solution)

नजिकिदै गएको बर्षायाम (Monsoon season) लाई मध्य नजर गरी गाऊँलाई कुनै पनि प्रकारको Rock fall type Debris flow

बाट बचाउन निम्न अनुसारको उपाय तत्कालिन रुपमा अवलम्वन गर्नु उचित हुने देखिन्छ ।

६.१.१. विशाल चट्टानको माथिल्लो सतहमा रहेको करिब १ देखि ३ मिटर सम्म मोटाई भएको ढुङ्गाको ब्लकलाई जस्मा ठाडो चिरा परिसकेका छन्, तिनलाई मानव श्रम साधन प्रयोग गरी (घन, गल, छिनो आदि) फुटाई तल खाली जमिनमा झार्नु पर्ने देखिन्छ । अति कडा चट्टानको हकमा सानो Jack hammer ले १ देखि १.५ मिटर गहिराई र १ मिटरको फरकमा (Spacing) मा Drill hole हरु गरी बजारमा उपलब्ध Brister (Expandable cement) को प्रयोग बाट पनि फुटाउन सकिन्छ । यस्तो सामाग्री उपलब्ध नभएको खण्डमा वरिपरिका स्थिर (stable) रुपमा रहेका चट्टानहरुलाई कुनै असर नपार्ने गरी controlled रुपमा selective minor blasting प्रयोग गरी अस्थिर अवस्थामा रहेका चट्टानहरुलाई मात्र फुटाउन सकिने देखिन्छ ।

६.१.२. पहिरोको दायाँ तथा बायाँ साईड तिर अस्थिर अवस्थामा रहेको चट्टानहरुलाई जति सक्दो चाँडो त्यहाँबाट निकाली तल नखस्ने गरी ब्यबस्थापन गर्नु पर्ने देखिन्छ ।

६.१.३. पहिरोदेखि माथि भागमा पहिरोसम्म बर्षाको पानी आउनबाट रोक्न बनाईएका Drainage path लाई सिमेन्टको प्रयोग गरेर नचुहिने नरसाउने गरी ब्यबस्थित गर्ने ताकि बर्षाको पानी भलको रुपमा पहिरोसम्म बगी नजाओस । साथै पहिरोबाट भल भई झर्ने पानीको पनि आवश्यक ब्यबस्था मिलाई ब्यबस्थापन गर्नु पर्दछ ।

६.१.४. Gabion पर्खालहरु बनाउँदा त्यसमा प्रयोग भएका ढुङ्गाहरुको तौलले गर्दा जमिनमा भार थपिन जाने भएको हुँदा बलियो जमिन (जग) नभएको ठाउँमा यसको बदलामा अन्य भार कम हुने खालका जस्तैः (बाँसका बारहरुको प्रयोग गरी Fence wall बनाउने । यस्ता बांसहरुबाट बनाउने Fence wall केहि मिटरको दुरीमा तह तहगत रुपमा राख्दा अझ राम्रो हुनसक्छ ।

६.१.५. गाऊँ भन्दा माथि कम्तिमा पनि ५० मिटरको दुरीसम्म तार जालीका बारहरु लगाउने ।

६.१.६. Unstable अबस्थामा रहेका बिशाल ढुङ्गाहरु फुटाउनको लागि ढुङ्गामा बनेका चिराहरु (Fractures) तथा Crack हरुमा तापको प्रयोग गरेर Expansion and contraction प्रक्रियाबाट ढुङ्गा फुटाउन सकिन्छ । साथै Jack hammering र Wedging बाट पनि ढुङ्गालाई फुटाउन सकिन्छ ।

६.१.७. बर्षाको पानीको कारण उक्त स्थानमा पार्न सक्ने असर (Landslide, debris flow, rock fall) बारे अग्रिम जानकारी पाउनको लागि उक्त स्थानमा बिकसित हुँदै गरेका अवस्थाहरुको नियमित अनुगमन (Monitoring) गर्ने व्यबस्था मिलाउने ।

६.२. दीर्घकालीन उपाय (Long term solution)

औल गाऊँको समस्यालाई न्यूनिकरण गर्न अपनाउनु पर्ने दीर्घकालिन उपायहरु निम्न प्रकारका छन् :

६.२.१. उक्त स्थानमा देखा परेको जटिल समस्यालाई दीर्घकालिन रुपमा हल गर्न बिभिन्न बिषयसंग सम्बन्धित विशेषज्ञहरुको संयुक्त टोली (Geologist, Geo-technical engineer, Civil engineer) बाट बिस्तृत अध्ययन (Detail study) गराउनु पर्ने देखिन्छ ।

६.२.२. अस्थिर अवस्थामा रहेका चट्टानहरुलाई फुटाई आवश्यकता अनुसार Retaining wall हरुको निर्माण गर्नु पर्ने जस्ले गर्दा माथिबाट खस्ने ढुङ्गा, माटो तथा पहिरो रोक्न सकोस ।

६.२.३. बर्षाको पानीको भलबाट उक्त क्षेत्रलाई बचाउन बैज्ञानिक प्रकारको Drainage system बनाई पानीको ब्यबस्थापन गर्नु पर्ने ।

६.२.४. Bio-engineering technique अपनाई औल गाऊं माथि तथा पहिरो भएको ठाऊँ वरिपरी ब्यापक रुपमा सुहाउँदो प्रकारको बृक्षारोपन गर्नु पर्ने ।

६.२.५. चिरा (Fracture) परेको ठाऊँमा बर्षाको पानी पस्नबाट रोक्न चिरा परेको ठाऊंमा Cement grouting गर्ने । Load कम गर्ने तथा slope stable गराउन stepping cutting गर्ने ।

६.२.६. त्यहां रहेको बिशाल चट्टान तथा वरिपरीका ढुङ्गालाई फुटाई निस्केका ढुङ्गाका टुक्राहरुलाई अन्यत्र ठाऊँमा ब्यबस्थापन गर्नु पर्ने ।

६.२.७. उक्त स्थानमा अस्थिर अवस्थामा रहेका चट्टानको vertical र horizontal चाल (Movement) थाहा पाउनको लागि नियमित रुपमा अनुगमन (Monitoring) गर्नु पर्ने ।

चित्र नं. १ : हिस्तान मण्डली गा.वि.स., औल गाऊंको दृश्य

चित्र नं. २ : गाऊं नजिकै २०६३ भदौ १५ गते खसेको ६.६ घन मिटरको ढुङ्गा

चित्र नं. ३ : गाऊंको मुख्य समस्याको रुपमा रहेको पहिरो तथा अस्थिर अवस्थामा रहेको चट्टान

चित्र नं. ४ : विशाल चट्टानमा देखिएका चिराहरु

चित्र नं. ५ : स्थानिय बासिन्दाहरुले चट्टानको खस्किने क्रमको अनुगमन गर्न राखेको चिन्ह

चित्र नं. ६ : समतलिय विस्थापित चट्टान (Horizontally displaced rock)

चित्र नं. ७ : स्थानिय बासिन्दाद्धारा विभिन्न संघ संस्थाहरुको सहयोगमा पहिरोबाट बच्न निर्माण गरिएका ग्याबियन पर्खाल

चित्र नं. ८ : विशाल चट्टानबाट छुट्टिएर आएको ढुङ्गालाई ग्याबियन पर्खालले रोकेको

चित्र नं. ९ : स्थानिय बासिन्दाहरुद्वारा बर्षाको पानी पहिरो तर्फ जानबाट रोक्न बनाएको पानी तर्काउने कुलो

चित्र नं. १० : पहिरोबाट बच्न बनाईएका अस्थाई गोठ टहराहरु

चित्र नं. ११ : पहिरोबाट बच्न अस्थाई टहराहरुमा रहेका स्थानिय बासिन्दाहरु (साभार : कान्तिपुर दैनिक २०६४ असार ५ गते)

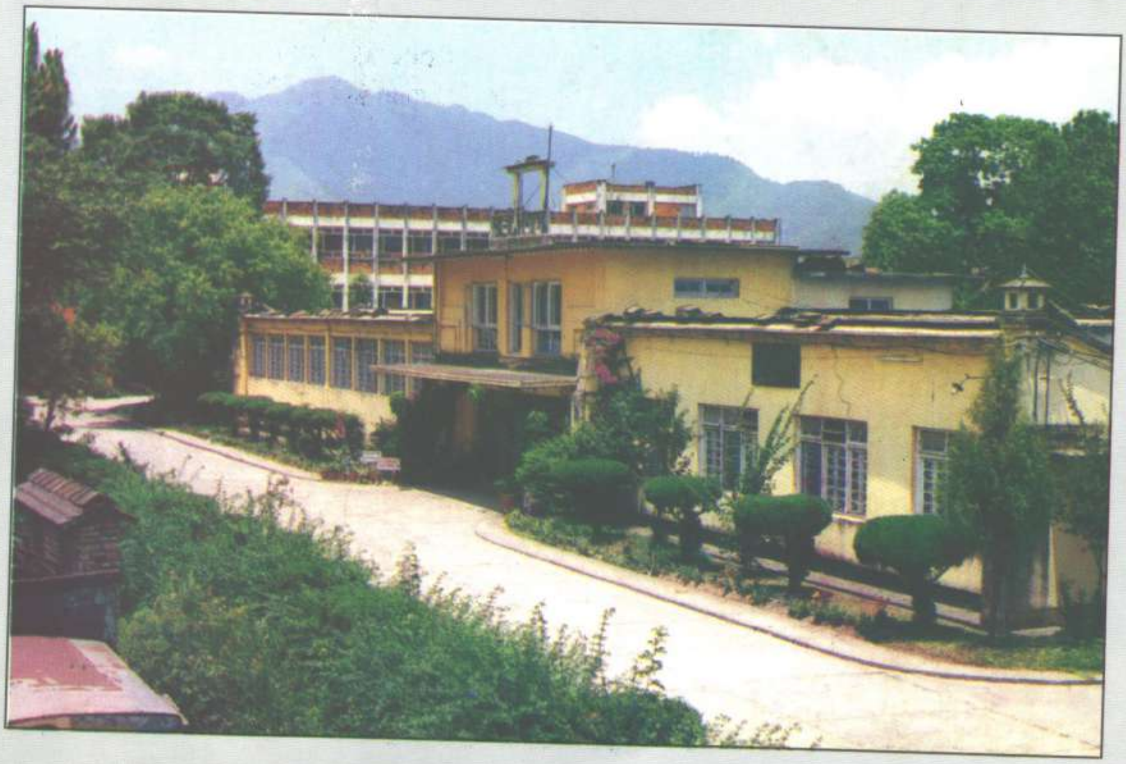
चित्र नं. १२ : औल क्षेत्रको भौगर्भिक नक्शा (खा.त.भू.वि. सन् २००२)

चित्र नं. १३ : खस्किने प्रक्रियामा रहेको बिशाल चट्टान

चित्र नं. १४ : पहिरोको पश्चिम तिर अस्थिर अवस्थामा रहेको चिरा युक्त चट्टान र भिरालो भूबनोट

चित्र नं. १५ : पहिरोदेखि तल गाऊंसम्मका] Panoramic दृश्य

चित्र नं. १६ : बिशाल चट्टानमा दक्षिण पट्टि देखिएको चिरा



Government of Nepal
Ministry of Industry
Department of Mines and Geology
Lainchour, Kathmandu, Nepal
Tel. : +977-1-4414740, 4412065
Fax : +977-1-4414806
Email : dmgplan@mos.com.np
Website : www.dmgnepal.gov.np