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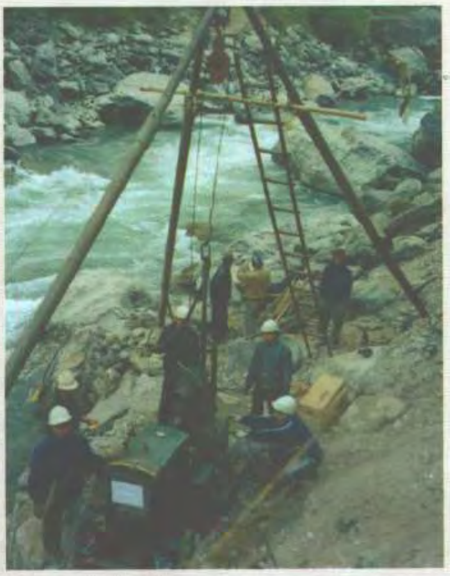
ANNUAL REPORT OF

DEPARTMENT OF MINES AND GEOLOGY



Annual Report No. 4, DMG

June, 2007(Ashad, 2064 B.S.)

PUBLISHER:

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FOREWORD

The Department of Mines and Geology (DMG) started publishing its technical publication in the form of Annual Report since 2003 compiling all the geo-scientific study and researches related to geology and mineral resources of the country conducted during the preceding year. So it is a sort of a single book conglomerating all the technical activities done in a year by the department that can be used as a means to disseminate information to related government agencies, geoscientists, geo-science students and entrepreneurs who have interest in the study and development of geosciences and mineral resources of the country.

The present Annual Report No.4, DMG is a compiled form of report being published as per the approved Annual Program of the Department of Mines and Geology, Government of Nepal for the fiscal year 2063/64. It reflects mainly the Geoscientific and Mineral Resources Development Activities of the year 2062/63. I am sure that contents of this report such as information on Geology and Geohazard, Engineering and Environmental Geology, Mineral Exploration, Petroleum Exploration etc. of the country will be a substantial asset of the department and government as well for future endeavors.

I therefore, would like to express sincere appreciation to all professionals who prepared their individual technical papers and to the contributors and service providers to bring out this series in this shape. My specific gratitude goes to all the members of the Editorial Board who have devoted priceless contribution with patience to bring this report in printed form within the time frame.

Pranab Lal Shrestha
Director General

EDITORIAL

The Department of Mines and Geology (DMG) has been publishing 'Annual Report' every year since 2003 besides other publications such as books, booklets, information brochures and various maps etc. Main purpose of the publication of annual report is to disseminate geo-scientific information acquired by the department through its regular activities of geo-scientific researches, mineral exploration and mining survey as well as other programs conducted every year by the department to the concerned people and agencies in order to contribute in fulfilling the objective of the department. The present volume is 4th in its publication series and thus has been numbered as the 'Annual Report No.4, DMG' although the Department had published its first bulletin in 1991 that encompassed the outcomes of the departmental activities of the previous year.

The Editorial Board is very much pleased to publish this volume and would like to extend its sincere appreciation and express thanks to all the authors and staff of the department for their contribution in its publication. Similarly, the Editorial Board would like to express its appreciation to the Drafting Section of the Department for its contribution in the preparation of various maps or figures.

Dr. Rajendra B. Shrestha
Chief Editor

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Preliminary Assessment of Polymetallic Sulphide Deposit in Bering Khola - Sunmai Area, Ilam District, Eastern Nepal

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INTRODUCTION

Preliminary assessment of polymetallic sulphide prospect and primary gold occurrences in Bering Khola - Sunmai Khola (Ti-Mai Khola) and further east up to Ninda Khola was conducted by the authors in 1998 (FY 2054/055). The investigated area lies in between latitude 26° 47' 30" to 26° 51' 00" North and longitude 88° 01' 00" to 88° 10' 00" East that covers about 100sq.km. in southernmost part of Ilam District and northern margin of Jhapa District in Eastern Nepal. It is bounded by Tangting Khola in the west and Ninda Khola in the east. The elevation ranges from 244m. at Telpani Khola and 1782m. near Kolbung village. The mineralization bands are exposed in Tangting Khola, Bering Khola, Handiya Khola, Bhalujhora Khola, Sunmai (Ti-Mai) Khola, Sukeninda Khola, Telpani Khola and Ninda Khola, which flow from north to south and drain the area. The climate in this area is tropical to subtropical. The average annual rainfall is about 1500mm. Mechi Highway passes through Sunmai village and the prospect lies 5 - 10km north of East - West Highway. The prospect area can be accessed from Budhbare, Char Ali, Sunmai and Kolbung villages by rough roads and foot tracks.

Yadav (1978/79) did the regional geological mapping of the area. Sharma and Thapa (1966) investigated around the Bering Khola (1.5sq km.) and reported pyrite and pyrrhotite occurrences in quartzite bands in a calcareous schist unit. Thapa (1967) did fairly detail exploration of Bering Khola sulphide deposit and traced 2 sulphide mineralization veins (bands) extending 1km in strike length. He did few trenching and drilling (one hole) and analyzed the channel and core samples. He has reported up to 0.72% Cu, 21.24% sulphur and 30.01% iron. However, no analytical result of gold and silver is given in his report. Talalov (1972) did geological investigation in Bering Khola - Sunmai Khola area and reported a complex polymetallic sulphide prospect which is confined to a skarn rock horizon that occurs in the upper part of the Proterozoic chlorite series at the frontal border of a wide area of granitization. He has also reported primary gold occurrences in the pyrite mineralization veins both in Bering Khola and Sunmai (Ti-Mai) Khola and claimed microscopic size (0.1 - 0.15mm) gold flakes in cracks of quartz and up to 0.4mm flake in quartz near the contact of quartz veins. He has also reported up to 0.03ppp gold in samples from the horizon below the graphite schist.

Jnawali (1974) did geochemical stream sediment survey in Bering Khola - Ti-Mai area. He had analyzed some grab samples collected from Bering Khola, Handiya Khola, and Ti-Mai Khola for Cu, Pb, Zn and Au and reported as high as 4700ppm Cu, 390ppm Pb, and 370ppm Zn in Handiya Khola and 1452ppm Cu, 1% Pb in Bering Khola. Gold was detected only in one sample from Handiya Khola (0.58ppm) and not even traces in other samples.

OBJECTIVE

The main objective of the investigation was to compile all the existing information, conduct follow up field investigation to trace the polymetal sulphide ore bodies, find out their extension length, thickness and depth of mineralization; collect chip, channel and grab samples for chemical analysis andpetrographic studies; calculate the geological ore reserve and grade along with gold content (if there is any) and make a quick accessment of the deposit.

METHODOLOGY

A topobase map (enlarged to 1:16,000 scale) was used to locate the outcrops, mineralized bodies, trenches, sample locations etc. Helps of Brunton compass and survey compass were taken to measure the trend of the rock units, mineralized body and prepare geological map (1:16,000 scale) and geological sections (in 1: 1000 and 1: 2000 scale) across the mineralization bands. The thickness and extension of the mineralized body were measured and documented. Cross bars, chisels and hammer were used to collect chip, channel and bulk samples. Atomic Absorption Spectrophotometer (AAS) was used for chemical analysis. Similarly stream sediment samples and heavy mineral concentrate samples were also collected and analyzed to identify the anomalous area and detect gold particles.

FIELD ACTIVITIES

Preliminary follow up exploration and quick assessment of polymetal sulphide deposit and primary gold occurrences was carried out in Tangting Khola, Bering Khola, Ti-Mai Khola, and further east up to Ninda Khola. During field investigation a semi detail geological map (scale 1:16,000) of the investigated area (Fig.1) was prepared, one/ two polymetal sulphide mineralization bands were traced by few shallow trenching across the ore bodies. 60 chip samples, 15 bulk samples and 25 floats samples were collected and analyzed for Cu, Pb, Zn and selected samples also for Ni, Bi, Au, Ag and sulphur. The field investigation was carried out to know about the nature and control of mineralization, mineral paragenesis, extension length, thickness, depth of mineralization, and grade and tonnage of the ore deposit.

Five detail geological sections across mineralization bands in Bering Khola (Fig.2a), Ti-Mai Khola (Fig.2b), Bhalujhora Khola (Fig.2c), Sukininda Khola Fig.2d), Telpani Khola (Fig.2e) and detail vertical cross sections of mineralization bands were also prepared.

Geochemical stream sediment survey covering the same 100sq.km area was completed. 252 stream sediment samples and 35 heavy concentrate samples (30 from active river course and 5 from old river terraces) were collected and analyzed for base metals and gold. Petrographic studies of different rock types and ore samples were carried out in Mineralogy and Petrography laboratory of Department of Mines and Geology (DMG).

GENERAL GEOLOGY AND STRUCTURE OF THE PROSPECT AREA

The investigated area is a part of Lesser Himalaya and lies towards north of the Main Boundary Thrust (MBT). It is represented by medium to high grade metamorphic rocks like gneiss, feldspathic schist, chloritic garnet mica schist, calc schist and quartzite of Pre-Cambrian age. Amphibolite (basic rock) bodies are quite common to this area. These metamorphic rocks are most probably equivalent to the rock units of Kathmandu Complex in Central Nepal and Darjeeling Gneiss/ Schist (?) in Darjeeling, Indian Himalaya. On the basis of regional structure (framework), lithology, grade of metamorphism (facies) and mineral composition, the rocks of this area are grouped as (1) Metamorphic Group (2) Gondwana Group and (3) Siwalik Group. Nine rock units encountered during the field investigation of this area are shown in the Geological map (Fig.1) and presented in the litho - stratigraphic table (Table-1). All these units are briefly described below.

(A) Ilam Metamorphic Group

This group is represented by medium to high grade metamorphic rocks. On the basis of grade of metamorphism, microstructure, typical metamorphic minerals present in the rock, the Ilam Metamorphic Group is further divided into six formations. In the sequence the lowermost unit Telpani Sericitic Chlorite Schist is less metamorphosed than the uppermost Ilam Gneiss and Schist.

Telpani Sericitic Chlorite Schist (TCS)

It is the oldest unit of Ilam Metamorphic Group. It is represented by medium to coarse grained, foliated, light green sericitic chlorite schist occasionally with sill like bodies of amphibolite. The schist mainly consists of chlorite, sericite, quartz and little feldspar. Quartz and quartz + chlorite veins are frequently recorded in it.

Bering Khola Quartzofeldspathic Mica Schist (BMS)

It is represented by medium to coarse grained, foliated, light colored quartzofeldspathic mica schist. At places porphyroblastic augen gneiss bands and small green amphibolite bodies are recorded. This unit is very well exposed on Bering Khola, Bhalujhora Khola, Ti- Mai Khola, Sukeninda Khola, and Telpani Khola sections. The rock mainly consists of quartz, feldspar, biotite, sericite and rarely garnet. Quartz veinlets and lenses are common in it.

Ti-Mai Calc Mica Schist (TMS)

It is represented by medium to coarse grained, faint pinkish to greenish gray calc mica schist, garnet mica schist, carbonaceous/ graphite schist, quartzite and few amphibolite bodies. Calc mica schist with pink dolomite layers/ bands and quartz lenses and veins are quite common. Two polymetal sulphide mineralization bands are confined to the basal part of this unit. The contact with overlying graphitic schist is marked by a 10cm thick sulphide bearing quartz vein in Telpani Khola.

Table-1: Tentative Litho-Stratigraphic Table

Age	Zone/ Complex	Group	Formation/ Rock Unit	Lithological description
Quaternary to Recent	-	QuaternaryTerraces	Alluvial Terraces (AT)	Loose, poorly sorted to illsorted isolated patches of river terraces with boulder, gravel, pebble, sand, silt and clay materials.
Mid-Miocene to Lower Pleistocene	Sub Himalayan Zone	Siwalik Group	Siwalik Sandstone Mudstone, Shale and Conglomerate (SW)	Medium to coarse grained, sandstone, siltstone, varigated mudstone, shale and conglomerate.
		MBT		
Carboniferous	Lesser Himalaya Zone	Gondwana Group	Ninda Quartzitic Sandstone with coaly materials and dolomite (NQS)	Medium grained, graywack type quartzitic sandstone and black coaly lenses and patches with quartzite and dolomite nodules. At places dolomite beds are also encountered.
		Thrust		
Pre-Cambrian	Crystalline Complex	Ilam Metamorphic Group	Ilam Gneiss and Schist (IGS)	Coarse grained, granet mica schist, kyanite/ sillimanite schist, micaceous quartzite, banded gneiss and porphyroblastic augen gneiss, migmatite and small bodies of granite and pegmatite.
			Jure Quartz Biotite Schist (JBS)	Med. to coarse grained, light colored foliated, quartz mica schist and micaceous quartzite and gneiss bands.
			Yangre Garnet Mica Schist (YMS)	Med. to coarse grained shining gray garnet mica schist with few sericitic white quartzite and small amphibolite bodies.
			Ti-Mai Calc Mica Schist (TMS)	Med. to coarse grained, faint pinkish to greenish gray calc. mica schist, garnet mica schist, carbonaceous/ graphitic schist, quartzite and few amphibolite bodies. Towards basal part polymetal sulphide mineralized bands are located.
			Bering Khola Quartzofelspathic Mica Schist (BMS)	Medium to coarse grained, foliated light colored quartzofelspathic mica schist at places with porphyroblastic augen gneiss bands and amphibolite bodies.
			Telpani Sericitic Chlorite Schist (TCS)	Medium to coarse grained, well foliated, light green sericitic chlorite schist occasionally with sill like bodies of amphibolite.

Yangre Garnet Mica Schist (YMS)

It is represented by medium to coarse grained, shining gray garnet mica schist with few bands and layers of sericitic white quartzite. At places small amphibolite bodies are recorded in this unit. It is well exposed in Yangre, Bering Khola, Goyang Khola, Ti-Mai Khola and Ilam road section. It consists of mainly biotite, sericite, quartz, feldspar and garnet. The size of garnet is $<$ 0.5cm.

Jure Quartz Biotite Schist (JBS)

It is represented by fractured, medium to coarse grained, light colored, foliated, quartz mica schist, micaceous quartzite and gneiss bands. It lies in between Ilam Gneiss and Schist and Yangre Garnet Mica Schist and very well exposed in Bering Khola and Ilam road cut section (Fig.1). In type locality at Jure and around, the quartzite are highly fractured, sericitic and rather micaceous. Famous landslide of Jure and few other landslides are recorded in this area.

Ilam Gneiss and Schist (IGS)

This unit occurs towards far northern part of the investigated area (Fig.1). It is represented by fractured, light colored, coarse grained, banded gneiss, porphyroblastic augen gneiss, kyanite/ sillimanite schist, garnet mica schist and micaceous quartzite. At places microfolds are developed in the gneiss. Migmatite, small granite bodies and pegmatites are also recorded within this unit. Some of the pegmatites (outside the present study area) are gem quality tourmaline and beryl bearing.

(B) Gondwana Group (SW)

In this area, this group is represented by only one unit.

Ninda Quartzitic Sandstone with coaly materials and Dolomite (NSD)

It is represented by medium grained greywacke type quartzitic sandstone and quartzite. At Bhalujhora Khola and Thakuri Khola silicious dolomite beds/ lenses and coaly materials are encountered in quartzite bands. In most of the sections this unit is not exposed since it is covered with young sediments. On the basis of location and its nature this unit is represented as an equivalent rock unit of Gondwana Group which is well exposed in Kokaha Khola section in Barahakshetra area (outside the present area).

(C) Siwalik Group

Rocks of Siwalik Group are separated from the Gondawana Group by Main Boundary Thrust (MBT). It is well exposed in Ninda Khola, Bhalujhora Khola and Thakuri Khola. Rocks are highly crushed and fragmented in MBT zone. Siwalik Group is represented by medium to coarse grained sandstone, fine grained siltstone, various colored mudstone, shale and very coarse grained conglomerate.

(D) Alluvial Terraces

In this area two to three levels of isolated patches of river terraces are present by the side of Ti-Mai Khola. They are represented by loose, poorly sorted to illsorted river gravel, boulder, pebble, sand, silt and clay materials. At present, the local farmers use these terraces as agricultural fields. River gravel, bolder and sand is mined as construction materials from the river beds.

Geological Structures

Main Boundary Thrust (MBT) is the prominent linear structural element that forms the southern boundary of the investigated area. It can be well traced in Thakuri Khola (a small left tributary of Bering Khola), one of the right tributary of Handiya Khola, Sukeninda Khola and Ninda Khola section where as in Ti-Mai Khola and Telpani Khola section it is covered with Quaternary sediment deposits. There is another thrust which separates the Gondwana Group from Metamorphic Group (Fig.1).

Three distinct transverse faults were traced during geological mapping. Tight microfolds and ptygmetic folds are recorded in sericitic quartzite, schist and Ilam gneiss. Microfolds are also recorded in sericitic chlorite schist and carbonaceous schist. Dark green amphibolite bodies of various size and thickness with or without garnet are encountered in this area irrespective to the particular unit. However, they are more common in calc mica schist. Late phase milky white quartz and quartz + chlorite veins and lenses are quite common in Ilam Gneiss and Schist. High grade metamorphic effects are represented by the presence of kyanite, sillimanite in schist, porphyroblast in augen gneiss and garnet in amphibolite. Presence of minor granite bodies and migmatite within Ilam Gneiss and Schist indicate some intrusive activities in the far northern part of the area.

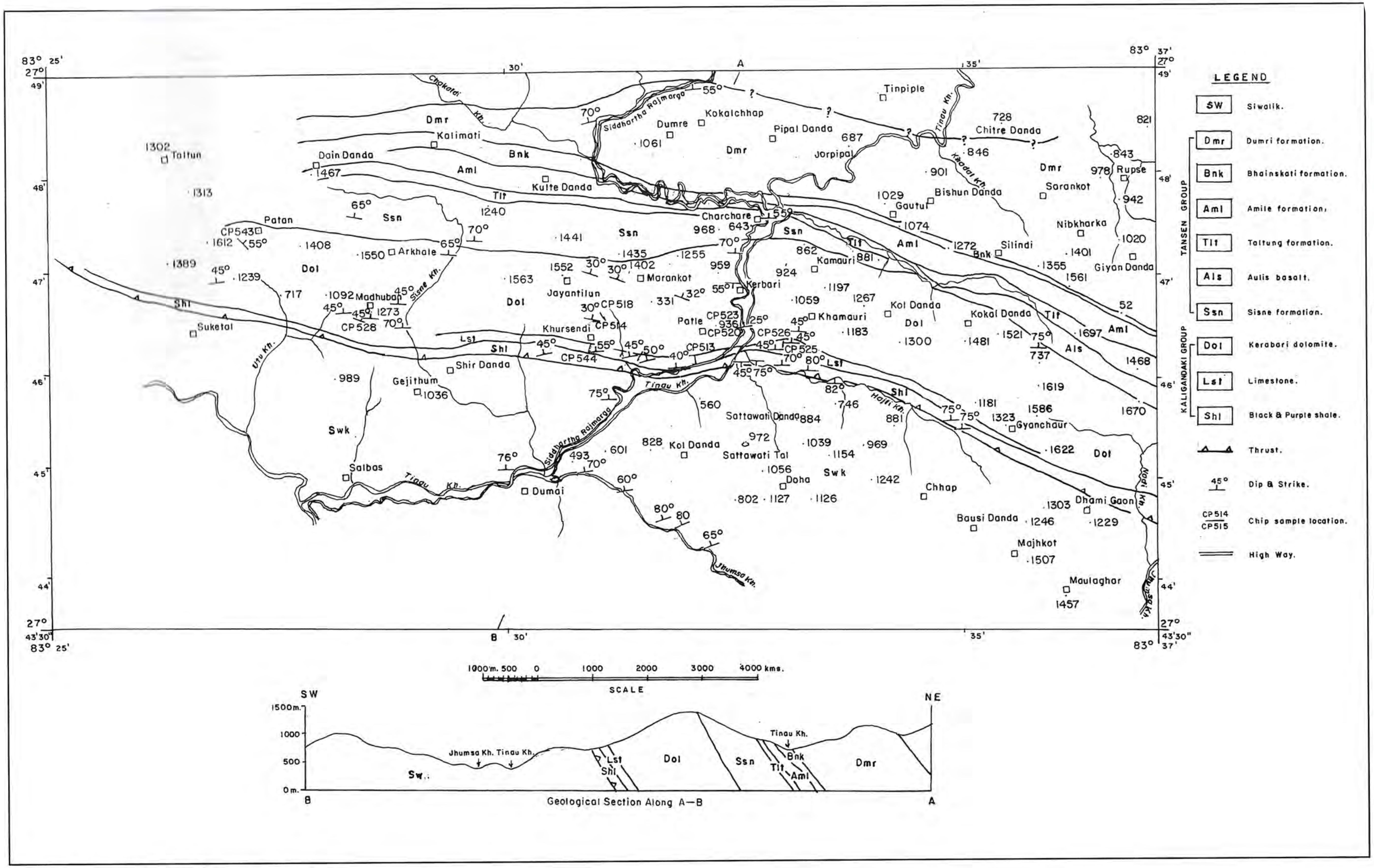

Fig.1. Geological Map of Kerabari and adjoining Area, Palpa District.

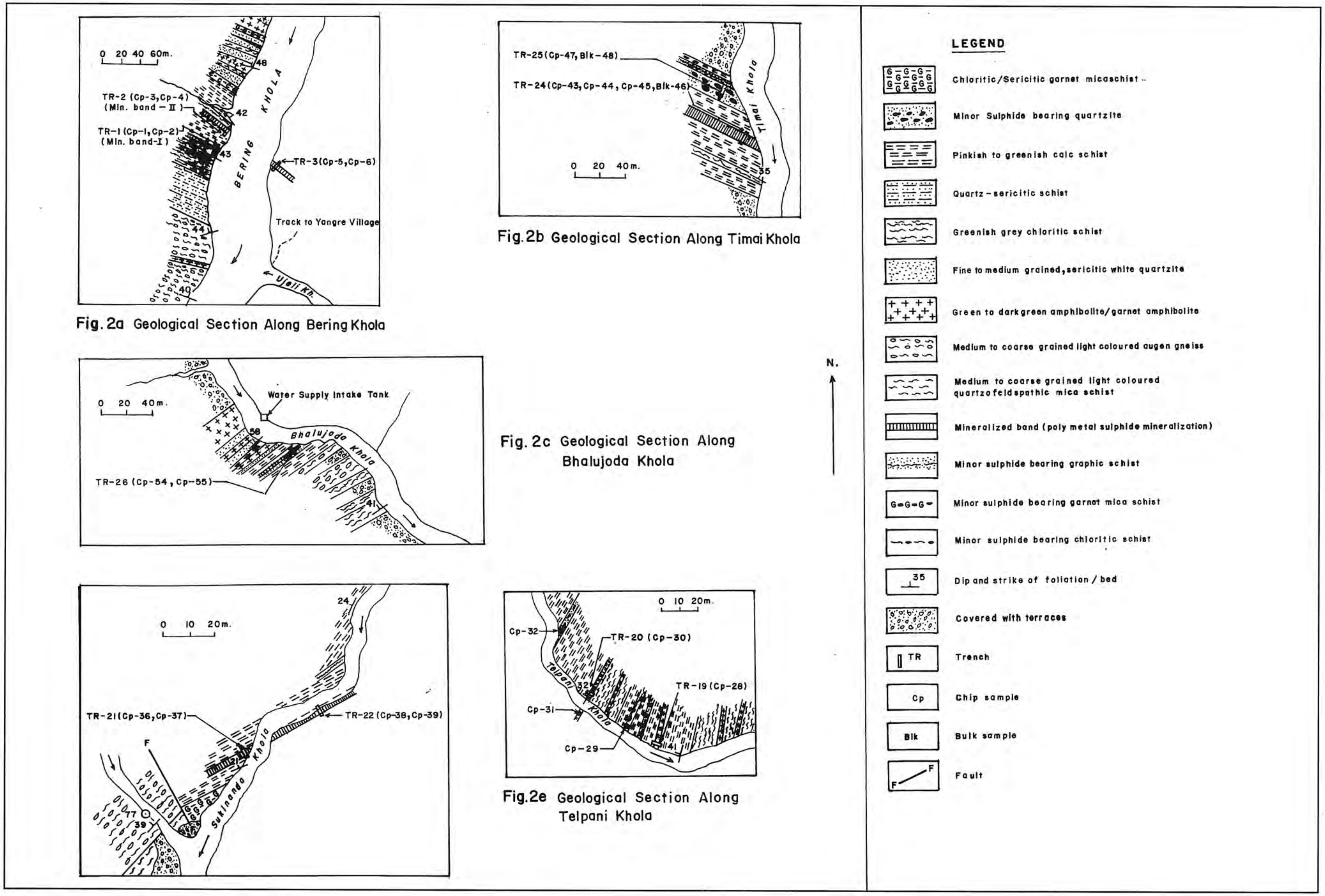

Fig.2. Geological Section Along Different River (Khola) Showing Mineralized Band.

GEOCHEMICAL PROSPECTING

Follow up geochemical prospecting was conducted on the whole (100sq.km) area. During fieldwork both stream sediment sampling and heavy mineral concentrate sampling method were adopted to know the various metals/ metallic minerals present in them. 252 stream sediment samples were collected from active river courses, they were sun dried and sieved to minus -80mesh size and analyzed mainly for copper, lead and zinc. All the chemical analysis data were plotted and interpreted to find out various geochemical parameters like back ground, threshold, anomalous and highly anomalous values.Based on these data the geochemical anomaly was categorized and anomalous areas of primary source of the base metals and gold identified.

Similarly 30 Heavy mineral concentrate samples from river course and 5 from old river terraces were collected and studied in the laboratory to find out whether the alluvial gold occur or not. However, no visible alluvial gold flake was detected. At the same time few ore samples were crushed and panned for heavy minerals to look for gold particles but none of the sample except one sample from Ojheli Khola has shown gold content in them. Other common heavy minerals detected in them are garnet, ilmenite, rutile, epidote, chalcopyrite, galena, pyrite, hematite, limonite, magnetite and amphibole.

MINERALIZATION

In the investigated area a polymetal sulphide mineralization band can be traced throughout from Goyang Khola in the west to Telpani Khola in the east extending in a strike length of about 12km. In Bering Khola, (Fig.2a and Fig.3) Ojheli Khola, Duple Khola, and Handiya Khola sections there are two separate sulpide

Fig.3: Two Polymetal sulphide mineralization bands in Bering Khola

Fig.4: Single Polymetal sulphide mineralization band in Ti-Mai Khola (Sunmai)

ore bodies/ bands where as in eastern part in Ti-Mai Khola (Fig.2b and Fig.4) and Sukininda there exists only one mineralization band (Fig.2d). The thickness of the mineralization band also varies considerably from less than 1m to 2.5m due to swelling and pinching nature. Mineralization is irregular in Goyang Khola and Bhalujhora Khola where the band is less than 1m thick. Therefore, while calculating the geological reserve total strike length of mineralized ore body is taken as only 9km.

In Ti-Mai Khola the mineralization is more or less similar to that of Bering Khola where pyrite and pyrrhotite are the main sulphide minerals associated with few chalcopyrite, arsenopyrite, magnetite, galena and sphalerite. However, the amount of galena and sphalerite content in Handiya Khola and Ti-Mai Khola sections are comparatively higher than in Bering Khola section. It appears that both the mineralization bands exposed in Bering Khola (lower band and upper band) might have merged into one band in Ti-Mai Khola and further east in Sukeninda Khola and Telpani Khola. Beside the main mineralization body there exist a pyrite and few chalcopyrite and secondary malachite bearing sericitic quartzite bands in Ti-Mai Khola. It lies just above the main mineralization band. This band cannot be traced in any other section. Therefore, it cannot be correlated with any of the main mineralized band exposed in other khola section.

The chief ore minerals identified in the ore are pyrite, pyrrhotite, chalcopyrite, galena, sphalerite, magnetite and arsenopyrite. Rare amount of niccolite, bismuthinite and scheelite are also encountered in Handiya Khola and Ti-Mai Khola. However, the distribution/ concentration of the ore minerals are not uniform and similar throughout. The amount of combined sulphide minerals in the ore also varies considerably from 5% in disseminated ore to almost 45% in massive sulphide ore. Visible primary gold was not detected either in the main mineralized body or in any of the quartz veins, calc schist, quartzite and graphitic schist. Only one gold flake was detected in one polished section of the ore from Ojheli Khola and similarly only one alluvial gold flake in heavy mineral concentrates sample from the same Ojheli Khola. This indicates that traces of primary gold may occur in Ojheli Khola section.

Ore Genesis and Mineral Paragenesis

Occurrence of ore body in the same stratigraphic sequence (horizon) within the Calc. Mica Schist Formation throughout the area indicates that the mineralization is stratigraphically controlled. The predominant ore minerals are pyrite and pyrrhotite. Frequent occurrence of quartz specks, veins, clast (along with or without calcite) with chalcopyrite and galena ± sphalerite especially on the basal part indicate that there was later hydrothermal effect in it. Mineral association and their relationship as well as the texture and grain size clearly indicate remobilization and reconcentration of the ore minerals at different time possibly during the process of regional metamorphism. Presence of pyrrhotite and sheelite (?) in the ore indicate fairly high temperature mineralization at depth. Field observation followed by petrographic and mineralogical study of some polished sections of the ore revealed that magnetite and pyrite were the first minerals to crystallize in sequence. It was followed by mineralization of pyrrhotite, chalcopyrite, galena and sphalerite. Chalcopyrite has partly replaced pyrite and pyrrhotite. Galena, sphalerite, pyrite and few chalcopyrite are associated with quartz veins indicating hydrothermal origin. Out of 26 polished section studies from this area, gold was detected only in one section. There is a possibility that gold may occur in the crystal lattices of pyrite/ pyrrhotite that we cannot identify even in the polished section but it can be detected by chemical analysis.

Geological Ore Reserve

The mineralized body can be divided into 3 blocks or sectors on the basis of thickness of the ore body and concentration of ore minerals. The geological ore reserve of each block is calculated separately. Chemical analysis of all the ore samples was carried out in DMG laboratory. However, some of the samples were also analyzed in Federal Institute of Geosciences and Natural Resources (BGR), Germany for cross checking. The analytical results of other elements received from both laboratories are more or less similar except gold (Table-2). The vast difference in gold analysis result may be due to analytical errors in DMG. Therefore, for our calculation the values of gold are taken from BGR laboratory.

(a) Western, Bering Khola Block (Goyang Khola - Handiya Khola Sector)

This sector extends at about 6km. in strike length from Goyang Khola to Handiya Khola. In this sector two mineralization bands can be traced throughout. However, their thickness (<1 to 2m.) and concentration of ore minerals varies considerably. Concentration is comparatively high in central part in Duple Khola, Bering Khola, Ojheli Khola and Handiya Khola sections where as it is very low in Goyang Khola. As a result the grade of ore varies remarkably in different sections. The geological ore reserve of this sector is as follows.

Estimated strike length of the ore body = 4000m (excluding very poorly mineralized parts)

Average thickness of the ore body = 1.6m (combined)
Expected depth extension = about 250m
*Volume of the deposit = 4000 * 1.6 * 250 = 1600,000m³.*

Average specific gravity of the ore = 4
Ore Reserve is 6,400,000mt with average grade of Cu<0.36%, Pb=2.6%, Zn=1.6%, Au<0.25ppm and Ag=300ppm (?)

(b) Central, Ti-Mai Khola Block (Handiya Khola - Dewanchhap Sector)

This block extends at about 4km. in strike length from Handiya Khola to Dewanchhap village. There is only one mineralization band (1 to 2.5m. hick) in this sector. Concentration of ore minerals is comparatively higher in Ti-Mai Khola and Handiya Khola sections where as it is very irregular and thin in Bhalujhora Khola. Because of thick soil cover the mineralization band cannot be traced on the hill top or on the slope except in the Khola section. The geological ore reserve in this sector is calculated as follows.

Estimated strike length of the ore body = 3000m (excluding very poorly mineralized part).

Average thickness of the ore body = 1.4m
Expected depth extension = 250m
*Volume of the ore deposit = 3000 * 1.4 * 250 = 1,050,000m³*

Average specific gravity of the ore = 4
Ore reserve is 4,200,000mt with an average grade of Cu=0.3%, Pb=0.5%, Zn=0.68%, Au<0.2ppp and Ag = 103ppm (?)

(c) Eastern, Telpani Khola Block (Dewan Chhap - Telpani Khola Sector)

It extends at about 2.5km. in strike length from Dewan Chhap to Telpani Khola. There is only one 70cm to 1m. thick mineralization band. Out of which the concentration of sulphide ore is high only in 50 to 70cm thick parts. The geological ore reserve in this sector is calculated as below:

Estimated strike length of the ore body = 2000m
Average thickness = 70cm
Expected depth extension = 200m
*Total Volume of the ore body = 2000 * 0.70 * 200 = 280,000m³*

Average specific gravity of the ore = 4
Ore reserve is 1,120,000mt with average grade of Cu=0.33%, Pb=0.25ppm, Zn<0.1%, Au<2.5ppm and Ag=50ppm (?)

Therefore, the combined Total ore reserve (three sectors a + b + c) = 11,720,000mt with an average grade of Cu = 0.21%, Pb = 1%, Zn <1%, Au <0.25ppm and Ag = 150ppm (?).

FINDINGS

Semi detail geological map (1:16,000scale) of over 100sq.km in Bering Khola - Sunmai Khola (Ti-Mai Khola) area covering polymetal sulphide prospect and surrounding area was prepared. Similarly semi-detail geochemical stream sediment survey of the same 100sq.km area was completed and few target areas were delineated for further follow up investigation of base metals.

1 to 2.5m thick polymetal sulphide ore body was traced from Goyang Khola in the west to Telpani Khola in the east (about 12km length) and roughly calculated the geological ore reserve of about 11.72 million metric tons of polymetal sulphide ore.

CONCLUSION AND RECOMMENDATION

Present investigation made it quite clear that Bering Khola - Sunmai (Tin-Mai Khola) mineralization is a polymetal sulphide ore deposit. It is confined to the basal part of the calc mica schist which is also the marker of the mineralization band. The mineralization band appears as only one in Ti-Mai Khola, Sukeninda Khola and Telpani Khola where as it appears as two separate bands in Bering Khola, Duple Khola, Ojheli Khola and Handiya Khola sections. It can be traced in all these khola sections throughout (almost 12km strike length). The thickness as well as the distribution of the ore minerals in the ore body is significant. But distribution/ concentration of ore minerals (combined) is not uniform throughout the band and overall sulphide mineral varies considerably from 5% in disseminated ore to almost 45% in massive sulphide ore.

The ore minerals identified in the ore samples are pyrite, pyrrhotite, chalcopyrite, galena, sphalerite, arsenopyrite, magnetite and limonite. At few places bismuthinite, niccolite and scheelite are also detected. Out of 27 polished sections gold was detected in only one sample. Similarly out of 35 heavy mineral concentrate samples only one visible gold flack (<1mm size) was traced in the heavy mineral concentrate sample from Ojheli Khola. However, gold can be associated with pyrite, chalcopyrite, arsenopyrite in their crystal lattice that cannot be seen with naked eye. Therefore, only standard chemical analysis of ore samples could provide better information about the presence of gold in the ore.

Visible gold is neither detected in the sulphide ore/ quartz veins nor in quartzite bodies in calc mica schist, garnet mica schist or graphitic schist. All types of schist, amphibolite, quartzite as well as ore samples were crushed and panned to look for primary gold. But neither primary nor alluvial gold could be detected except in one sample. Therefore, the chances of finding out recoverable amount of primary or placer gold are very low. However, chemical analysis of selected ore samples, vein quartz and other samples in DMG laboratory has indicated fairly high Au (?) content. Some selected ore samples were also analyzed in BGR laboratory, Germany for cross checking. Gold analysis results of the same samples in two different laboratories do not match (Table-2) which may be due to analytical error in DMG laboratory. Analytical result from DMG laboratory has shown fairly high silver content in some of the ores from Timai Khola and Duple Khola. However, silver content in the ore has yet to be confirmed by cross checking in BGR laboratory or any other standard laboratory.

Talalov (1972) has mentioned about primary gold occurrence in this area and recommended for follow up investigation. Just seeing only one or two gold flakes along the cracks of quartz vein and chemical analysis of only 3 quartz veins/ore samples showing 0.1 to 0.3ppm gold could not represent the whole mineralized band. Present investigation and its results have proved it very clearly.

Bering Khola -Sunmai (Ti-Mai Khola) mineralization is a low to medium grade and large tonnage, complex polymetallic sulphide ore deposit. It consists of mainly

Table-2 Analytical Results of the Ore Samples

Sample No	Location	Cu %	Pb %	Zn %	S %	Ni ppm	Bi ppm	W ppm	As ppm	Ag ppm	Au ppm	Remarks
Ilm/2054-55/ KK/Tr-2/Cp.3	Bering Kh	0.44 0.60	0.02 0.01	0.02 0.03	- 18	62 -	- 87	- 4	- 133	24 -	9.5 0.3	DMG Lab BGR Lab
KK/Tr-2/Cp.4	Bering Kh	0.22 0.79	0.01 0.01	0.01 0.02	- 23	44 40	- 30	- 3	- 314	12 -	- 0.1	DMG Lab BGR Lab
KK/Tr-3/Cp.5	Bering Kh	056	0.03	0.01	-	20	-	-	-	-	-	DMG Lab
KK/Tr-3/Cp6	Bering Kh	**0.99** **0.77**	0.005 0.02	0.01 0.01	- -	26 20	- 55	- 3	- -	- -	- -	DMG Lab BGR Lab
KK/Tr-4/Cp.7	Ojheli Kh	0.21 0.22	0.04 0.03	0.07 0.30	- 17	46 14	- 17	- -	- 69	24 -	- 0.1	DMG Lab BGR Lab
KK/Tr-5/Cp.8	Ojheli Kh	0.02	0.08	0.03	-	24	-		-		-	DMG Lab
KK/Tr-6/Cp.9	Ojheli Kh	0.02 0.22	0.30 0.29	0.25 0.47	- 16	36 28	- 69	- 3	- 31	- -	- 0.1	DMG Lab BGR Lab
KK/Tr-7/Cp.10	Ojheli Kh	0.22	0.46 0.23	0.37 0.25	- -	62 -	-		-	72 -	- -	DMG Lab BGR Lab
KK/Tr-8/Cp.11	Chune Kh	0.50	0.07	0.02	-	38	-		-	-	-	DMG Lab
KK/Tr-9/Cp.12	Chune Kh	**0.98**	0.04	0.01	-	14	-		-	-	-	DMG Lab
KK/Tr-10/Cp.13	Bering Kh	0.03	0.03	0.02	-	-	-		-	2.5	4.28	DMG Lab
KK/Tr-11/Cp.14	Bering Kh	0.003	0.04	0.02	-	22	-		-		-	DMG Lab
KK/Tr-12/Cp.15	Bering Kh	0.002	0.004	0.04	-	20	-		-	-	-	DMG Lab
KK/Tr-13/Cp.16	Bering Kh	0.03	0.14	0.06	-	38	-		-	-	-	DMG Lab
KK/Tr-14/Cp.17	Duple Kh	0.007 0.12	0.16 0.17	**4.20** **3.86**	- 12	44 27	- 15	- 3	- 69	-	- 0.1	DMG Lab BGR Lab
KK/Tr-14/Cp.18	Duple Kh	0.022 0.02	2.75 3.75	0.09 0.30	- 4	34 6	- 45	- 24	- 304	**1120** -	- 0.1	DMG Lab BGR Lab
KK/Tr-14/Cp.19	Duple Kh	0.005 0.011	4.06 3.73	0.1 0.16	- 1	18 3	- 21	- 3	- 264	-	- 0.1	DMG Lab BGR Lab
KK/Tr-14/Cp.20	Duple Kh	0.006 0.033	**6.10** **5.95**	0.16 0.84	- 9	14 3	- 37	- 3	- **643**	-	- 0.2	DMG Lab BGR Lab
KK/Tr-15/Cp.21	Duple Kh	0.001	3.30	0.10	-	22	-	-	-	-	-	DMG Lab
KK/Tr-15/Cp.22	Duple Kh	0.01	3.52	0.23	-	22	-	-	-	-	-	DMG Lab
KK/Tr-16/Cp.23	Duple Kh	0.006	2.68	0.55	-	20	-	-	-	-	-	DMG Lab
KK/Tr-16/Cp.24	Duple Kh	0.005	0.14	0.30	-	34	-	-	-	-	-	DMG Lab
KK/Tr-17/Cp.25	Tugne Kh	0.56 0.05	**3.8** **18.88**	1.66 0.80	-	**6424** 36	- **102**	- **50**	-	**640** -	-	DMG Lab BGR Lab
KK/Tr-18/Cp.26	Goyang Kh	0.01	0.05	0.45	-	20	-	-	-		-	DMG Lab
KK/Tr-18/Cp.27	Goyang Kh	0.26 -	0.03 0.03	0.01 0.03	-	34	-	-	-	20 -	- -	DMG Lab BGR Lab
KK/Tr-19/Cp.28	Telpani Kh	0.011	0.02	0.02	-	22	-	-	-	-	-	DMG Lab
KK/Cp.29	Telpani Kh	0.034	0.005	0.03	-	18	-	-	-	-	-	DMG Lab
KK/Tr-20/Cp.30	Telpani Kh	0.60 0.56	0.019 0.03	0.07 0.08	- 15	70 52	- 23	- 3	- 24	16 -	- 0.2	DMG Lab BGR Lab
KK/Cp.31	Telpani Kh	0.041	0.02	0.01	-	48	-	-	-	-	-	DMG Lab
KK/Cp.32	Telpani Kh	0.044	0.06	0.13	-	26	-	-	-	-	-	DMG Lab
KK/Cp.33	Telpani Kh	0.013	0.024	0.01	-	8	-	-	-	-	-	DMG Lab
KK/Cp.34	Telpani Kh	0.006	0.01	0.02	-	38	-	-	-	-	-	DMG Lab

KK/Cp.35	Telpani Kh	0.04	0.05	0.04	-	34	-	-	-	-	-	DMG Lab
KK/Tr-21/Cp.36	Sukininda Kh	0.34	0.09	0.10	-	108	-	-		240	-	DMG Lab
KK/Tr-21/Cp.37	Sukininda Kh	0.18	0.01	0.00	-	**128**	-	-	-	40	-	DMG Lab
KK/Tr-22/Cp.38	Sukininda Kh	0.04 0.35	0.08 0.098	0.07 0.07	18 -	46 554	- 54	- 3	- 44	-	- 0.2	DMG Lab BGR Lab
KK/Tr-22/Cp.39	Sukininda Kh	0.04 0.24	0.05 0.08	0.12 0.11	- **27**	114 115	- 44	- 10	- 23	-	- 0.1	DMG Lab BGR Lab
KK/Cp.40	Qtz. vein Py, Cp	0.08	0.01	0.02	-	16	-	-	-	-	-	DMG Lab
KK/Tr-23/Cp.41	Sukininda Kh	0.14	0.174	0.30	-	20	-	-	-	-		DMG Lab
KK/Tr-23/Cp.42	Sukininda Kh	0.24	0.01	0.78	-	12	-	-	-	0.9	3.5	DMG Lab
KK/Tr-24/Cp.43	Ti-Mai kh	0.29 0.07	**2.5** **6.33**	0.08 0.01	- -	62 3	- **1100**	- 3	-	800 136	9.5 -	DMG Lab BGR Lab
KK/Tr-24/Cp.44	Ti-Mai kh	0.29 0.34	0.44 0.45	1.00 0.32	- 23	70 36	- 47	- 3	- 16	68 -	- 0.1	DMG Lab BGR Lab
KK/Tr-24/Cp.45	Ti-Mai kh	0.53 0.23	0.56 0.41	0.27 0.38	- 24	42 40	- 61	- 3	- 28	0.7 -	5.5 0.2	DMG Lab BGR Lab
KK/Blk-46	Ti-Mai kh	0.25 0.24	0.8 0.1	0.11 0.16	- -	80 27	- 20	- 3	- -	140 5.2	11 -	DMG Lab BGR Lab
KK/Tr-25/Cp.47	Ti-Mai kh	0.06 0.09	0.05 0.04	0.02 0.02	- 4	16 4	- 8	- -	- 28	2.2 -	4.5 0.1	DMG Lab BGR Lab
KK/Blk-48	Ti-Mai kh	0.013	0.35	0.26	-	18	-	-	-	11	4.5	DMG Lab
KK/Tr-26/Cp.54	Bhalujhora Kh	0.16	0.06	0.06	-	90	-	-	-	24	13	DMG Lab
KK/Tr-26/Cp.55	Bhalujhora Kh	- 0.084	- 0.01	- 0.03	- -	- 52	- 4	- 3	- -	7 -	**17** -	DMG Lab BGR Lab
KK/Tr-27/Cp.56	Handiya Kh	0.044 0.031	2.2 1.0	3.4 6.6	- 21	50 24	- 3	- 3	- 648	24 -	11 0.1	DMG Lab BGR Lab
KK/Tr-24/Cp.57	Handiya Kh	0.061 0.26	0.17 0.16	0.30 0.61	- 14	14 28	- 54	- 3	- 101	9.5 -	9 0.1	DMG Lab BGR Lab
KK/Tr-28/Cp.58	Handiya Kh	0.072 0.06	1.00 0.70	**3.4** **5.41**	- 19	60 29	- 10	- 3	- 355	24 -	12 0.1	DMG Lab BGR Lab
KK/Tr-28/Cp.59	Handiya Kh	0.09	1.8	**3.64**	-	36		-	-	22	6	DMG Lab
KK/Cp.60	Ilam road	0.023	0.23	0.36	-	48	-	-	-	3	17	DMG Lab
KK/Bds-2	Thakur Khola	-	-	-	-	-	-	-	-	16	6	DMG Lab
KK/Bds-28	Thakuri Kh	0.02	0.18	0.36	-	-	-	-	-	1.5	2.5	DMG Lab
KK/Bds-35A	Thakuri Kh	0.01	1.16	0.39	-	-	-	-	-	1.7	3.8	DMG Lab
KK/Bds-176A	Telpani Kh	0.25	0.03	0.02	-	-	-	-	-	4	4.5	DMG Lab
KK/Bds-196	Sukininda Kh	0.19	0.65	0.48	-	-	-	-	-	8	16	DMG Lab
KK/Bds-221A	Sukininda Kh	0.08	0.01	0.13	**30**	-	-	-	-	-	-	DMG Lab
KK/Bds-240	Handiya Kh	0.006	0.61	0.29	14	-	-	-	-	-	-	DMG Lab
KK/Bds-244	Handiya Kh	0.002	0.78	0.38	24	-	-	-	-	-	-	DMG Lab
KK/Bds-245	Handiya Kh	0.01	1.6	0.39	24	-	-	-	-	-	-	DMG Lab
KK/Bds-254	Road side	0.01	0.04	0.16	-	28	-	-	-	-	-	DMG Lab

Cp = Chip sample Bds= float sample S = Rock sample

Blk = Bulk sample Tr = Trench kh= Khola

DMG Lab = Department of Mines and Geology Chemical Laboratory, Nepal

BGR Lab = Federal Institute of Geosciences and Natural Resources Chemical Laboratory, Germany pyrite, pyrrhotite, along with few chalcopyrite, galena, sphalerite, arsenopyrite and at places very low amount of niccolite and bismuthinite and rare amount of silver and traces of gold. Overall grade of the ore is low. High tech metallurgical process is required to extract various metals from the complex polymetal sulphide ore. Chemical analysis data (from BGR lab, Germany) indicate that the prospect is not promising for gold exploration, however, multi mineral mining could be feasible if the infrastructure (e.g. road access, electricity lines etc.) are available. But at this stage underground mining of such medium to low grade ore do not look feasible.

Among the three mineralized sectors the western block appears more promising. If the amount of silver content with minor amount of gold in the ore appear interesting then mining of this ore with a view to extract more than one metals (Ag, Zn, Cu, Pb and Au) could bring it as an interesting economic deposit. Therefore, gold and silver analysis of selected ore samples in any standard laboratory with high precision and preliminary metallurgical testing of the complex ore to extract more than one metal and detail petrographic investigation is recommended.

ACKNOWLEDGEMENT

The authors would like to express their sincere thanks to Mr. P.L. Shrestha, Director General, DMG for the permission to use all the related references available in DMG library and publish this paper. The authors also would like to extend their thanks to Dr. Klaus Busch, Former Project Chief, EGP Project, from BGR Germany for arrangement to analyze few ore samples in BGR laboratory and colleague from chemical laboratory of DMG for chemical analysis. Our sincere thank also goes to Dr. R.B. Shrestha for going through the manuscript and valuable comments.

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Annual Report of Department of Mines and Geology, 2007, No. 4, pp. 15 - 24

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

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INTRODUCTION

The Department of Mines and Geology (DMG) has been exploring cement grade limestone since late sixties with a view to set up cement industries in all development regions of the country to achieve balanced economic growth. Present study area comprises of 150 sq. km. in some parts of Toposheet No. 2783 03B and 04A, 2883 15D and 16C covering in between N 27°57'30" to 28°04'00" latitude and E 83°41'15" to 87°49'00" longitude. It includes some parts of 9 VDCs and the Waling Municipality of Syangja District adjacent to the Siddhartha Highway. Tater (1967), Hirayama et al (1988), Shrestha (1981, 1983), Jnawali et al (1999), Shrestha et. al.(2000), Paudyal et. al (2000), Dhital et. al. (2002) established stratigraphy and tectonics of the area. Madhikarmi (2000) carried out preliminary geological investigation for cement grade limestone and industrial dolomite in some parts of the Syangja district around Siddhartha Highway. Present study substantiates preliminary investigation in order to identify the target areas for further follow-up exploration of limestone and dolomite resources in the area.

OBJECTIVE

The main objectives of the study were to carryout geological mapping of 160 sq. km. area in the scale of 1:25,000 to locate the cement grade limestone bodies and also dolomite of industrial use and find out their extension length and thickness as well as continuous chip sampling of representative limestone to determine its tentative grade.

METHODOLOGY

The possibilities of limestone and dolomite domains were assessed on the basis of the grade and tonnage of the limestone deposit, infrastructure, mineability, environmental situation of the area etc. Geological section measurement of limestone and dolomite bands was carried out simultaneously with continuous chip sampling in an interval of approximately 5m (true thickness). The fresh chips were collected weighing about 1.5 to 2 kg and packed and labeled as a single chip sample portraying from different areas to analyze for the confirmation of the grade.

This encompasses continuous chip sampling through the domains identified for limestone and dolomite. 79 chip samples over the 5 limestone domains and 21 chip samples over the 4 dolomite domains were sampled. A total of 100 samples covering 362m. length of limestone and 103m. length of dolomite were sampled.

REGIONAL GEOLOGY

The rock units of Lesser Himalaya are sandwiched between two prominent thrusts i.e. Main Central Thrust (MCT) and Main Boundary Thrust (MBT) (Amatya and Jnawali, 1996). The lithostratigraphy of the central sector was established by Stocklin and Bhattarai (1977, 1980) which consists of the Lower Nawakot and the Upper Nawakot Groups separated by a disconformity. Similarly, the lithostratigraphy of western sector around Kaligandaki was established by Sakai in 1985 and divided into Kaligandaki Supergroup and Tansen Group for the outer Lesser Himalayan rocks. The Kerabari Formation consisting of thick sequence of dolomite alternating with shale and siltstone has been correlated with the Krol formation of Kumaon outer Lesser Himalaya of India (Valdiya, 1998). The Inner Lesser Himalaya of westen Nepal was studied by Dhital et. al. in 2002 and introduced the Sirkot Group. These works are tremendously helpful to understand the tectonics, stratigraphy, tentative age and correlation of rock successions with the other parts of the Himalayan sector.

The present study area is a part of the inner Lesser Himalaya around Sidhartha Highway in Syangja District. Startigraphically, it consists of the Lower Nawakot, Upper Nawakot and Sirkot Group of rocks from older to younger sequence.

Lower Nawakot Group

In the study area the Lower Nawakot Group is represented by thick sequence of gritty phyllite and quartzite followed by gray dolomite and slate. It consists of only Nourpul Formation and Dhading Dolomite and other units are absent.

Nourpul Formation

The Nourpul Formation crops out in Bayatari, Khanidada, Phaudi Khola and also lower reaches of Bhakunde to upper reaches of Chiuri section along the Siddhartha Highway as well as Andhi Khola (Fig.1). The Bayatari section consists of gray green phyllite, slate and quartzite followed by pink quartzite and gray green slate. The dolomite is intercalated with slate and quartzite in the upper part representing hanging wall of the south dipping imbricate fault. It also consists of red purple, gray and gray green slate or phyllite alternating with light yellow, white, pink and light gray quartzite. The thickness of the formation in the study area is about 1000m. The age of the formation is considered to be of middle Proterozoic on the basis of stratigraphical position and correlable Kumaon Himalayan rock units (Dhital et. al. 2002).

Dhading Dolomite

The Dhading Dolomite is well exposed in Chiuri area, Surkaudi - Rambachhacha and Darsing -Lamachaur area (Fig.1). It can be seen around Chiuri and Darsing on the Sidhartha Highway. It consists of gray and light gray dolomite with dark gray and black slate partings and interbeds. The dolomite frequently contains dome shaped, columnar shaped and branching stromatolites. The downward facing stromatolite has algal mats, intraclasts and chert nodules (Dhital et al 2002). The dolomite consists of cross cutting calcite veins in mm. scale. The well exposed dolomite bands of Surkaudi - Rambachhacha area consist of detrital quartz grains. The columnar stromatolites at Surkaudi are 10 to 30cm. long. 1mm. to 1 cm. thick slate partings are recorded within the thick bedded dolomite at the Surkaudi section. Here, it is tectonically rests over the slates of Sorek Formation. Tectonically, it rests over dolomites of Ripa Member in the Darsing- Lamachaur area. The thickness of the formation in the study area is >500m. in various level. The competent Dhading dolomite successions form the basis for the imbrications of the complex duplex structure. The age of this formation is considered to be of middle Proterozoic.

Upper Nawakot Group

The Upper Nawakot Group here is represented by the Benighat Slates.

Benighat Slates

The Benighat Slates are distributed around Bhakunde-Waling- Phaudi Khola, Dahathum-Bayarghari areas overlying the Dhading Dolomites (Fig.1). This formation is represented by thinly cleaved black slates. They contain thin stripes of black carbonaceous matter with continuous and parallel laminae. A carbonate band encountered at Karadi is correlable with Jhiku carbonate beds of Stocklin 1980 (Dhital et al 2002). They show small scale polyclinal folds. The Benighat Slates transitionally passes into overlying Sorek Formation. It is about 2500m thick around Bayarghari section. The age of the formation is considered to be of late Proterozoic.

Sirkot Group

The Sirkot Group and its rock units are introduced by Dhital et al. (2002). The rocks of the Sirkot Group can be traced in the central part of the study area. It is subdivided into the Sorek Formation and the Dhanpure Limestone. The group conformably overlies the Benighat Slates in the study area (Fig.1).

Sorek Formation with Ripa Member

This formation is distributed around the Devisthan, Triyasi, Chyangdi Khola, Gairithok, and Helu. The dark gray to greenish gray laminated Benighat Slates transitionally grades into interlaminated to thinly interbeds of red purple and green slates and fine grained greenish gray quartzite in Armadi Khola section. This Formation consists of an intercalation of gray green laminated slate and fine grained gray quartzite at the lower part. It is followed by an interbedding of purple, gray green slate and pale yellow, pink and gray quartzite. The stromatolitic dolomite of the Ripa Member is intercalated with slate and quartzite in the upper part. It is exposed around Dharampani and Helu areas. The Ripa Member dolomite is different from the Dhading Dolomite. The Dhading Dolomite has columnar stromatolites where as Ripa Member dolomite consists of small columnar stromatolites in the lower part and wide dome shaped stromatolites in the upper part. It is about 1700m. thick and transitionally passes into the overlying Dhanpure Limestone. The age of this formation is considered to be of late Proterozoic.

Dhanpure Limestone

The Dhanpure Limestone is the youngest formation in the study area and crops out in Devisthan, Dhanpure, Phaudi Khola and Chhanchhangdi areas (Fig.1). The Dhanpure Limestone is composed of gray to greenish gray parallel laminated limestone with slate partings and interbeds. Towards the upper part, few pale yellow to light gray quartzite beds are also intercalated in the Phaudi Khola section. The Dhanpure Limestone is about 100m thick. The age of the formation is considered to be of late Proterozoic.

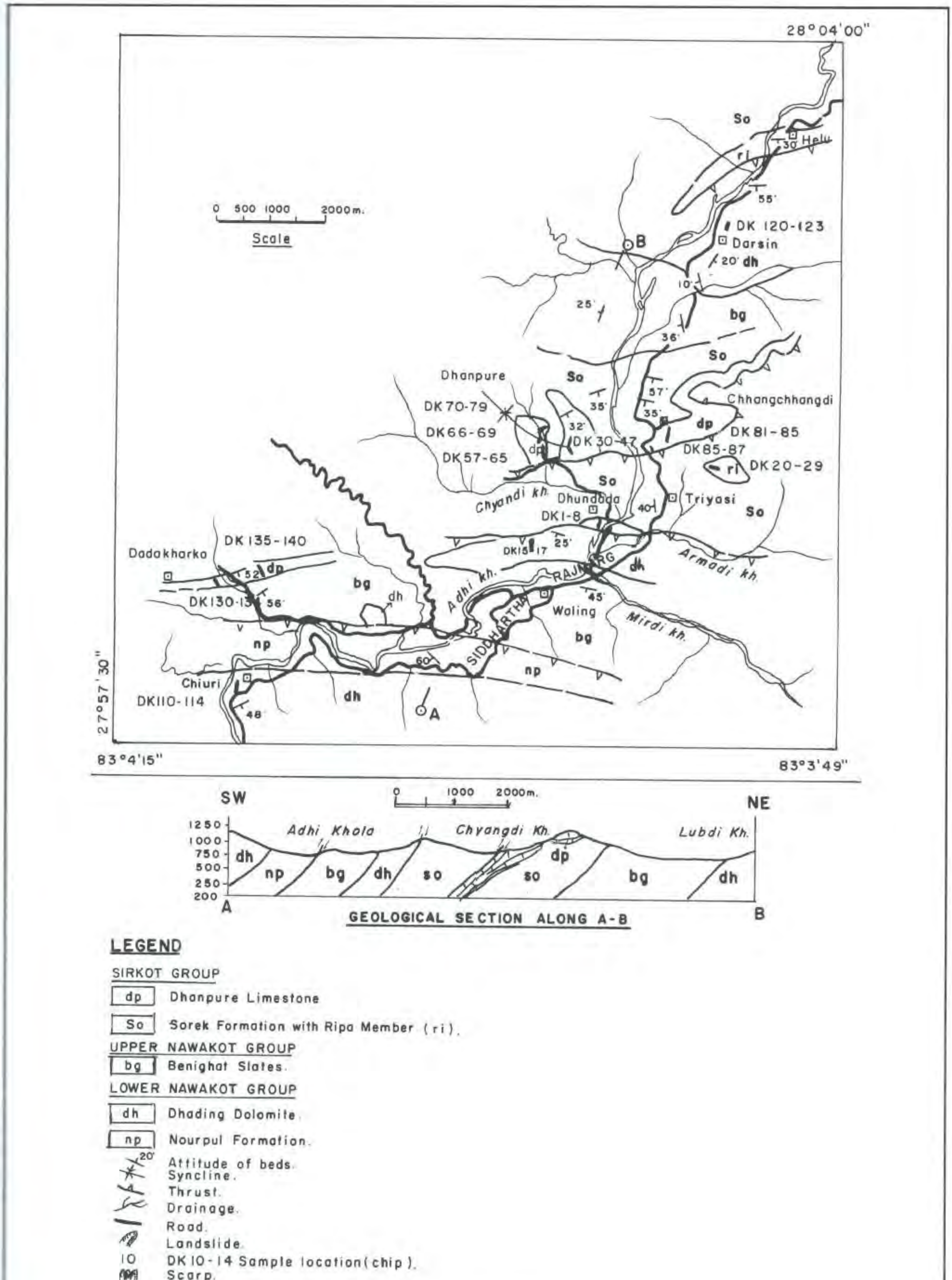

Fig. 1. Geological map of some parts of Syangja district with limestone and dolomite Chip Sample Location, Lesser Himalaya, Western Nepal.

GEOLOGICAL STRUCTURE

Geological structures like thrusts and folds are present in the study area. Bayatari Thrust passes through Phaudi Khola-Bayatari - Phulbari area with the footwall of Benighat Slates and the hanging wall of Nourpul Formation. It is the southernmost north vergent back thrust (Dhital et. al. 2002) in the study area (Fig.1). Armadi Khola Thrust passes through Armadi Khola-Devisthan-Surkaudi areas in which the Sorek Formation forms the footwall and hanging wall with the Dhading Dolomite. It is also the north vergent imbricate fault of a complex duplex system (Fig.1). Dauwa-Odare Thrust passes through Dauwa-Odare areas. The Sorek Formation and the Dhanpure Limestone are overridden by Sorek Formation itself and is a hinterland vergence backthrust (Fig.1). Helu Thrust passes through south of the Helu Bazaar and consists of Ripa Member dolomite at the footwall and the Dhading Dolomite at the hangingwall. A prominent syncline passes through Dhanpure-Dauwa areas. The axial plane orientation of the syncline is 172^0/31^0S.

LIMESTONE RESOURCES

The limestone resources belong to the Dhanpure Limestone of Sirkot Group in the present investigated area. The limestones found in five localities are–

(a) Dhundada – Devisthan Limestone
(b) Chhangchhangdi Limestone
(c) Phaudi Khola-Dadakharka Limestone
(d) Dhanpure Limestone (Right) and
(e) Dhanpure Limestone (Left)

Dhundada-Devisthan Limestone

The deposit is located at the Dhundada and Devisthan areas of Waling Municipality (Fig.1).The deposit area lies within the Dhanpure Limestone unit of Sirkot Group. It consists of gray, fine grained, medium to thick bedded parallel laminated limestone with slate partings. The lower part of the deposit consists of medium to thick bedded limestone where as middle part is represented by thick to massive bedded limestone sometimes with parallel calcite veins. Structurally, all beds are dipping towards south. The attitude of the beds is 210^0/ 43^0 S. The beds are extended almost towards E-W. The strike length of the deposit is about 0.5km around Dhundada with true thickness of almost about 30-50m. Only eight samples were collected from the interval of 5m. on the way to the Dhundada from Andhi Khola covering about a total thickness of the deposit. The sampling of the Devisthan area was abandoned due to very proximity of the road head about a distance of 50m. It is about 1 km west of Armadi Khola Bridge on Siddhartha Highway. Fair weather road connection and electricity facilities are there. Since the deposit is at the hillslope, high overburden of Sorek Formation prevails less significant mining condition. Houses and agricultural fields are nearby the deposit.

The chemical result shows the intercalation of cement grade, magnesiam limestone as well as dolomitic limestone in Dhundada domain (Table-1).

Chhangchhangdi Limestone

The deposit is located at the Chhangchhangdi, Dharapani and upper reaches of the Syampokhari (Fig.1).The lower part of this domain consists of gray to greenish gray limestone with <1mm to 1cm thick gray slate partings. A cave has been identified on the Siddhartha Highway road cut section near Chhangchhangdi and consists of parallel laminated limestone. It has chevron folds sometimes in the middle part in which prominent dark gray limestone bands are dominant. Thinly laminated limestone occurs in the upper part. Structurally, the deposit has attitude of 210^0/20^0S. The true thickness of the deposit ranges from 40-100m. The extension of the deposit is about 4km and has moderate to high overburden. It is about 0.5km. from the road head. Since the deposit is at the hilltop and slope, moderate to high overburden and anti-dip situation predicts less significant mining condition. There are no houses, agricultural fields, public places except Chhangchhandi temple within the deposit area but the area is covered with dense jungle. The chemical result shows the intercalation of Magnesian Limestone and low grade limestone (Table-2).

Phaudi Khola - Dadakharka Limestone

The deposit is located at the Phaudi Khola-Dadakharka areas (Fig.1). It consists of dark gray to light gray, thin to medium (5cm. to 50cm.) bedded limestone with dark gray, mm to cm scale calcareous slates. The sampled area lays both to the left and right banks of the Phaudi Khola. Structurally the deposit has attitude of 242^0/56^0S, 250^0/60^0 S. The true thickness of the deposit ranges from 30-60m. Some of the beds are cross laminated and some of them show ribs and furrows on the weathering surface. The extension of the deposit is about 3km. and has moderate overburden. It is about 2km. NW of Bayatari on the Siddhartha Highway. Village road runs at the base of the deposit. Since the deposit is at the hillslope, fairly low to high overburden indicates less significant deposit.

The chemical results show the less significant deposit in terms of sample grade and chemistry. The sample grade shows the intercalation of dolomitic limestone, magnesiam limestone and low grade limestone (Table-3).

Dhanpure Limestone (Right)

The deposit is located at the right side of Dhanpure and also some parts of Dauwa and Chhapani (Fig.1). It consists of parallel laminated limestone. Basal part consists of 1cm. to 10cm. thick light gray to greenish gray limestone and sometimes with calcite coatings. It grades up to the medium bedded limestone and people used to exploit construction material out of it. The weathered surface shows pit-holes and brown to maroon discoloration. The upper part consists of thin to wavy laminations. It has continuous alternating parallel laminae of slate and limestone. The true thickness of the deposit ranges from 50-100m. The extension of the deposit is about 500m.-1km. and has no overburden. It is about 2km. NE of Waling, Siddhartha Highway. Village road reaches at the base of the deposit and also available electricity is also available in the area.

The chemistry of the deposit gives rise to mixed result as shown in (Table-4). Lower and upper bands have cement grade limestone. Majority of them are of Magnesian grade limestone with dolomitic limestone intercalation. Chemical results show marginal possibilities of cement grade limestone. Higher the CaO content lesser the MgO content.

Dhanpure Limestone (Left)

The deposit is located at the Dhanpure and also some parts of Dhunure. Geologically it consists of parallel laminated limestone. Basal part consists of 1cm to 10cm. thick light gray to dark gray limestone and sometimes with mm scale cross cutting calcite veins. It grades up to the medium bedded limestone at the middle part of the deposit as in Dhanpure limestone (right). The weathered surface shows brown to maroon discoloration. The upper part consists of thin to wavy laminations. It has continuous alternating parallel laminae of slate and limestone. The true thickness of the deposit is about 100m (Fig.2). The extension of the deposit is about 600m. -1km. and has no overburden. It is about 2.5km NE of Waling, Siddhartha Highway. Village road passes at the base of the deposit and also has electricity nearby. Since the deposit is at the hilltop with no overburden and it can be concluded that mining condition is favorable. The minimum and maximum CaO content is 37.85% and 52.05% respectively. This deposit has cement grade limestone domination over low-grade and magnesiam limestone. The low-grade limestone has high alumina content. The lower part of the deposit has high alumina values probably resulting from the weathering effect. Similarly, the upper middle part of the deposit has higher Fe_2O_3 content. The MgO content is fairly good throughout the deposit section (Table-5).

Table-1: Chemical results of the chip samples of Dhundada-Devisthan Limestone

S.No.	Sample. No	LOI %	Insoluble %	R_2O_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Thickness (m)	Remarks
1	DK-1	40.77	3.96	1.70	0.20	1.50	49.62	2.99	5	CG
2	DK-2	41.10	2.68	1.60	0.15	1.45	51.70	2.25	5	CG
3	DK-3	39.40	6.54	2.13	0.31	1.82	47.19	3.99	5	ML
4	DK-4	41.62	5.34	1.53	0.21	1.32	49.27	2.00	5	CG
5	DK-5	38.59	9.06	2.15	0.40	1.75	43.03	7.23	5	DL
6	DK-6	39.49	6.76	1.78	0.13	1.65	49.62	1.50	5	CG
7	DK-7	38.95	9.95	2.25	0.45	2.10	44.42	4.24	5	ML
8	DK-7	40.09	7.52	2.67	0.68	2.00	39.56	9.73	5	DL

(Note: CG=Cement Grade Limestone, ML=Magnesian Limestone, DL=Dolomitic Limestone, LG=Low Grade Limestone)

Table-2: Chemical results of the chip samples of Chhangchhangdi Limestone

S.No.	Sample. No	LOI %	Insoluble %	R_2O_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Thickness (m)	Remarks
1	DK-81	34.16	17.89	2.74	0.69	2.04	40.78	4.97	5	ML
2	DK-82	36.25	13.91	1.84	0.61	1.22	43.06	2.81	4	LG
3	DK-83	35.32	13.21	2.21	0.63	1.59	42.70	5.37	5	ML
4	DK-84	36.03	15.01	2.38	0.89	1.48	41.82	4.47	4	ML
5	DK-85	35.71	15.05	2.70	1.11	1.59	41.13	3.98	5	ML
6	DK-86	33.40	18.11	2.31	0.99	1.32	41.47	2.73	5	LG
7	DK-87	36.81	13.16	1.92	0.78	1.14	41.47	5.96	5	ML

(Note: CG=Cement Grade Limestone, ML=Magnesian Limestone, DL=Dolomitic Limestone, LG=Low Grade Limestone)

DOLOMITE RESOURCES

In the investigated area, dolomite resources have been identified in 4 main domains: Surkaudi, Ripa Member, Darsing and Chiuri dolomite (Fig.1). The Surkaudi, Darsing and Chiuri domains fall under the Dhading Dolomite of Lower Nawakot Group and Ripa Member comes under the Sorek Formation of Sirkot Group of rocks.

Surkaudi Dolomite

The deposit is located at the upper reaches of the Surkaudigaon, Waling Municipality. It lies within the Dhading dolomite unit of Lower Nawakot Group. It consists of gray crystalline, fine to medium grained, thick to massive bedded dolomite. It shows splintery nature and intercalated with thin strips of black carbonaceous slates. The lower part of the deposit consists of medium

Table-3: Chemical results of the chip samples of Phaudikhola-Dadakharka Limestone

S.No.	Sample. No	LOI %	Insoluble %	R_2O_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Thickness (m)	Remarks
1	DK-130	37.08	12.89	1.79	0.69	1.10	41.01	7.18	3	DL
2	DK-131	38.0	7.87	1.2	0.33	0.87	48.37	3.15	5	ML
3	DK-132	32.86	23.82	2.17	0.80	1.37	32.60	6.68	4	DL
4	DK-133	36.85	13.21	1.68	0.53	1.14	42.06	4.66	5	ML
5	DK-134	31.72	27.26	2.75	0.95	1.80	29.09	8.44	6	DL
6	DK-135	35.71	15.48	2.00	0.71	1.29	43.11	3.15	4	ML
7	DK-136	35.88	15.60	1.46	0.33	1.14	44.51	1.39	5	LG
8	DK-137	36.16	13.66	2.28	0.75	1.52	43.81	2.65	5	LG
9	DK-138	35.78	15.16	2.17	0.63	1.55	43.46	2.90	3	LG
10	DK-139	34.54	19.07	2.20	0.69	1.51	40.31	3.15	5	ML
11	DK-140	34.37	17.66	3.67	0.74	2.94	40.31	3.40	5	ML
12	DK-141	35.20	15.62	3.00	0.39	2.61	43.11	2.39	4	LG
13	DK-142	38.38	13.20	1.08	1.07	0.01	41.36	5.80	5	ML
14	DK-143	37.26	13.16	1.08	1.00	0.07	39.26	6.80	4	DL
15	DK-144	38.02	11.36	0.80	0.72	0.08	41.36	6.55	5	DL

(Note: CG=Cement Grade Limestone, ML=Magnesian Limestone, DL=Dolomitic Limestone, LG=Low Grade Limestone)

Table-4: Chemical results of the chip samples of Dhanpure limestone (Right)

S.No.	Sample. No	LOI %	Insoluble %	R_2O_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Thickness (m)	Remarks
1	DK-30	37.91	10.92	2.80	0.29	2.51	45.79	2.24	4	CG
2	DK-31	35.83	15.05	3.31	0.60	2.71	38.88	5.22	4	ML
3	DK-32	35.78	15.67	2.81	0.60	2.21	45.10	1.24	3	CG
4	DK-33	37.43	13.38	2.64	0.58	2.06	39.74	6.58	5	DL
5	DK-34	35.65	15.80	2.91	0.66	2.25	38.53	5.59	5	ML
6	DK-35	36.41	15.22	3.03	0.64	2.39	39.22	6.34	5	DL
7	DK-36	37.53	12.51	2.08	0.80	1.28	46.31	2.24	4	CG
8	DK-37	38.81	10.88	2.16	0.35	1.81	41.64	4.60	5	ML
9	DK-38	37.07	13.54	2.08	0.39	1.69	42.16	5.84	5	ML
10	DK-39	36.00	14.20	2.59	0.54	2.05	40.09	5.96	5	ML
11	DK-40	37.43	10.19	2.07	0.54	1.53	45.57	3.40	4	ML
12	DK-41	36.62	12.22	2.60	0.72	1.89	43.11	3.40	5	ML
13	DK-42	36.10	12.09	6.03	0.56	5.46	42.76	2.90	3	LG
14	DK-43	37.14	12.35	1.83	0.49	1.33	43.99	3.28	5	ML
15	DK-44	37.03	10.98	1.62	0.41	1.22	45.21	2.90	5	CG
16	DK-45	35.61	13.79	1.80	0.45	1.35	44.16	2.14	5	CG
17	DK-46	35.16	16.71	2.37	0.64	1.73	40.66	4.16	5	ML
18	DK-47	34.60	17.84	4.72	0.89	3.84	37.85	4.16	5	ML

(Note: CG=Cement Grade Limestone, ML=Magnesian Limestone, DL=Dolomitic Limestone, LG=Low Grade Limestone)

Table-5: Chemical results of the chip samples of Dhanpure Limestone (Left)

S.No.	Sample. No	LOI %	Insoluble %	R_2O_3 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Thickness (m)	Remarks
1	DK-51	41.34	6.42	1.60	0.12	1.48	48.37	2.27	4	CG
2	DK-52	37.83	10.08	10.90	0.16	10.74	40.31	0.76	5	LG
3	DK-53	39.01	10.4	1.67	0.01	1.67	46.97	1.76	5	CG
4	DK-54	38.90	7.80	10.52	0.26	10.26	40.66	1.76	4	LG
5	DK-55	41.04	4.90	1.90	0.12	1.78	51.87	0.25	5	CG
6	DK56	42.18	6.06	1.78	0.11	1.66	42.06	7.81	4	DL
7	DK-57	43.00	6.26	2.10	0.13	1.97	46.27	2.02	5	CG
8	DK-58	36.96	11.40	11.47	0.12	11.35	37.85	2.02	5	LG
9	DK-59	42.72	4.64	1.92	0.10	1.82	44.86	4.28	5	ML
10	DK-60	39.42	5.46	10.32	0.13	10.2	43.46	1.26	5	LG
11	DK-61	41.11	5.67	0.44	0.15	0.28	49.42	1.51	5	CG
12	DK-62	40.26	8.33	0.52	0.23	0.30	46.62	3.53	5	ML
13	DK-63	39.78	9.05	0.38	0.16	0.21	48.72	1.26	5	CG
14	DK-64	41.18	5.06	0.50	0.27	0.23	52.05	0.63	5	CG
15	DK-65	37.93	7.16	2.30	2.80	2.20	48.72	2.52	5	CG
16	DK-66	39.16	4.02	2.05	3.60	1.79	49.42	2.20	5	CG
17	DK-67	39.00	9.72	1.82	2.90	1.82	46.97	2.52	5	CG
18	DK-68	36.93	8.38	1.45	5.40	1.45	44.16	5.04	4	ML
19	DK-69	36.61	10.92	1.48	4.00	1.48	45.57	4.54	4	ML
20	DK-70	38.54	7.58	2.42	4.10	2.42	48.02	2.77	5	CG
21	DK-71	37.09	9.02	1.68	3.70	1.68	46.62	5.29	5	ML
22	DK-72	38.90	4.90	1.95	2.50	1.95	49.42	1.10	5	CG
23	DK-73	37.38	8.82	1.70	3.60	1.70	45.57	4.54	4	ML
24	DK-74	37.23	7.90	1.92	2.50	1.92	47.32	3.78	5	ML
25	DK-75	40.53	5.28	2.60	0.15	2.45	49.77	2.77	5	CG
26	DK-76	40.96	5.84	0.62	0.21	0.41	47.32	4.79	5	ML
27	DK-77	38.66	7.55	0.90	0.01	0.89	49.42	2.02	5	CG
28	DK-78	40.27	6.74	0.47	0.21	0.26	50.12	2.52	5	CG
29	DK-79	40.13	6.30	0.50	0.16	0.34	50.12	2.02	5	CG

(Note: CG=Cement Grade Limestone, ML=Magnesian Limestone, DL=Dolomitic Limestone, LG=Low Grade Limestone)

to thick bedded dolomite where as middle part is represented by columnar to domal stromatolites and is thick to massive bedded (Fig.1).

The chemical results (Table-6) show that the lower dolomite band has MgO 18.14%. Middle band is dolomitic limestone and the upper band is dolomite with low MgO content.

Ripa Member Dolomite

The deposit is located at the upper reaches of the Dharapanigaon (Fig.1). It is about 2km. NE of Triyasi on the Siddhartha Highway. It is medium to thick bedded, short columnar and dome shaped stromatolite with red purple slate intercalation and also interbeds of light gray to pink quartzite. The dolomite sometimes contains

Fig.2. Dhanpure Limestone (Left), lower part

intraclasts of dolomite as well as quartzite. Some of the bands have cross laminations and also have chert nodules. Structurally the deposit has attitude of 160^0/23^{0}N. The true thickness of the deposit ranges from 200-500m. The extension of the deposit is about 1km. and has no overburden. The chemical results show that the whole band is of fairly low MgO % rather a sample in the upper part of the deposit (DK-28) which is of industrial grade. But the deposit as a whole has no significant deposits of industrial quality dolomite. The lower band has higher insoluble, could be due to presence of cherty nodules at the surface of the beds. Higher the insoluble lesser the CaO content could represent the possibility of silicification due to chert (Table-7).

Darsing Dolomite

The deposit is located at the Darsing and Hegdada (Fig.1). It has gray crystalline dolomite with slate partings. Its physical appearance is more shattered with irregular joints over the surface. The attitude of the bed is 200^0/26^{0}S. The strike length is about 3km. long and thickness is about 400m. and has no overburden. It lies about 500m. SE from the Siddhartha highway at Darsing. The deposit is at the hilltop.

The chemical result shows that the deposit is less significant in terms of MgO % content and only the uppermost band has marginal grade (Table-8).

Chiuri Dolomite

It is located near Chiuri village, on the left side of the Sidhartha Highway from Waling (Fig.1). It lies within the Dhading dolomite. It is dark gray to blue crystalline dolomite with black slate partings. Structurally, the attitude of the beds is 151^0/41^{0}N.The thickness of the outcrop is about 400m. and the extension is about 2.5km. It is about 500m. away from the Sidhartha Highway near Chiuri.

The chemical result shows that the upper band is significant in terms of MgO % content with industrial grade (Table-9).

DISCUSSION

Based on the grading scheme for cement grade limestone: CaO% >44, and MgO%~3, Low grade limestone: CaO% <44, MgO% <2.5, Magnesian limestone: MgO% 3-6, Dolomitic limestone: MgO% 6-10, Dolomite: MgO% 10-20, the chemistry of the domains show that

- Dhundada Devisthan domain has fairy high cement grade limestone.
- Chhangchhangdi domain has dominant magnesiam limestone.

Table-6: The chemical result of the chip samples, Surkaudi Dolomite

S.No.	Sample. No	LOI %	Insoluble %	R_2O_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Thickness (m)	Remarks
1	DK-15	32.19	27.56	4.50	2.28	2.22	15.07	18.14	5	
2	DK-16	33.91	25.96	3.50	1.49	2.01	28.04	8.32	5	
3	DK-17	37.23	17.08	2.25	0.23	2.02	25.24	15.62	5	

Table-7: Chemical results of Ripa Member Dolomite

S.No.	Sample. No	LOI %	Insoluble %	R_2O_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Thickness (m)	Remarks
1	DK-20	28.57	35.68	2.35	0.69	1.66	21.73	10.33	4	
2	DK-22	25.09	44.20	2.08	0.59	1.48	15.77	11.34	5	
3	DK-23	34.46	23.02	2.98	0.54	2.43	27.34	11.59	5	
4	DK-24	39.62	10.78	2.67	0.65	2.02	25.59	17.64	6	
5	DK-25	39.52	8.22	2.50	0.59	1.91	28.04	15.88	4	
6	DK-26	34.88	25.08	2.37	0.64	1.74	24.18	12.85	5	
7	DK-27	34.67	24.00	2.08	0.74	1.33	20.68	15.88	5	
8	DK-28	39.18	12.26	2.17	0.35	1.82	26.01	19.21	5	
9	DK-29	34.76	23.74	2.05	0.51	1.54	22.90	16.47	5	

Table-8: Chemical results of Darsing Dolomite

S.No.	Sample. No	LOI %	Insoluble %	R_2O_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Thickness (m)	Remarks
1	DK-120	38.44	17.30	1.00	0.26	0.74	24.07	18.39	4	
2	DK-121	27.30	38.94	0.39	0.23	0.16	17.69	13.73	5	
3	DK-122	29.22	35.72	0.80	0.27	0.53	19.09	13.86	5	
4	DK-123	29.08	36.14	0.41	0.25	0.16	19.44	13.98	5	

Table-9: Chemical results of the Chiuri Dolomite

S.No.	Sample. No	LOI %	Insoluble %	R_2O_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Thickness (m)	Remarks
1	DK-110	34.49	20.16	1.45	0.28	1.17	23.50	18.14	5	
2	DK-111	38.77	15.16	1.37	0.27	1.10	24.88	19.88	5	
3	DK-112	28.55	36.62	2.06	0.32	1.74	20.74	12.67	4	
4	DK-113	19.63	55.58	0.58	0.44	0.14	12.79	10.46	6	
5	DK-114	22.92	48.92	1.35	0.36	0.99	14.89	10.58	5	

- Phaudi Khola Dadakharka domain has low grade limestone and magnesiam limestone
- Dhanpure (Right) domain has cement grade, magnesiam, and dolomitic limestone.
- Dhanpure (Left) domain has good potential of cement grade limestone.

The industrial grade dolomite has >18-20 MgO% indicates that Chiuri domain of Dhading Dolomite could have potential deposit of this grade.

CONCLUSION AND RECOMMENDATION

Out of 5 limestone domains, the chemical grading of the Dhanpure Limestone (Left) shows encouraging results with mean 46.83 and standard deviation 3.439 CaO%; and mean 2.743 and standard deviation 1.699 MgO% confirming dominant cement grade limestone. Dhanpure Limestone (Right) and Dhundada-Devisthan limestone have also cement grade limestone potential.

The chemical grading of samples of Chiuri Dolomite show industrial quality.

As the Dhanpure Limestone is located centrally from the marketing point of view as well as infrastructure, mineability, and nature of the outcrop supporting the deposit, Dhanpure Limestone (Left) should be carried out detailed follow-up exploration in order to establish an iso-grade map with the help of topo-geological survey along with systematic channel sampling. Continuous chip samples are warranted from the remaining areas. Similarly, Chiuri Dolomite could be the potential domain for further follow up studies in order to establish an industrial quality dolomite.

ACKNOWLEDGEMENT

I am very much indebted to the former Director General Mr. N.R. Sthapit for the encouragement and facilities provided during the field work and various phases of the assessment of this report. I would also like to extend my gratitude to Mr. P.L. Shrestha (Director General), Mr. B. R. Aryal (Deputy Director General) and Mr. K. P. Kaphle (Superintendent Geologist) for valuable suggestions during the various phases of the project and valuable comments. My thanks are due to Mr. K.D. Jha (Planning Chief) for the support. I would like to acknowledge Mrs. Rita Shrestha (Senior Divisional Chemist), Mr. H. Rahaman and Mr. T.R. Pant (Senior Divisional Geologists) for fruitful discussions and suggestions.

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Preliminary Exploration of Limestone and Dolomite Around Kerabari and Sisne Khola Area, Palpa District, Western Nepal

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INTRODUCTION

The exploration for the cement grade limestone and dolomite for industrial use was carried out in Kerabari area of Palpa district in the FY 2062/063 B.S. The area of investigation lies in Government of Nepal, Survey Department's toposheet nos. 099 – 05, 098 – 8, 099 – 9 and 098 – 12 and include southern parts of Palpa district. The area of investigation lies between 83^0 24'00" - 83^0 40'00" E longitude and 27^0 44'00" - 27^0 48'00" N latitude.

The area is accessible by Sunauli – Pokhara Highway (Siddhartha Rajmarg). During the exploration work geological mapping of limestone and dolomite occurrences and systematic chip sampling and grab sampling has been done. A geological map of 160 sq.km. area in 1:25,000 scales has been prepared. 56 continuous chip samples from different limestone and dolomite horizons have been collected and analyzed in the Department of Mines and Geology (DMG).

OBJECTIVE

The main objective of the exploration work was to identify and explore the cement grade limestone and industrial dolomite deposit around Kerabari area of Palpa district.

METHODOLOGY

- The preliminary exploration work consists of geological mapping of the area, chip sampling and grab sampling of the limestone and dolomite encountered in this region.
- The investigation work was carried out with the help of brunton compass, geological hammer, measuring tape, 1:25000 scale topo base map and 10 % dilute Hydrochloric acid. Extensive geological traverses along foot tacks, road sides, streams and ridges have been carried out.
- All the chip samples of limestone and dolomite were analyzed for the identification of the grade.
- Different works completed are:

  a. Geological mapping of 160 sq. km. in 1:25000 scale
  b. Continuous chip sampling of 500 meters limestone and 50 meters dolomite, in 5 - 10 meter spacing or interval.
  c. Grab sampling as required.
  d. An updated geological map of the area has been prepared with further subdivisions of Kerabari Carbonate Formation.

REGIONAL GEOLOGY

The area of investigation is a part of the Lesser Himalayan Region. This region comprises of Paleozoic, Mesozoic and Cenozoic formations in the southern part of the Lesser Himalayas. The rocks are divided into three major divisions: The Kaligandaki Group, the Tansen Group and the Siwalik Group. The Kaligandaki Group and the overlying Tansen Group is separated by disconformity. The rests of Siwalik Group are separated with the Tansen Group by the Main Boundary Thrusts (MBT). The Kaligandaki Group comprised of thick carbonate sequence, quartzite and argillaceous rocks underlying the Tansen Group of rocks.

GEOLOGY OF KERABARI LIMESTONE DEPOSIT

A thick sequence (about 2 km.) of dolomite terrain is exposed along Tinau River, Sisne Khola, Kurman Khola, to the north side of MBT. The dolomite form steep cliffs. Kerabari Limestone is composed of mainly light gray to dark gray, thin to thick bedded dolomite with limestone at basal part and thin interbeds of chert in the middle and upper parts. Stromatolites are common. This formation is divided into following members:

a. Basal limestone

Thickness of the basal limestone varies from 20 to 100 meter. Maximum thickness is measured near Khursandi village. The basal limestone is exposed all along the basal part of the Kerabari Formation. The limestone is gray to dark gray and black colored, fine grained platy bedded argillaceous limestone which is highly fractured and crushed. Several slides are confined to this limestone exposed area.

b. The lower platy dolomite

The dolomite is gray to dark gray colored, fine grained, having dark gray and lighter gray interlayers. The dolomite is massive on the top.

c. Laminated stromatolitic dolomite

This dolomite is gray colored, fine grained, and laminated with intercalation of cherty bands. Some bands are silicious in nature.

d. Dolomite interbedded with shale

Thick dolomite is interbedded with purple shale. The dolomite is gray colored, fine grained and medium bedded. Thin bands of chert and quartzite are also intercalated.

FINDINGS

Limestone occurrences

All together five limestone occurrences have been identified in the present investigated area within Kerabari Carbonate Formation. They areas follows:

a. Kerabari Limestone
b. Hiunde Khola Limestone
c. Khursandi Limestone
d. Sisne Khola Limestone
e. Madhuban Limestone

a. Kerabari Limestone

The basal part of the Kerabari Limestone consists of monotonous sequence of gray to dark gray and black coloured, thin platy bedded limestone. The limestone is fractured and crushed. Thickness of the limestone band ranges from few meters to 100 meters. The limestone is laminated and argillaceous. The limestone can be traced all along the basal part of the Kerabari Limestone Formation. The maximum exposed thickness of the Kerabari Limestone is at Khursandi village, 3km south of the Kerabari. Many landslides are confined to this limestone band. The limestone overlies the black carbonaceous and purple shale and underlain by the Kerabari Limestone Formation.

Continuous chip sampling of this limestone band has been done in five sections (Fig.1). The Chemical analysis result of the chip samples is given in the table below.

This limestone band occurs at the basal part of the Kerabari Carbonate Formation. On the basis of the chemical analysis result of the continuous chip samples, this limestone band is not of cement grade throughout except at the right bank of the Tinau Khola. The composition of the limestone band of the right bank of the Tinau Khola is of cement grade but the thickness and strike length of the limestone band is less and overburden is very high. At road section, thin bands of limestone appear to be of cement grade but the thickness of the limestone band ranges from 5 to 10 meters only (Table-1).

b. Hiunde Khola Limestone

This limestone band is exposed along the Hiunde Khola section. It is the further extension of the basal part of the Kerabari Carbonate Formation. It consists of monotonous sequence of gray to dark gray coloured, thin bedded limestone. Thickness of the limestone band ranges from 40 to 60 meters. The limestone overlies the black carbonaceous and purple shale and is underlying the Kerabari Dolomite. Continuous chip sampling of this band has been done along Hiunde Khola section only (Table-2).

c. Khursandi Limestone

The Khursandi Limestone is present within the Kerabari Carbonate Formation. It is well exposed near the Khursandi village which is 3km. south of the Kerabari village. The thickness of this limestone band is 80 – 100 meters and strike length is about 600 meters. This limestone is different from the Kerabari Limestone. It is medium bedded, fine grained and gray to dark gray coloured. This limestone is less fractured and crushed as compared to Kerabari Limestone. Continuous chip sampling of this limestone band from one horizon has been done. Results of the chemical analysis of the chip samples show that the limestone is a dolomitic limestone (Table 3). The limestone band is present right on the top of the hill. So, there is no overburden.

d. Sisne Khola Limestone

The Sisne Khola limestone is present within the Kerabari Carbonate Formation and well exposed along the Sisne Khola section, 4 - 5 Km. north of the Jhumsa Bridge. Thickness of this limestone band varies from 50 to 60 meters and strike length is about 200 - 300 meters. This limestone is different from the Kerabari limestone. It is medium bedded, fine grained and gray to dark gray coloured. Continuous chip sampling of this limestone band from one horizon has been done. Few bands of this limestone are cement grade but tonnage is low and overburden is high (Table 4). The limestone band exposed at the Sisne Khola section has high dip of 70^{0} - 75^{0}.

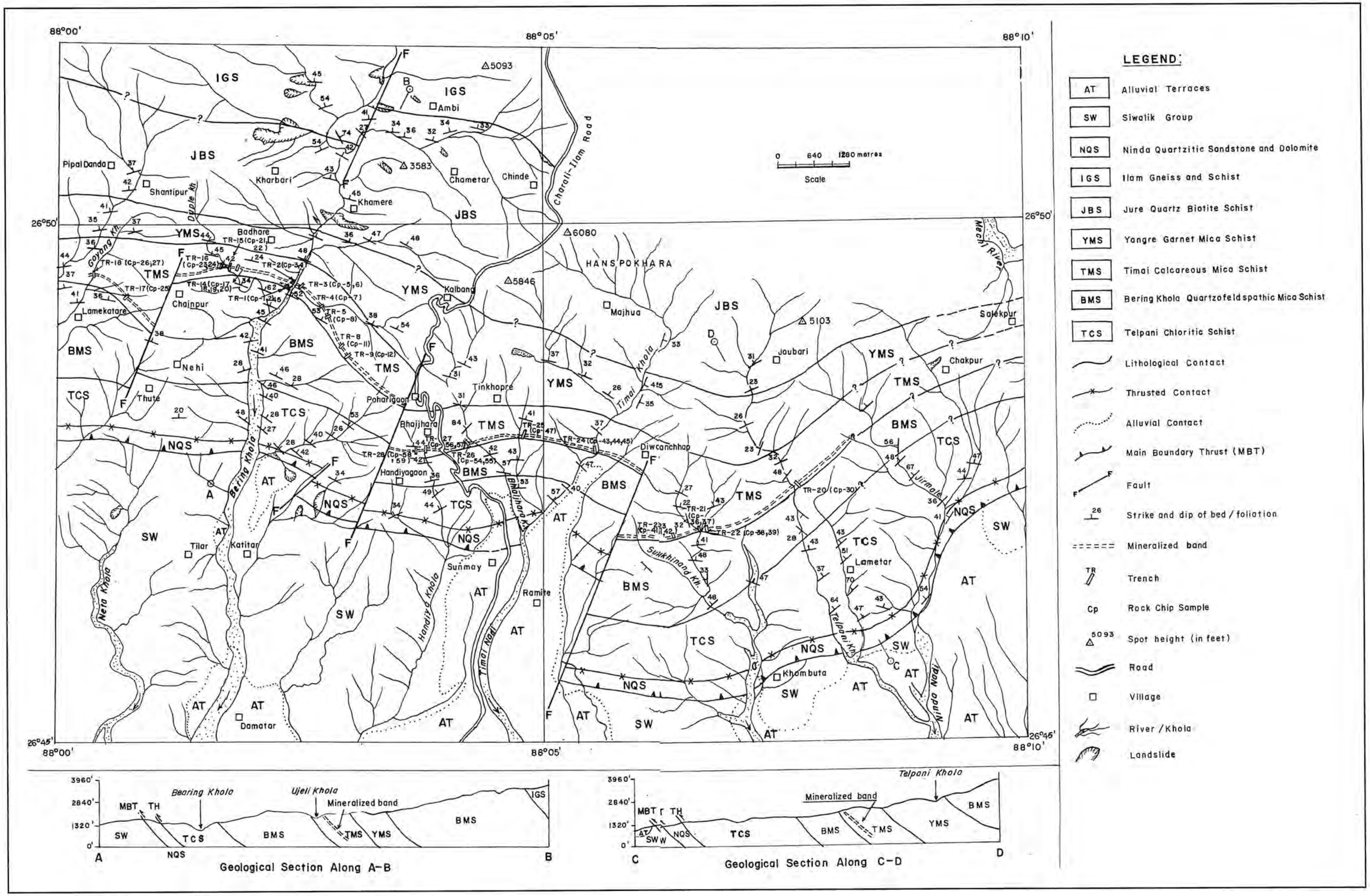

Fig.1. Geological Map of Bering Khola and Timai (Sunmai) Khola Area, Ilam District, Eastern Nepal.

Table -1: Chemical Analysis of Chip samples from nearby road section, Kerabari Limestone

Chip Samples Near Road Section, Quarry Area								
Sample. No	**LOI %**	**Insoluble %**	**R_2O_2 %**	**Fe_2O_3 %**	**Al_2O_3 %**	**CaO %**	**MgO %**	**Remarks**
TR-PK/CP -508	31.66	27.18	2.20	0.99	1.21	30.49	6.80	Quarry area
TR-PK/CP -509	37.82	14.84	1.90	0.49	1.41	38.91	6.43	Quarry area
TR-PK/CP -510	38.67	14.24	1.37	0.48	0.90	37.85	7.43	Quarry area
TR-PK/CP -511	38.08	12.44	1.08	0.29	0.79	40.83	6.55	Quarry area
TR-PK/CP -512	37.18	14.02	0.70	0.24	0.46	40.83	7.06	Quarry area
TR-PK/CP -513	35.74	17.48	1.32	0.33	1.00	40.13	5.42	Quarry area
Chip Samples, left bank of the Tinau Khola								
TR-PK/CP -524	39.57	8.12	1.40.	0.26.	.1.14	49.77	1.01	Left bank
TR-PK/CP -525	39.86	7.78	1.40.	0.19	1.21	49.07	1.76	Left bank
TR-PK/CP -526	39.92	6.24	0.90	0.19	0.71	49.77	1.51	Left bank
TR-PK/CP -520	34.59	20.86	2.02	0.46	1.56	32.42	9.58	Road section
TR-PK/CP -521	39.00	11.16	1.30	0.29	1.01	45.92	3.28	Road section
TR-PK/CP -522	38.67	12.84	1.15	0.26	0.89	43.46	4.54	Road section
TR-PK/CP -523	40.04	7.82	1.80	0.22	1.58	46.62	3.28	Road section

Table-2: Chemical Analysis of Hiunde Khola limestone

Chip Samples, Hiunde Khola Section							
Sample No.	LOI %	Insoluble %	R_2O_3 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %
TR-PK/CP -544	41.07	6.94	7.62	0.24	7.38	45.57	4.79
TR-PK/CP -545	36.81	15.76	5.20	0.41	4.79	42.06	6.30
TR-PK/CP -546	37.51	15.90	5.72	0.1	5.72	42.41	3.28
TR-PK/CP -547	40.05	11.36	2.63	0.39	2.23	43.11	4.79
TR-PK/CP -548	35.94	19.78	4.02	0.54	3.49	42.76	1.51
TR-PK/CP -549	38.36	16.88	3.15	0.43	2.72	41.36	3.02

Table-3: Chemical Analysis of Khursandi Limestone

Chip Samples, Khursandi Section								
Sample No.	LOI % %	Insoluble %	R_2O_3 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Remarks
TR-PK/CP -514	39.50	9.56	0.95	0.29	0.66	44.34	5.80	
TR-PK/CP -515	39.57	9.14	1.43	0.33	1.10	41.36	8.19	
TR-PK/CP -516	39.86	9.12	1.32	0.31	1.02	41.88	7.56	
TR-PK/CP -517	39.18	10.02	1.25	0.28	0.97	40.83	8.57	
TR-PK/CP -518	39.70	9.66	1.05	0.21	0.84	40.48	9.07	

e. Madhuban Limestone

The Madhuban Limestone is well exposed at about 500 meters south of the Madhuban village which is 5 -6km north west of Jhumsa and Dobhan village (Siddhartha Rajmarg). The Madhuban Limestone is present right on the top of the hill. So the limestone has no overburden. Continuous chip sampling from one horizon has been done. Thickness of this limestone band is about 175 meters and strike length is about 800 meters. The strike of the limestone band is 180° and dip is 45°– 50° towards north (Table 5).

This limestone is light gray to dark gray coloured. It is thin to medium bedded and fine grained. Occasional dolomitic bands are also present. This limestone band is also present within the Kerabari Carbonate Formation. The top and basal part of the limestone is dolomite. The

Table-4: Chemical Analysis of Sisne Khola Limestone

Chip Samples, Sisne Khola Section								
Sample No.	LOI % %	Insoluble %	R_2O_3 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Remarks
TR-PK/CP-501	39.97	11.12	0.83	0.27	0.55	42.06	5.67	
TR-PK/CP-502	42.33	3.00	0.45	0.11	0.34	51.52	1.89	
TR-PK/CP-503	42.47	5.82	0.68	0.21	0.47	45.39	4.54	
TR-PK/CP-504	40.82	6.54	0.70	0.20	0.50	46.97	3.28	
TR-PK/CP-505	40.43	7.52	0.68	0,19	0.49	45.92	4.16	
TR-PK/CP-506	39.37	10.50	0.88	0.34	0.54	43.11	4.91	

Table-5: Chemical Analysis of Madhuban Limestone

Chip Samples, Hill Top near Madhuban Village								
Sample No.	LOI % %	Insoluble %	R_2O_3 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Remarks
TR-PK/CP -528	40.21	8.16	1.13	0.23	0.90	45.57	4.28	
TR-PK/CP -529	39.24	8.08	1.00	0.19	0.81	47.67	2.27	
TR-PK/CP -530	38.94	9.14	1.50	0.29	1.21	46.97	2.52	
TR-PK/CP -531	38.80	8.16	0.43	0.14	0.29	46.94	3.02	
TR-PK/CP -532	40.03	5.42	1.26	0.15	1.11	48.34	3.52	
TR-PK/CP -533	39.69	5.80	0.50	0.18	0.32	47.64	4.03	
TR-PK/CP -534	39.36	8.57	2.36	0.21	2.15	43.16	6.04	
TR-PK/CP -535	39.55	7.08	0.54	0.21	0.33	45.19	5.04	
TR-PK/CP -536	39.06	5.54	4.42	0.13	4.29	47.99	2.02	
TR-PK/CP -537	38.44	10.63	0.54	0.20	0.34	40.63	6.80	
TR-PK/CP -538	40.28	5.95	1.23	0.17	1.06	44.83	5.29	
TR-PK/CP -539	39.24	6.00	0.71	0.14	0.57	46.59	5.04	
TR-PK/CP -540	37.92	9.26	0.81	0.18	0.63	43.29	5.94	
TR-PK/CP -541	42.32	4.90	1.92	0.16	1.76	44.16	6.55	
TR-PK/CP -542	41.43	7.60	1.97	0.19	1.78	45.92	4.79	

landscape of the limestone exposed area is different from the dolomite area. It appears as a cement grade limestone with occasional thin dolomitic bands/layers.

DOLOMITE OCCURRENCES

The objective of the field work was to identify and explore the cement grade limestone and dolomite deposit around Kerabari area of the Palpa district. During the field work dolomite samples from four localities were collected. Dolomite from the Madhuban village and Jantelung are of industrial grade (Table 6).

Dolomite near the Madhuban village is greyish white colored, fine grained and medium bedded. Thickness of this dolomite band is 35 - 40 meters. The dolomite band is monotonous across the whole thickness.

Dolomite of the Jantelung village is light grey to grayish white, fine grained, medium bedded and fractured. Thickness of the dolomite band varies from 50 to 60

Table-6 Chemical Analysis of Chip samples of Kerabari Dolomite

Sample No.	Location	LOI %	Insoluble %	R_2O_3 %	Fe_2O_3 %	[illegible]	[illegible]	[illegible]	Remark
TR-PK/CP-507	Madhuban	43.19	8.20	0.63	[illegible]	[illegible]	[illegible]	[illegible]	
TR-PK/CP-519	Jantelung	42.70	6.54	1.15	[illegible]	[illegible]	[illegible]	[illegible]	
TR-PK/CP-527	Koldanda	37.82	17.97	1.13	[illegible]	[illegible]	[illegible]	[illegible]	

meters. The dolomite band is monotonous across the whole thickness.

CONCLUSION AND RECOMMENDATIONS

- Out of the identified limestone occurrences, the limestone of the road section and limestone of the left bank of the Tinau Khola, Sisne Khola and Madhuban limestone appears to be of cement grade.
- The limestone of the road section, left bank of the Tinau Khola and Sisne Khola has very low tonnage and high overburden. As a result, mining is not economic.
- Limestone from other localities has low CaO and high MgO content.
- Madhuban Limestone occurrence has considerable tonnage, no overburden and warrants a follow up exploration to determine the grade, tonnage and mineability. On the basis of field observation and Chemical analysis the result seems encouraging. The Kerabari Limestone and Hiunde Khola Limestone also appears to be of cement grade with a bit higher in MgO content. But the draw back is huge overburden of dolomite sequence. The Khursandi Limestone has less overburden but low CaO and high MgO content as well as small reserve. The Kerabari Limestone can be used for cement production by developing small scale quarries at different horizons. Two quarries are already in operation. These quarries are supplying limestone to the cement industries and for aggregate.
- Dolomite from the Madhuban village and Jantelung appear to be of industrial grade.
- Follow-up work to test the grade, tonnage, and mineability of the Madhuban limestone occurrences is recommended.
- Follow up exploration work for dolomite at Madhuban and Jantelung is also recommended.

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Exploration of Polished and Dimension Stone in some Parts of Makawanpur and Lalitpur Districts, Central Nepal

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INTRODUCTION

The demand of polished and dimension stone is increasing day by day due to rapid urbanization. Marble, Granite, Quartzite slabs etc. are available in the market to fulfill the demands. Considering the growing demand for polished and dimension stones, Department of Mines and Geology (DMG) carried out the exploration of polished and dimension stone in the annual program of the F.Y. 2062/63 of the 10th five year plan. The exploration target covers an area of 100 sq. km. including preliminary and follow up investigation of the potential areas in some parts of Makwanpur and Lalitpur districts as recommended by previous studies (Joshi, 1973 and 74; UNDP, 1981; Ghimire and Napit, 2003, Ghimire and Dhakal, 2004). These previous studies provided geological information of the areas in the regional scale showing the existence of marble, quartzite and intrusive granite.

The study areas lie in the northern parts of Makwanpur district and the western parts of Lalitpur district. The preliminary investigation areas lie in the part of Government of Nepal, Survey Department's Topo-sheet Nos. 2785 05 D, 2785 06 C and 2785 10 A (scale 1: 25,000) of Makwanpur and Lalitpur districts as bounded within Latitudes 27° 28' 19" - 27° 32' 30" N and Longitudes 85° 12'30" – 85° 18' 56" E. It covers 70 sq. km. area that lies in Ghusel, Malta, Bhattedada, Ipa Pancha-kanya VDC on east and west side of Bagmati River. In addition, the followed up study area lies in Government of Nepal, Survey Department's Toposheet No. 2785 05 'D' of Makwanpur district. It covers 33 sq. km. area in Sisneri, Kogate and Kulekhani VDC and the area under Kulekhani watershed namely Debaltar, Sanotar, Sisneri, Thulotar, Todke-bhanjyang, Lamabagar and Takersisneri in the northern part of Makwanpur district. The area is bounded by Latitude 27° 32' 30" - 27° 35' 00" N and Longitude 85° 10' 27" – 85° 15' 00" E.

Kulekhani and Sisneri areas are accessible through the proposed Birendra Rajmarg that passes along Pharphing – Phakhel - Kulekhani. It is about 28 km. long gravelled and seasonal road. Alternate road from Daxinkali, Kathmandu to Kulekhani via Sisneri is about 36 km. It is also a gravelled and seasonal road. Kulekhani area is also accessible through Chitlang - Markhu road and Bhainse – Bhimphedi – Kulekhani road (34 km.). Some parts of the northern and the eastern part of the preliminary study area are accessible from Kanti Rajpath and local road through Tikabhairab to Ghusel. The southern parts of the preliminary study area are difficult to access. (Fig.1)

OBJECTIVE

The objectives of the present study are:

- to find out the potential prospect areas suitable for polished and dimension stones.
- to delineate the deposit by examining its durability and suitability to assess the quality.

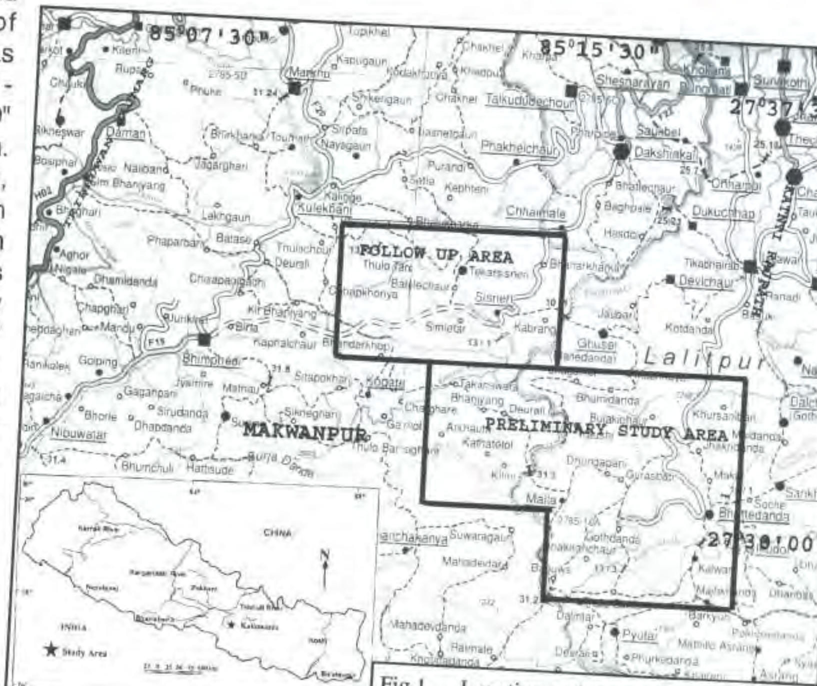

Fig.1. Location and Accessibility Map

- to recommend for the next phase of exploration.

METHODOLOGY

The field investigation included geological traverses along the roads, foot tracks, rivers and ridges. During field investigation, topography of the area from the mining point of view, physical properties of rocks e.g. appearance, color, texture, luster etc. were studied. Different rock units as well as rock types were identified. The attitudes of beddings, joints, weathering nature, rock strength, roughness, blocks size etc were measured. Some trenching pitting (120 m^3) to expose the fresh rock and collect the samples were carried out. Geological map of preliminary investigated area was prepared in the scale of 1:25,000 (Fig.2) whereas the follow-up areas were prepared in the scale of 1:10,000 (Fig.3).

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

GEOLOGY

The study area lies in the Lesser Himalayan zone in Central Nepal. Mineral exploration map of Central Nepal (UNDP, 1981) has been used as base map of the study area. Rock types encountered in the study area belong to the Phulchoki Group and Bhimphedi Group of Kathmandu Complex along with Ipa Granite as intrusion.

Geologically the study area as shown in Figure 2 lies north to the Main Boundary Thrust (MBT). In this area, MBT runs east-west and passes through Baguwa village at the confluence of Khani Khola and Bagmati River. The area is characterized by different metamorphic rocks and granites bodies. The metamorphic assemblage is represented by marbles, calc-schists, phyllites, quartzites and siliceous limestones. Granite covers almost half of the study area in central part namely Chhapeli, Dadagaon, Ikudol, Dobhan, Ipa. The southern part of it is composed of schists, quartzites, schist-quartzite intercalation, marble and limestone. The marble prospect at Salledanda and Trikhandi on the east and west of Khani Khola shows grey to white colored thin bands. It has an eastern extension for more than 3 km. but the thickness of the band and the schist intercalation is more frequent as moved towards east. In the northern part, main types of rocks are schist, limestone, schist-marble intercalation and metasandstone. Most of the rock exposures in this region are characterized by high degree of weathering, irregularly disturbed, highly fractured and jointed. Rocks of Kulekhani Formation and Tistung Formation as observed in the study area are highly fractured and jointed and broken and can be used as stone aggregate.

Major rock types that occur in the study area are granite, marble, schists and siliceous limestone (Fig.3). More than 50% of the area mainly in central to the northern part comprises essentially of slates, phyllites and metasandstone. In the central part marble beds extend from east to west along the Kulekhani Khola. Marble lies in the northern slope of the ridge and granite are exposed on the ridge top. Markhu Marble bulges out to significant thickness in the middle of the extension at Simletar area and gets thinning out before reaching Kulekhani Khola. Further the calc schist unit extends up to Bagmati River in the east. Two small faults are observed around the Simletar area with relatively low displacement. These faults have very insignificant role in defining the quality of the marble. Granites are also observed in the southeast part near Simletar, Kuntar and Dobhan area on the right bank of Bagmati River. The central part of the ridge in between the Bagmati and Kulekhani Khola requires promising topography for mining. Rocks of Kulekhani Formation, Tistung Formation and Sopyang Formation are highly fractured and jointed and they can be used as stone aggregate.

FIELD INVESTIGATION

In the investigated area, granite and marble are the main resources for polished and dimension stones belonging to Ipa Granite and Markhu Formation respectively. Their features are briefly described below:

Granite

Ipa Granite is intruded into Kulekhani Quartzite and Markhu Marble. It runs from Khanate Khola in the west to Todkebhanjyang - Kulekhani Khola-Bagmati River (Dobhan) - Dhungapani dada - Chhapeli to Thosne Khola in the east. The granite body is lenticular in shape with approximately 6 km X 12 km in dimension. The granite has smooth and slightly irregular and sharp contact with the country rock. Chief mineral constituents in the granite are quartz, plagioclase, orthoclase, biotite, muscovite and tourmaline. Quartz is medium to coarse grained. Plagioclase and orthoclase are equally present. Both biotite and muscovite are present in these granites.

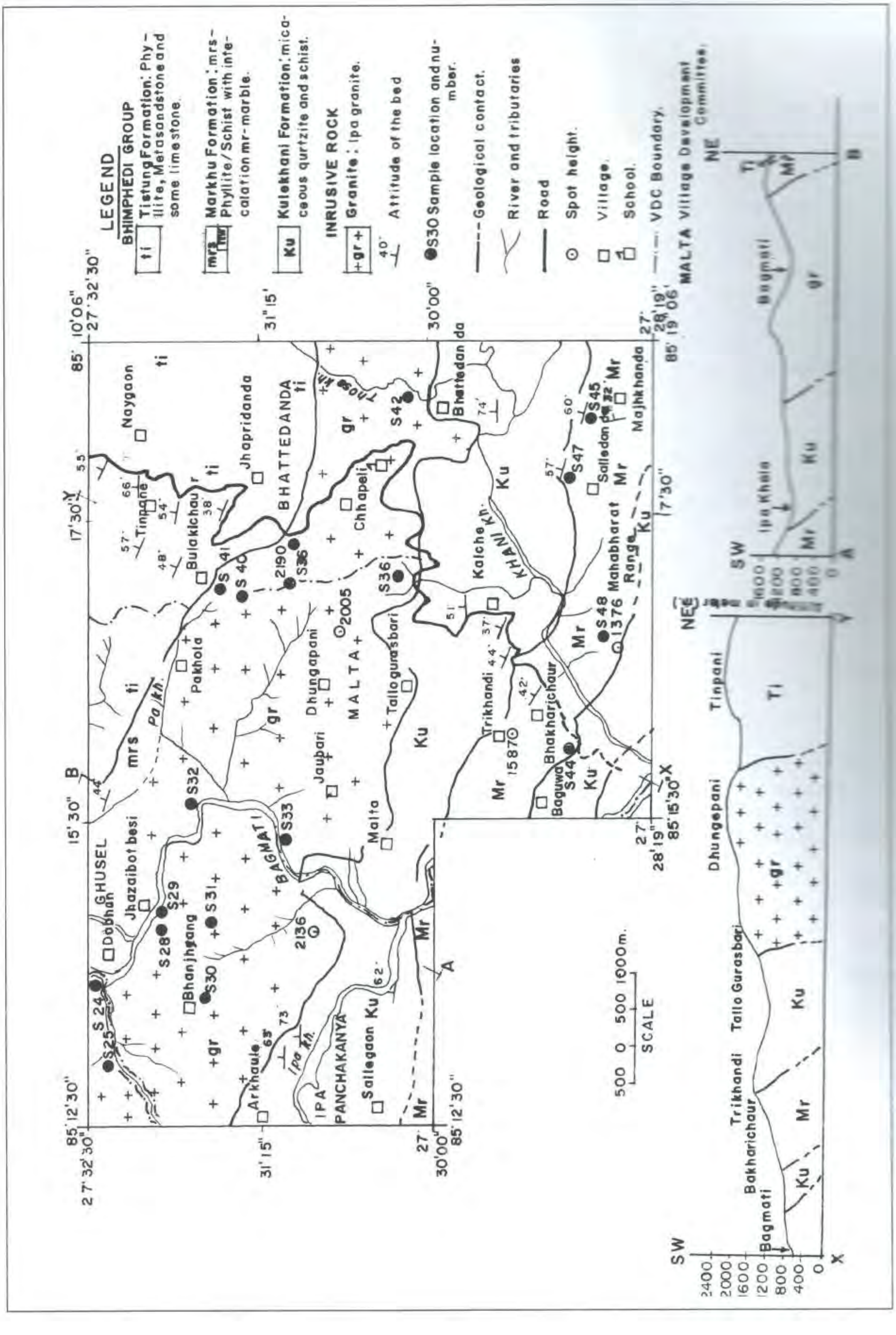

Fig. 2. Geological map of Ghusel Bhattedanda, Malta and Ipa Area

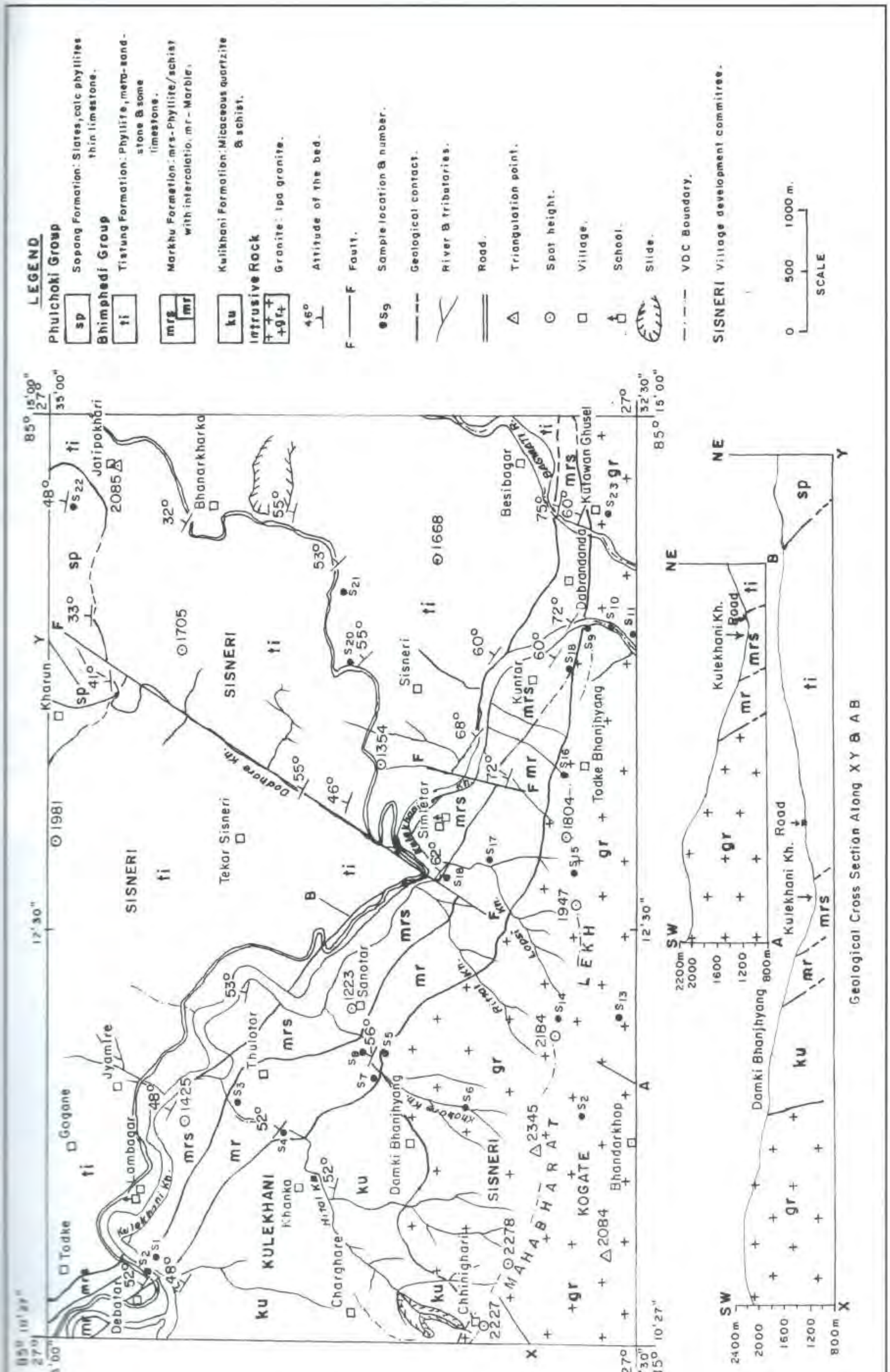

Fig. 3. Geological map of Kulekhani, Sisneri Area (Follow-up Study Area).

In the south and to the east of the Bagmati River, the gneissic granites are common. They are medium to coarse grained, inequigrannular and tourmaline is rare. Commonly small augens are developed due to presence of porphyroblast feldspar.

The kaolinization/ alternation of feldspar are fairly active. Most of the study areas show deep weathering. The weathering is more intense at the Deurali area (south of Dobhan), Ipa area and Dhungepani dada. Granite at Ipa area shows weathered topsoil as high as 10 m. However, the portion between Todkebhanjyang and Dobhan (Bagmati - Kulekhani Khola confluence) shows somewhat less weathering effect on the surface. The granite is characterized by 3 major joint sets generally represented along the drainage pattern i.e. north – south with V- dip, along the strike and oblique to the strike.

Marble

Marble belongs to the Markhu Formation. The stratigraphy sequence shows Kulekhani Formation as underlying rock and Tistung Formation as overlying rock units. The marble are medium to coarse crystalline, light grey to grey with light pink to dirty white color. The thickness of the marble band is about 300 m. The marble looks massive from a distance, but at close view, the beds are highly fractured, jointed with bed thickness of about 1 m maximum. General trend of the rock varies from the N30^0 W to N70^0 W and dip 40^0 - 70^0 towards north. The chief mineral constituent is calcite. However, biotite, quartz, pyrite and opaque minerals are also present as accessory minerals. It is well exposed along the Kulekhani Khola and kholsi sections and at Kanti Rajpath.

Near the northern contact, marble is interbedded with few bands of schist and quartzite whereas towards southern contact with Kulekhani Quartzite and Ipa Granite, it shows siliceous in nature. The marble is highly jointed and fractured. Four major types of joint sets are common. Good sizeable marble block for polished stone is not readily available, however it can be used as marble chips or powder or aggregates.

RESULTS OF LABORATORY TESTS

The marble and granite samples collected during field investigation were performed laboratory tests in the DMG laboratory to supplement the field study data to delineate the possible prospect areas. Samples were polished to check for its suitability to obtain the information on color, appearance and luster. Petrographic study, chemical analysis and physico-mechanical tests were also performed to check their durability.

(a) Suitability Tests

Cutting and Polishing

The polished surfaces of both granite and marble show good shining luster and attractive appearances The polished surface of granite (Fig.4a) shows irregular crystal grain with abundance of feldspar and mica whereas the polished surface of marble (Fig.4b) shows pyrite and mica minerals on the surface.

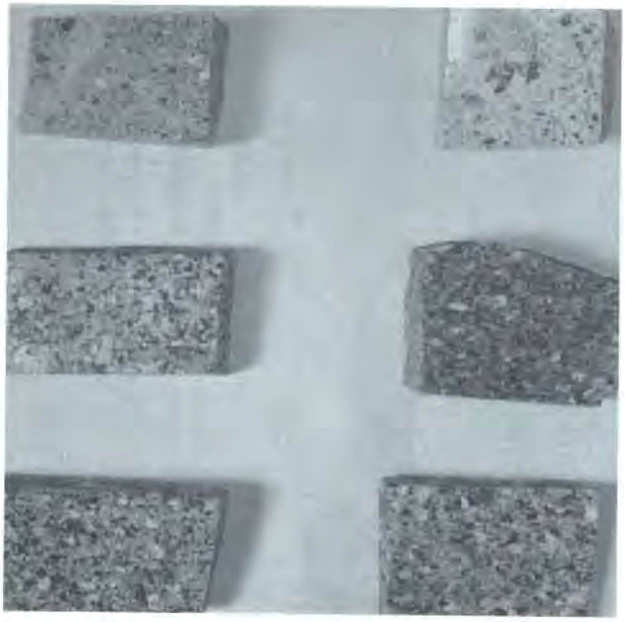

Fig.4. (a) Polished Samples of Ipa Granite and

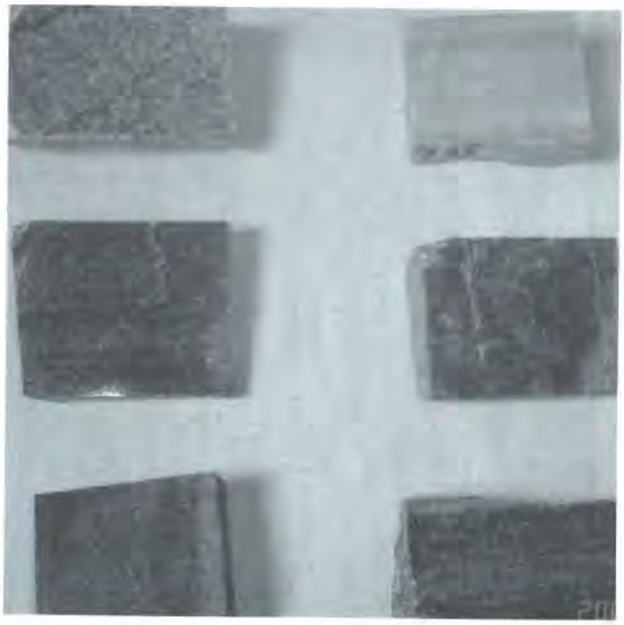

Fig.4. (b) Markhu Marble

Table-1: Results of Petrographic Study

Rock Type	Color	Texture	Mineral Constituents (%)											Remarks
				Quartz	Plagioclase	Orthoclase	Biotite	Muscovite	Calcite	Dolomite	Garnet	Tourmaline	Opaque	
Ipa Granite	Light greyish white, brown, black spots / patches of biotite and tourmaline	Medium to coarse grained, anhedral to subhedral, crystalline, interlocked crystals		45 - 62	10 - 25	8 - 20	5 - 15	<1 - 5	-	-	-	<1	1 - 4	Granite
			Av	58	13	13	8	3	-	-	-	<1	2	
	Light greyish white, brown, black spots / patches of biotite	Fine to medium grained, anhedral to subhedral, porphyroblastic. Foliation defined by parallel orientation of mica.		63 -75	10 - 12 7-	8	5 - 10	2 - 5	-	-	-	0	1 - 4	Gneissic Granite
			Av	69	11	8	8	4	-	-	-	0	3	
Markhu Marble	Light Grey, Light Pink, Grey	Medium to coarse grained, crystalline, massive, sacchoridal or sugary texture, rarely micas in the foliation plane.		1 - 5	0 - 5	-	<1 - 4	<1 - 2	75 - 93	3 - 6	0 - 1	-	1 - 2	Marble
			Av	3	1	-	2	1	86	5	<	1	<2	
	Light Grey to Grey with dirty white	Medium to Coarse grained, foliation defined by parallel orientation of calcite with minor amount of sericite (mica).		15 - 20	<1 - 8	-	<1 - 5	<1 - 4	58 - 72	4 -10	0	-	2 - 4	Siliceous Marble
			Av	17	4	-	4	3	64	6	0	-	3	
Calc Schist	Light grey to grey	Fine to medium grained, schistosity defined by micas.		50	4	5	10	4	25	-	-	-	2	Calc schist

(b) Durability Tests

Petrographic Study

The petrographic study is based on 8 thin sections of marble and 11 thin sections of granite. The summary of the results of petrograhical study is presented in Table-1. The test results are generalized based on the limited thin sections study. High calcite presents in few marble thin sections show the presence of high grade crystalline limestone band within the marble bands.

Chemical Analysis

Results of chemical analysis of granite and marble samples (grab samples) are presented in Table-2. Chemical analysis of few marble samples show cement grade.

Physico-Mechanical Study

The physico-mechanical tests of 11 granite and 8 marble samples were conducted. Bulk Specific Gravity (D), Absorption by weight, % (Abs.) @ 24 hours soaking was performed according to ASTM test methods (ASTM, 1996). Uni-axial Compressive Strength (Cu) tests of cubical rock specimen of average surface area of 7.6 cm X 6.9 cm with average height of 8.8 cm. were calculated. The Modulus of Rupture (E) was calculated from the breaking load applied. The test results are compared with ASTM requirements.

The results of physico-mechanical tests obtained from laboratory study for granite and marble specimens are presented in Table-3.

CONCLUSION

Huge quantity of granite, quartzite and marble are available in the study area.

The field investigation shows that good sizes of marble blocks of Markhu Formation are not readily available because of the fractured nature and small thickness of bed. The laboratory tests show that polished surfaces of marble show shining lustre and attractive appearance. These marble meet the specifications required by ASTM except for the compressive strength. The field investigations supplemented by laboratory tests and analysis of the rock samples for suitability and durability show that marble cannot be recommended to establish polished marble slab industry. However, it can be used to produce marble chips or marble block as dimension stones.

The petrographic study and chemical analysis is based on the limited rock samples. The field investigation and laboratory study shows the presence of thin band of cement grade crystalline limestone within the marble band. Follow-up study with detail sampling on crystalline limestone band is required to judge the economic importance of it.

Table-2: Results of Chemical Analysis

Sample No.	LOI %	Insoluble	SiO_2 %	R_2O_3 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO	Remark
S_9	0.89	-	73.86	12.65	0.06	12.59	8.76	3.53	Granite
S_6	1.42	-	72.28	13.55	0.04	13.51	9.81	1.01	Granite
S_{24}	1.18	-	73.86	20.40	0.06	20.34	2.10	1.26	Granite
S_{32}	1.26	-	72.36	14.05	0.06	13.99	8.41	2.02	Granite
S_{40}	0.86	-	72.94	16.70	0.04	16.66	8.76	1.26	Granite
S_{36}	1.00	-	73.10	15.75	0.04	15.71	6.31	2.02	Granite
S_1	28.00	28.30	-	3.97	2.71	1.27	35.40	3.53	Marble
S_7	33.91	18.66	-	2.35	2.02	0.33	41.36	2.52	Marble
S_{43}	39.20	7.16	-	0.82	0.79	0.04	49.07	2.27	Marble
S_{44}	40.06	4.24	-	1.68	1.33	0.35	49.07	3.53	Marble
S_{45}	32.90	21.50	-	1.55	1.03	0.52	39.26	2.27	Marble

Table-3: Results of Physico-Mechanical Tests

Rock Type	Bulk Density D (Kg/m^3)		Absorption by weight Abs (%)		Compressive Strength Cu (Mpa)		Modulus of Rupture E (Mpa)	
	Required by ASTM	Value Obtained	Required by ASTM	Value Obtained	Required by ASTM	Value Obtained	Required by ASTM	Value Obtained
Granite (Ipa Granite)	2560 min.	3000 max. (S_6) 2500 min. (S_{36}) 2670 av.	0.40 max.	0.86 max. (S_{24}) 0.28 min. (S_6) 0.55 av.	131 min.	81 max. (S_{24}) 30 min. (S_{39}) 41 av.	10.3 min.	132 max. (S_{24}) 47 min. (S_{40}) 81 av.
Marble (Markhu Marble)	2305 min. - 2800 min. (Travertine - Dolomite)	2830 max. (S_7) 2530 min. (S_{46}) 2660 av.	0.7 max.	0.52 max. (S_3) 0.14 min. (S_{45}) 0.32 av.	52 min.	45 max. (S_{19}) 28 min. (S_3) 33 av.	6.87 min.	95 max. (S_{19}) 49 min. (S_3) 70 av.

The field investigation for granite shows that granite rock available around Todkebhanjyang to Dobhan area at Sisneri and Kogate VDC is less weathered and good sizable granite blocks (about 1 m) are available. Granite available in the rest of the study area is characterized by deep weathering. Though granites give good polish with abundance of irregular crystals, these rocks shows less values for compressive strength tests to meet ASTM standards.

Field investigation of quartzites of Kulekhani and Tistung Formations show economic importance only for the purpose of construction stone (raw stone) and stone aggregates because of the nearness to market and accessibility.

RECOMMENDATION

Granite available around Todkebhanjyang to Dobhan area of 5 sq. km is recommended for further detail exploration including its weathering profile, possible block size and estimation of mineable quantity.

Marble and quartzite available around the study areas are recommended as good sites for construction stone industry to manufacture dimension stone, raw stone and stone aggregates. Detail follow-up exploration is recommended around Salledanda and Trikhandi area on the east and west of Khani Khola to study possibility of the marble to be used as cement grade limestone. Additional laboratory testing of thin section study is recommended to generalize the data.

ACKNOWLEDGEMENT

The authors would like to express their sincere thanks to Mr. Pranab Lal Shrestha, Director General, Department of Mines and Geology for giving permission to make use all the existing reports and maps to prepare the paper. We are also grateful to Dr. R. B. Shrestha, Deputy Director General and Mr. K. P. Kaphle, Superintendent Geologist, Department of Mines and Geology for their valuable suggestion and editing the paper.

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

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INTRODUCTION

Biratnagar town is situated 550 Km towards East from the capital city Kathmandu as per the distance based on the Prithivi Highway and Mahendra Highway (Fig.1). It is situated in the Terai Plain (Indogangetic Plain) and lies in the eastern development region of Nepal. It is one of the fast growing and developing urban areas and is a major industrial zone of Nepal. Country's many manufacturing industries are located in this region. Biratnagar was established as town in the year 1971 B.S. when the headquarter of Morang district was transferred from Rangeli to Biratnagar. The city was established as municipality in 2008 B.S. and has become the focal point of the eastern development region. Commercially, politically and industrially it is very important city of Nepal. The population of the town according to 2001 census is 166,674. It is situated at an altitude of 70m from mean sea level. It is the district headquarter. The study area is bordered by Singhiya River in the east, Kesaliya River in the west, Tankisunwari VDC in the North, and, Budhanagar VDC and India in the South. The town of Biratnagar acts as a main gateway for entering into Nepal territory from Jogbani India. It has subtropical climate with average rainfall of 1832 mm. per year with temperature variation of minimum 0^0 Centigrade in winter season to maximum temperature of 42° Centigrade in summer season. The municipality has high literacy rate of 63.58% (source: Municipality).

The Department of Mines and Geology (DMG) had initiated to prepare an Engineering and Environmental Geological Map of fast growing urban areas since 1998. Engineering geological mapping, urban and environmental geological investigation and Geohazard assessment of Biratnagar and the surrounding area is a continuation of the same. It was carried out with an objective to prepare a comprehensive 'Engineering and Environmental Geological Map' at 1:25,000 scale with a view to provide basic information on engineering geology, urban and environmental geology and geohazards to the concerned people and agencies.

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

The field work is carried out in Biratnagar Sub Metropolitan city and its adjacent areas located between 2918000 to 2932000 meters Northing and 523000 to 533000 meters Easting. The study area covers an area of 100 square kilometers out of which about 55 sq. km. is covered by municipality areas. Dharan Road connects the town with East – West highway in the north at Itahari and with rest of the country. The study area has been shown in Figure-1.

PREVIOUS WORKS

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

The Department of Mines and Geology has published Geological Map of Eastern Nepal (1984) at 1:250,000 scale that shows the occurrence of recent sediments in the area and consisting of alluvium boulders, gravels, sands and clays.

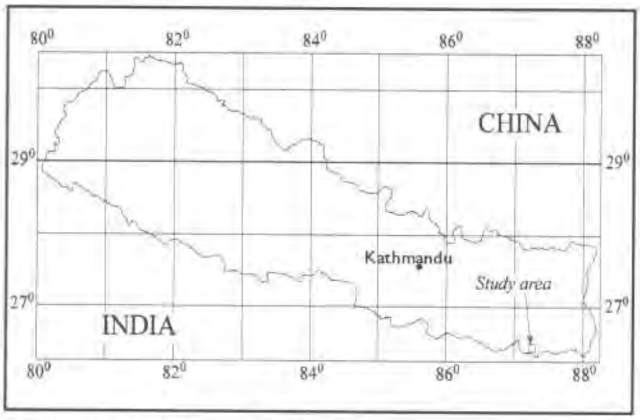

Fig. 1. Location Map of the Study Area

Land Resources Mapping Project (LRMP) of Survey Department carried out for the preparation of the reconnaissance level Land Use, Land Systems, Land Capability mapping at 1: 50,000 in 1984.

Amatya et. al. (1994) compiled the Geological Map of Nepal at a scale of 1:1,000,000. In the map Quaternary Alluvial deposits of Gangetic Plain represent the area.

OBJECTIVE

The main objectives of the present study are:

- To identify the various soil units and prepare Engineering and environmental Geological map at 1:25,000.
- To identify the hazardous/risk areas and recommend appropriate mitigation measures.
- To identify the existing environmental problems that affects the human health and
- Delineation of the area susceptible to liquefaction and ground settlement and associated risks so as to provide suitable preventive measures to reduce its effect on existing environment and structures.

METHODOLOGY

The methodology of the study comprises of desk study, field investigations and post field study. In the desktop study, existing relevant literatures on geology, geohazards and regional geological as well as land use maps were reviewed. Available reports on groundwater provided by Ground Water Resources Development Board (GWRDB) Babarmahal were also studied. Additional information was also collected from local individuals. LANDSAT TM Scenes of 1: 125,000 scale (November 1990); aerial photographs of 1: 15,000 scale (December 23, 1998) and of 1: 50,000 scale (1978-79) were studied and necessary interpretations were made. Topo maps of 1: 25,000 scale (1992) and the digital database of this map was acquired from Topographical Survey Branch. They were used to prepare a base map. The results obtained from engineering geological mapping and the urban and environmental geo hazard studies were incorporated and the final Engineering and Environmental Geological map was prepared by using software such as Arcinfo, Arcview and Freehand.

FIELD ACTIVITIES

The fieldwork was carried out for 45 days in the month of Poush- Falgun 2062 B.S. As planned before, previously interpreted geological features such as thrusts, faults, lithological formations, boundaries, land use types and the existing infrastructures were checked in the field and were verified in the aerial photographs and the satellite images. The field survey also enabled to delineate the potential areas of instabilities on the ground, soil erosions, flood prone areas, the area of low bearing capacity, liquefaction potential areas and neotectonic features. Preliminary survey was also made for to find out the suitable sanitary landfill sites for waste disposal in Biratnagar Sub Metropolitan city.

Auger holes (Fig.2) were drilled for the investigation of the subsurface soil layer from which required soil samples were collected from different depth of the boreholes for laboratory analysis. Similarly Standard Penetration Tests (SPT) was carried out to determine the stiffness of the ground at different locations (Fig.3). These tests were carried out to the maximum depth of 7 meter only because of the limitation of the type of the equipment used for the test. During the field survey a number of traverses were taken at different places along riverbanks, trails and roads to delineate geological units and to identify areas prone to flooding, riverbank erosion and riverbed scouring. Soil sections exposed along riverbanks were measured. A number of pits were dug in order to expose the soil section in areas other than river sections. The sediments up to the depth of 7m.are broadly classified into different lithological units.Field data and information collected from aerial photographs were transferred in to the topographical base map. Analyses of collected samples from the field were carried out in the geotechnical laboratory of the department. Geographical Information System (GIS) analysis was carried out using ARC/INFO software. The process here includes the digitization of the map, input of data and its storage, data processing, plotting and then producing the Engineering and Environmental Geological Map. A number of layers were created which include polygon, line and point features. Each Arc Info layer was converted into shape (shp) files using Arc View software. Shape files were transferred to freehand software for final cartographic design of the map.

GEOLOGICAL SETTING

The investigated area comprises of Holocene to recent sediments. The Quaternary fluvial sediments of the study area are part of the Indogangetic Plains that is extended up to the India in the south. The area consists of the sediments derived from rivers such as Singhiya Khola in the east and Kesaliya River in the west which originate from the Siwalik Hills in the north. Based on the study of soils derived from the auger drill holes, river sections, pits and existing litho logs, they are differentiated into four different units. They are:

- Flood Plain Deposit (fp)
- Katahari deposit (Kd)
- Buddhanagar deposit (Bd)
- Ramgunj Deposit (Rd)

Their brief descriptions are given below:

Floodplain Deposit (Fd)

The deposit is distributed mainly along the river courses of Singhiya River in the east and Kesaliya River in the west. It consists of medium to coarse-grained sand mixed with gravel. The bearing capacity in this deposit area varies from moderate to high and possess high liquefaction susceptible zone.

Katahari Deposit (Kd)

The deposit is clay dominant area. It consists of brown to light gray clayey silt to silty clay up to the depth of 6 to 11meters (Fig.4). The field N-values in this area varies from 0 to 15. The zero N values are also observed at places (SPT 28) at Katahari village. In this unit N-value increases as the depth increases. This unit indicates low to very low bearing capacity. This deposit is mainly developed along the main highway to Biratnagar in the northern and northeastern part in Katahari, Pokharia and Dhanpura areas. Because of the low N values in this area, it lies in moderate to high liquefaction potential area in case of the high magnitude earthquake.

Ramgunj Deposit (Rd)

This deposit is dominant over the other deposits and is distributed widely mainly in the central part of the study area. This unit consists of yellowish brown to bluish gray colors clayey silt to silty clay up to the depth of 5 meters (Fig.5). Below 5 m depth it consists of fine to coarse-grained sand. The field N-values in this area is generally less than 10 but at places it reaches up to 24 at Hildegard at a depth of 6m. The greater N- value is obtained at a depth of 5m. and below it.

The N- value at a depth less than 5m. is between 3 to 9. The thickness of this unit is greater than 7 meters. This unit is found in Ramganj, Jhatiyahi areas. This unit indicates low to moderate bearing capacity and at places it shows moderate to high. The area lies in moderate to high liquefaction potential.

Buddhanagar Deposit (Bd)

The unit is dominant in sand deposits (Fig. 6). It consists of brown to gray colored clayey silt and silty clay up to 3m. from the ground surface and below it consists of fine to medium sand (> 4m. thick). This unit is distributed mainly in the southern and southeastern part of the Map in the major industrial area of Biratnagar town such as in Darahiya, Rani Mill area and Budhanagar areas. The field N-values in this area varies from 2 to 19. The higher N-

Fig. 2. Men performing Auger hole drill in the field

Fig. 3. Men Performing Standard Penetration Test (SPT) in the field.

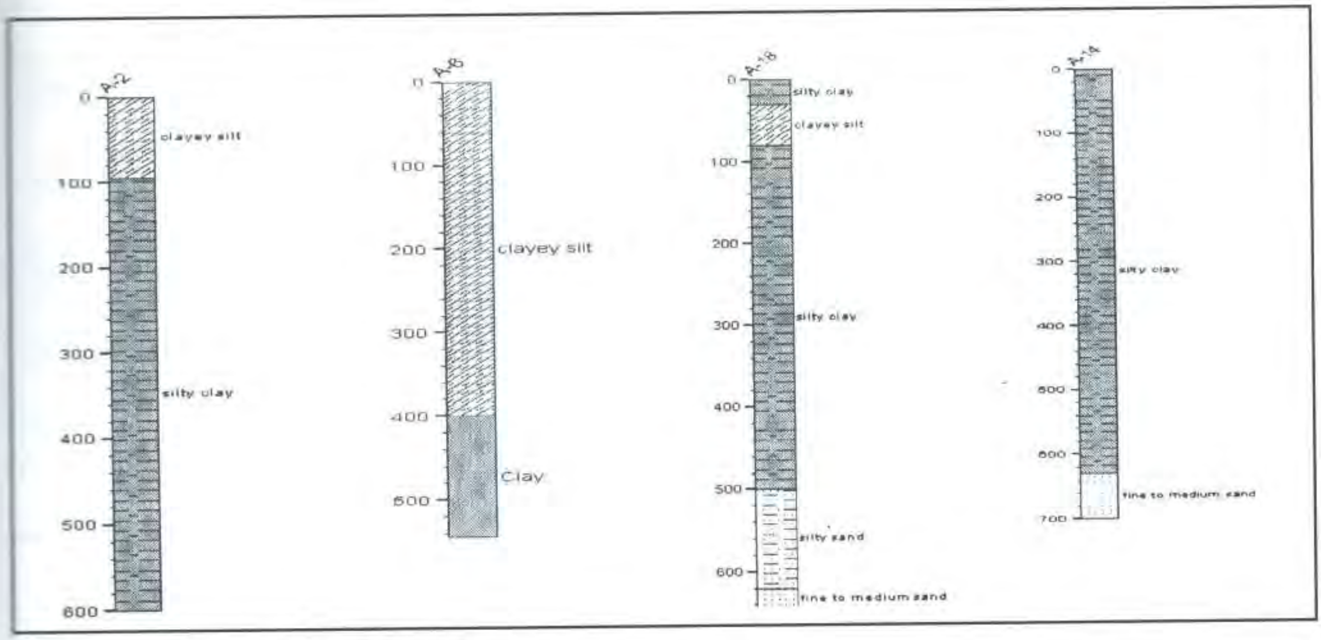

Fig. 4. Lithologs representing Katahari deposit

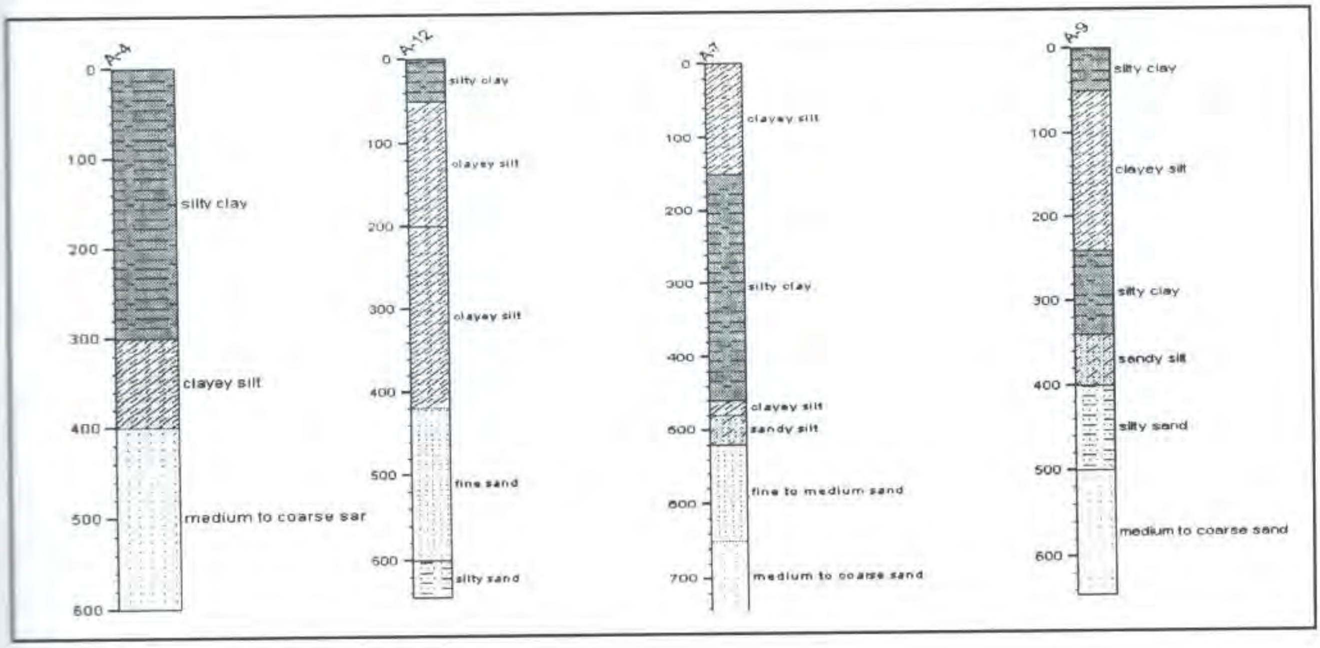

Fig. 5. Lithologs representing Ramgunj deposit

value is obtained at a depth below 3 meters mostly which mainly consists of sand deposits. Where as at the upper depth N–value is less.

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

Laboratory Tests

From the samples collected in the field during the auger drill and SPT tests, a number of engineering tests such as grain size analysis; Atterberg's limit tests were conducted. The results of the laboratory tests of some of the samples are shown in the Table-1 below. The sieve curve for one of the samples tested is shown in Fig.7.

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

Sample No.	Depth (m)	Fine (%)	Coarse (%)	Water Content W%	Liquid Limit (%)	Plastic Limit(%)	PI (k) m/s	Soil type	Perm	Remarks
SPT-1b	2.0-2.45	54	46	56.47	39.8	22.2	17.6	Sandy Silt	$2.6*10^{-6}$	Uniform
SPT-2c	4.0-4.45				32	38.4	-6.4			
SPT-3b	3.0-3.45	78	22	27.47	36	21.25	14.75	Sandy silt	$1.3*10^{-6}$	Uniform
SPT-5a	2.0-2.45	78	22	27.21	26	23.05	2.95	Sandy silt	$1.3*10^{-6}$	Uniform
SPT-6b	4.0-4.45	84	16	30.28	30	21.02	8.98	Sandy silt	$1.2*10^{-6}$	Uniform
7b	3.0-3.45	81	19	26.30	33	18.77	14.23	Sandy silt	$1.2*10^{-6}$	Uniform
SPT 8 a	2.0-2.45				43	23.65	19.35			
9b	3.0-3.45	64	36	28.22	39.8	24.85	14.95	Sandy silt	$1.9*10^{-6}$	Uniform
SPT10a	2.0-2.45				34	21.2	12.8			

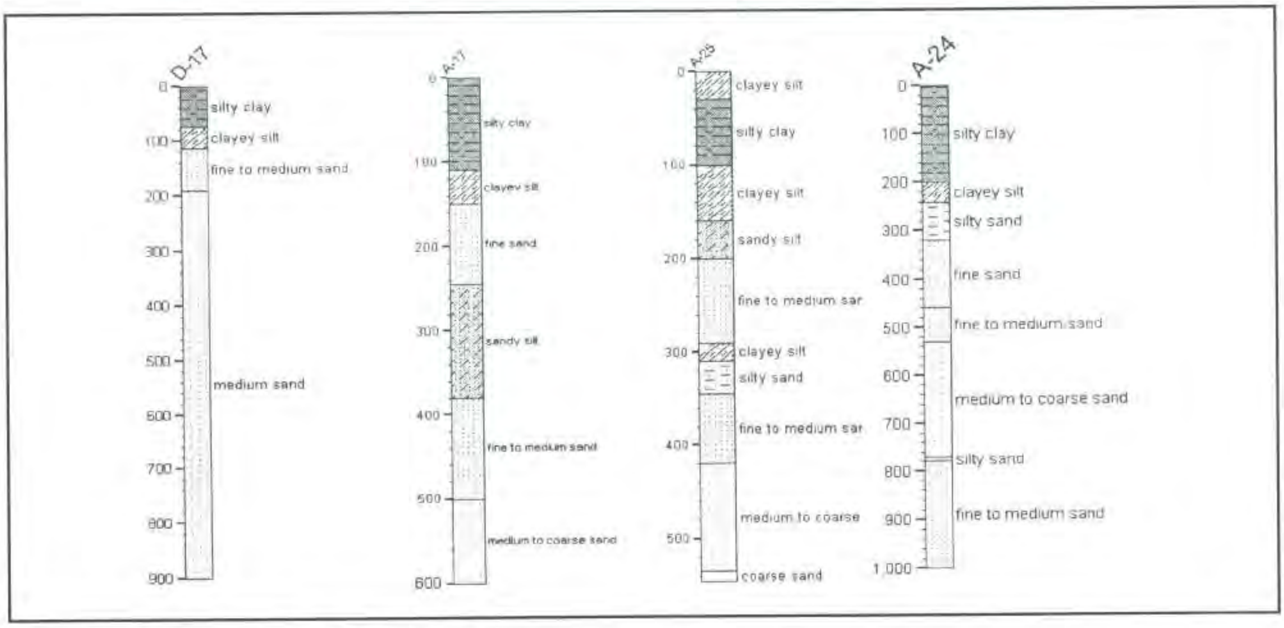

Fig. 6. Lithologs representing Buddhanagar deposit

NATURAL HAZARDS / GEO - HAZARDS

Floods and soil erosion are the major types of natural hazards frequently occurring in the Biratnagar and the surrounding areas. Evidences of floods and soil erosions are observed along the Kesaliya River in the west and Singhiya River in the east. The study area also lies in the liquefaction potential zone. There is report that some parts of the study area were affected by liquefaction hazard in 1934 and 1988 earthquakes of magnitude 8.3 and 6.5 respectively.

River Bank Cutting

River Bank cutting is one of the common natural hazards in the study area. River Bank collapse is caused due to toe cutting of the stream and high flow velocity of the river water during the monsoon time.

River Bank cutting was observed both in Singhiya Khola and in the Kesaliya River (Fig.8). The area close to Singhiya Khola suffers more from bank erosion than that in Kesaliya River. Many houses along the right bank of Singhiya Khola (from Hat Khola upstream up to Bhattachok) are found vulnerable for riverbank cutting. In the right bank (West) of the Singhiya Khola near the Saraswoti tole, many houses are built on the bank cut, due to which they seem very vulnerable. Similarly in the Jamtoki ward no. 2, riverbank cutting is found on the left bank of the Singhiya Khola, which has already destroyed two houses, and bank cutting is continued towards east. The riverbank in this area needs appropriate protection wall to stop further cutting. Similar condition is also found in the Ashokchok and Kadamcholi area.

Similarly along the Kesaliya River the river cutting problem was observed along Ikarahi, Belgachhiya and Malhanawa.

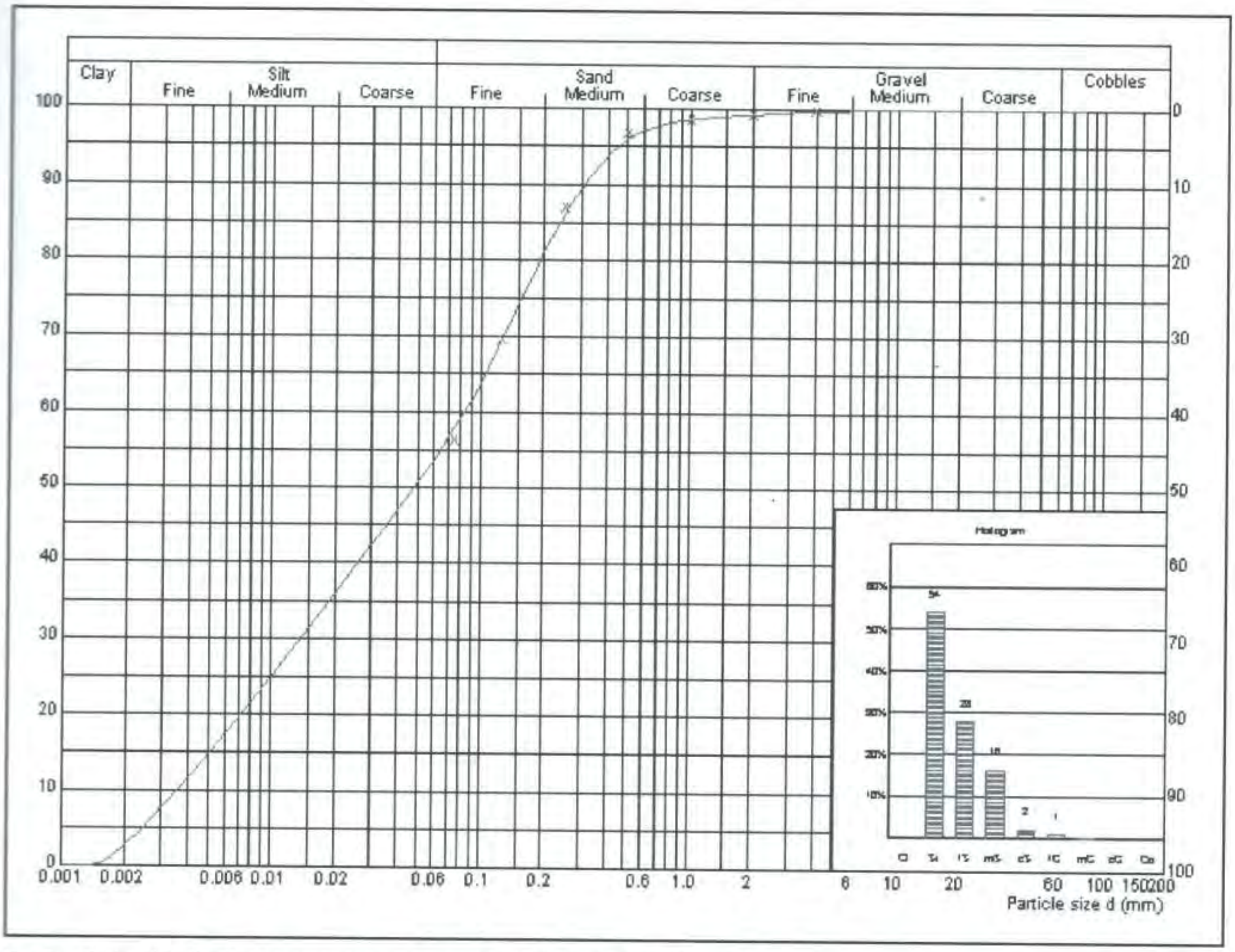

Fig. 7. Grain size distribution curve for a soil sample of SPT1-b1,depth 2.0 - 2.45m.

Near Ikarahi (Fig.9), Kesaliya Khola changes its meandering course towards east due to which it is continuously eroding its right bank. Similarly near Belgachiya, riverbank erosion is more pronounced on the right bank destroying the agricultural land. According to the local people, road along the left bank near Jhanglabad -16 was destroyed by the flood of last year. A natural hazard turns into a disaster when an event causes heavy loss of life and property damage. Since villages are located quite far from this riverside, risk is less in terms of loss of life.

In the Dhanpura Khadara village situated in the north of Biratnagar city, bank erosion in the nala (stream) is severe (Fig.10). Previously a dam was constructed in this nala for irrigation purpose. Few years ago dam was destroyed by local people. Today, the nala is widening due to soil erosion and there has been continuous loss of fertile soil every year during the monsoon time.

Flooding

Western part of the study area near Kesaliya Khola is regarded as flood prone area. Floods are more or less a recurring phenomenon in the area near the Kesaliya Khola and often have been within tolerable limits. During the rainy season when the water flow exceeds the holding capacity of Kesaliya Khola, low-lying areas are inundated causing damage to crops, roads and other properties. The cause of frequent floods in the study area is generally due to the low-lying topography. The average depth of riverbed from the adjoining ground level is 3 meters. According to the local people the floodwater also carries sediments and deposits randomly throughout the stream channels. Nalas, which are flowing through Karkhanatol, Bramhapura, Malhanawa and Darahiya villages, also creates problem in these areas during rainy season. The water spills over the bank and inundates the villages during the time of flooding, According to the villagers,

Fig. 8. A typical example of riverbank failure

Fig. 9. Collapse structures found in the nala which was collapsed during the construction phase.

during the flood the level of water reaches up to 1 meter. from the ground surface. Since the study area is composed of clay and silty clay material, which are less permeable, the water runs off through the surface rather than percolating into the ground. Next, the city has not well managed drainage system due to which, the rainwater is blocked off and flows through the surface causing floods along the roads.

Haphazard Mining

Besides above-mentioned geo-hazard, haphazard clay mining has been taking place along the bank of Kesaliya (near Ikarahi) and Singhiya Khola (near Bhathigachh village). In the Ikarahi-5, clay is directly mined from the left bank up to the riverbed level using an excavator (Fig.11). Due to the continued mining activities along the riverbank area there is probability of river course changes that would ultimately affect the fertile land during flooding season. Similarly, clay is haphazardly mined from the right bank of Singiya Khola near Bhathigachh village. Mining for sand in the riverbeds and bank near the bridge may cause serious damage to the bridge. In Kesaliya Khola near Ikarahi village sand is mined within the 30 meters downstream from the newly constructed bridge

Bearing Capacity and Liquefaction potential

The bearing capacity of the soil in the investigated area was determined by using Standard Penetration Tests (SPT). The bearing capacity calculated in the study area varies from low to low-medium types. Low to medium bearing capacity is observed in the areas such as in Ikarahi, Singhiyahi, Nawatoli, Shantichok, Sarauchiya, Mahendrachok, Ramchok, Shanihot, Budhha-nagar, Bengali Tol, Dhatatol etc. The bearing capacity map is shown in the Fig.12. The soil condition in the study area according to Peck et al. varies from very soft to very stiff with SPT value ranging from 0 to 22. The SPT tests carried out in different places of the study area shows that, N-Values in Katahari deposit are less than 8, except in some places at greater depth where it reaches up to 13. Hence this zone lies in extremely low to low bearing capacity zone. N-Values in Buddhanagar deposit ranges from 1 to 13, except in one place, where N value is 23 at a depth of 6m. Hence this zone lies in extremely low to moderate bearing capacity zone. N-Values in Ramgunj deposit ranges from 3 up to 22 in some places, the greater value is encountered at a depth more than 6m, and hence this zone lies in very low to moderate bearing capacity zone. The result shows that, 70.23% of the total area has low to very low bearing capacity. 29.11% of the total area has low to moderate and 0.58% area has moderate bearing capacity (Table 2).

Liquefaction analysis was carried out for 75 borehole locations using qualitative analysis of Juang and Elton (1991). Out of 75 boreholes, 63 of the borehole showed high potential, 5 of them showed moderate potential, 6 of them showed low potential and only one of them showed very low potential (Fig.13). It indicates that, most of the areas in Biratnagar lie in high to moderate liquefaction potential for PGA value of 0.1g to 0.2g. High potential liquefaction is also indicated in the flood plain areas as shown in the Figure 13. However this result is only a preliminary result and requires a site-specific investigation (Quantitative analysis) for the further development activities. Water table in the area varies from 2m. up to 5m. in drill holes measured and it is not uniform.

The sieve analysis carried out for most of the samples showed uniformly graded soils. Very few of them are well graded. The liquid limit test carried out for some of

Table-2: N values for different SPT tests

SPT No.	Location	Depth 2 - 2.45m	Depth 3 - 3.45m	Depth 4 - 4.45m	Depth 5 - 5.45m	Depth 6 - 6.45m	Depth 7 - 7.45m
1	Basta tole-5	5	7	13			
2	Ikarahi-5	3	4	10	10	15	
3	Bugdahari-8,	6	5	3	5	5	
4	Gelhabari - 1	3	5	6	7		
5	Khodiya -3	7	3	7			
6	Dhanpura - 7	5	6	4	6		
7	Katahari - 5	6	4	4	5	6	14
8	Bengali tol - 5	5	5	2	9	24	
9	Budhanagar-1	5	9	9	22	18	
10	Malan gaun-2	2	5	12			
11	Harinagara-8	3	5	9	11	10	
12	Hatibandha milan chowk	3	2	4	4	3	
13	Karkhana tol	5	6	6	7	8	
14	Bramhapura basti -15	4	5	8	9	6	
15	Bakhari, swagatam tol	5	3	2	11	7	
16	Darahiya - 20	1	3	3	12		
17	Bhimpur - 7	4	3	8	4		
18	Ramgunj Belgacchiya	4	7	7	4	16	
19	Dhatatol - 9	5	3	9	6	9	
20	Amduwa farmtol - 1	3	6	14	18		
21	Bayarban - 18	4	5	10			
22	Majhare Dhangraha	6	5	5	8	10	
23	Balwahi,	5	6	6	4	5	
24	Jatuwa - 18	5	3	4	13		
25	Lawaghat	2	6	10	19		
26	Jatiyahi - 1	5	6	5	11	18	
27	Bhatigunj - 2	6	5	11	5	8	
28	Katahari -2	4	3	0	5	8	
29	Dhanpura, Khadara	7	7	10	12	12	
30	Sikiyahi - 17	4	5	6	8	23	
31	Kanchanbari - 4	3	3	6	8	8	
32	Sarrochiya - 7	5	4	5	5	13	

Fig. 10. Bank erosion in Dhanpura Khadara Village.

Fig. 11. Improper clay mining from the right bank of Singhiya Khola near Bhatigachh.

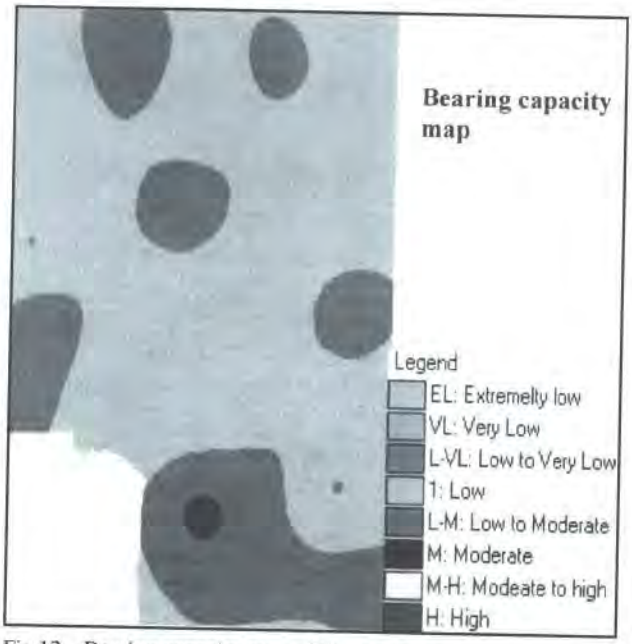

Fig.12. Bearing capacity map of the study area.

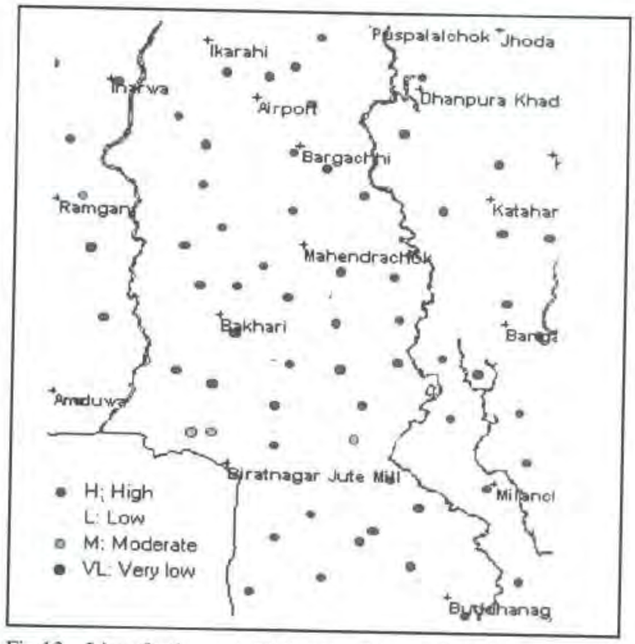

Fig.13. Liquefaction potential map of the study area.

the sample indicated the liquid limit value ranging from 30 to 40 and the PL from 18 to 25 (Table-1).

GEO-ENVIRONMENT AND POLLUTION

Drainage system in the Biratnagar municipality is poor and inadequate. The condition of the drainage in the municipality area is poor due to lack of regular maintenance and cleaning. Only people of the city center has access to proper toilet facilities while people living outside the city center generally use open spaces like riversides, open field areas. Direct connection of sewage drainage from center town to the Singhiya Khola and other industrial effluents directly into the river as well as dumping of solid wastes into the bank of the river and in the open spaces have caused serious pollution to the river water. This has threatened the environment of the area. Basta Nala flowing through airport and Karkhanatol is getting polluted due to discharge of industrial effluents. The presence of settlements by the sides of the Singhiya Khola (Hatkhola upstream) has boost up for the pollution to the river in a number of ways such as lack of proper sewerage and waste disposal facilities and lack in the maintenance of the existing facilities. As such most of the sewage generated within the area is channeled directly to the river. One of the leather factory situated along the road to Jhatiyahi Phadani produces bad smells in the surrounding and the chemicals discharged by it is polluting water, since they are dumped without any treatment. Besides these, pollution in the study area is accelerating due to generation of smokes and ashes from the factory chimneys, ashes dumped along the road sides and waste water left out by the sides of the road etc. All these cause not only groundwater/ surface water pollution but also air and ground pollution.

Waste Disposal Sites

Biratnagar Sub-Metropolitan city is lacking its own permanent sanitary landfill site to manage the safe disposal of the daily wastes produced from the urban settlement, industrial sites and Hospital etc. Dumping of solid wastes in different sites by the sides of roads, rivers and canals has deteriorated the environment of the Biratnagar city. Therefore, there is an urgent need for identifying an appropriate waste disposal site based on the environmental impact assessment.

The average capita household waste generation rate in Biratnagar was 0.172 kg./person/day. Considering the total population of Biratnagar in 2003, which is estimated to be 1,75,333 the total amount of household waste generated in the municipality alone comes out to be 30.16 tons per day (According to Ministry of Local Development/ Solid Waste Management and Resource Mobilization Center report, 200). The municipality has also signed an agreement with a private party (BMC Silt) for solid waste management services. Previously the collected waste was disposed by BMC-Silt in properly managed dumping sites (leased land) about 6 km. south from the city. The site with an area of 0.13 ha has been used for the past two years and now it is closed. Previously waste was haphazardly dumped by the municipality along the bank of the Singiya Khola. Now a days waste has been throwing haphazardly along the Kesaliya road side (Rampur-7) and along the canal near Jatuwa without taking any proper care of the environmental issues.

Infact, the Biratnagar municipality was planning to establish a new landfill site at Tankisunwari. The proposed landfill site is located at a distance of about 10 km. towards northeast from the city and has an area of about 10 ha. But presently the area has been occupied by the armed police force to set up a camp there. Beside this, Morang District Development Committee (DDC), Sunsari DDC, Dharan, Biratnagar, Itahari and Inaruwa municipalities are also working jointly to construct a regional landfill site. But it has not yet been finalized.

Landuse

In terms of land use, the study area is mainly used for cultivation where rice in the rainy season and wheat, sugarcane in winter seasons are grown. Patches of mango trees and bamboo trees as garden are also grown in the area. No particular forestland and recreational parks are observed in the area. The central part of the study area is covered by settlements. There are no identified sites for mining sand and clay. However people are mining them haphazardly. Industrial sites are located mainly along the southern part of the study area near the India Border.

NATURAL RESOURCES

Groundwater, Sand and clays are the main natural resources found in the study area. Sand is being mined along the Kesaliya River as well as along the Singhiya River. The existence of many ponds in the study area indicates that a lot of clay mining activity took place here in the past. The existing ponds are now being used for fish farming, cattle feeding as well as for washing and cleaning purpose. Some water ponds can also be used as a recreational place. The Biratnagar area is rich in groundwater resources and is the main source of drinking water. It is also used for irrigation purpose by deep boring. The chances of groundwater pollution in the study area are high since the groundwater level is high just 2-5 meters below the surface.

CONCLUSION AND RECOMMENDATION

Main town of Biratnagar is situated in the Indogangetic alluvial plains consisting mainly of sand, clay, silt and very few fine gravels at few localities. From engineering geological point of view the Biratnagar sub metropolitan city and the surrounding area can be divided into 4 units based on geological setting and engineering geological properties of soil/rocks. They are Katahari deposit, Budhhanagar deposit, Ramgunj deposit and the Flood Plain deposit.

The ground condition of the study area has ben revealed as very soft to stiff. However soft to medium ground condition is dominant in the area. Similarly bearing capacity of the ground ranges from extremely low to medium. The liquefaction potential in the study area is moderate to high, according to the qualitative analysis carried out on it.

Flood plain deposits provide source of construction materials like sand in few places of Singhiya Khola and Kesaliya Khola. The study area is rich in clay which is used in brick factories.

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

The western low lying parts of the municipality which are close to the Kesaliya Khola are mostly affected by flooding and water logging during rainy season.

It is recommended to follow proper land use pattern in Biratnagar Sub Metropolitan city and surrounding area to agree with the engineering geological properties of the soil obtained from the present study as far as practicable.

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

It is recommended to carry out proper site investigation before construction of heavy structures to make the structures safe.

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

Since the city area lies in moderate to high liquefaction area with low bearing capacity, a proper mitigation measures should be applied while designing and constructing buildings and other infrastructures.

The artificial depression or lands left behind by past clay mining should be utilized for temporary sanitary landfill purposes instead of haphazardly dumping wastes along the Kesaliya road side, near the canal and in the Singhiya Khola as these areas have thick layers of clay which protects the ground water from pollution through leachates.

The extraction of construction materials such as sand should be managed properly.

Haphazard clay mining from the bank of Kesaliya and Singiya Kholas should be stopped to prevent soil erosion and shifting of the river course.

Natural drains should not be obstructed while constructing new structures like road and canal.

The new sanitary landfill-sites should be selected as soon as possible for proper management of the wastes.

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Landslide Hazard Mapping in Some Parts of Kaski, Myagdi and Parbat Districts, Western Nepal

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INTRODUCTION

In accordance with the annual programme of the Department of Mines and Geology for the fiscal year 2005/2006, a 'Landslide Hazard Mapping' was carried out to address the basic geo-scientific information along with the possibilities of landslide hazards within the study area.

The study area is bounded by latitudes 28° 15' 00" to 28° 30' 00"N and longitudes 83° 45' 00" to 84° 00' 00" E, covering 650 sq.km. area in some parts of Kaski, Myagdi and Parbat districts of Gandaki and Dhaulagiri Zones. 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 Toposheet No. 62 P/15. It includes some trekking routes, also around Annapurna Sanctuary and covers many other tourist areas of national interest. As such, no hazard mapping work was carried out so far in this area. The results of present study will be basically beneficial for infrastructure development planning with the information on possible natural hazards.

OBJECTIVES

The present investigation aimed to achieve the following main objectives:

- to study the major landslides and register in the Preliminary Landslide Inventory Form
- 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 1:50,000 scale by optimum utilization of Remote Sensing and GIS techniques.
- to identify the major causes of landslides and recommend the possible preventive measures

METHODOLOGY

Desk Study

- Aerial photographs of 1996 at a scale of 1:50,000 were examined to identify the various lithological units, landslides, erosional features, tectonic structures etc.
- LANDSAT - TM Scene of December 1992 was studied for lineament mapping.
- The Land Capability, Land Utilization, and Land System maps published by the Land Resource Mapping Project (LRMP), Survey Department in 1994 were referred.
- The topographic maps of 1:25,000 and 1:50,000 scales from the Survey Department were used as a base map for the investigation.
- Existing geological maps and relevant literatures of the study area were reviewed.

Field investigation and Data Inputs:

Fieldwork and verification of existing information were carried out using aerial photographs of 1:50,000 scale in conjunction with topographic base maps 1:50,000 and 1:25,000 scales. Emphasis was given in checking the landslides and areas which are prone to further soil erosion. Some of the major landslides within the area had been studied in details using 'Preliminary Landslide Inventory Forms' for regional inventory. The optimum data, required for the present field investigation were acquired from various sources and field investigation. The data overlays, sources, derived parameters, and method of generation are given in the Table–1.

GEOLOGY AND STRUCTURE

A number of Nepalese and foreign geo-scientists like Hagen, (1968); Fuchs and Frank, (1970); Bordet et.al, Table-1: Data overlays, Sources, Parameters and Method of generation

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

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

(1972); Hasimoto et.al, (1973); Arita et.al; (1982); Sakai, (1983 and 1985); Kano, (1984); Shrestha, (1984); Colchen et.al, (1986); Duvadi, (1996); Poudel et.al, (1998) have studied the area in the past. However, the published geological map from the DMG, (2002) elaborates and provides the regional geological information on lithological, stratigraphical and structural aspects of the study area. The strength of a rock mass depends on the type of rock and the nature of discontinuities such as joints and fractures. Obviously, weak and incompetent rock is more likely to fail than strong and competent rock Thus, if more discontinuities are present in the bedrock, the greater is the chance of rock instability.

In general, the rocks of Lesser Himalaya, Higher Himalayan Crystalline and Tibetan Tethys Sediments represent the study area. The Lesser Himalayan rocks occurring in the study area composed of dark grey to black carbonaceous slate of Benighat Slate, light greenish grey to dark grey sericitic, chloritic phyllite of Kunchha Formation along with Fagfog and Kushma Quartzite of Pre-Cambrian Nawakot Group. Ulleri Gneiss is exposed at places within the Kunchha Formation. The Higher Himalayan Crystalline consists of a thick sequence of high-grade metamorphic rocks representing the Pre-Cambrian basement with intense deformation, migmatization and granitization. However, from lower to upper sequence, kyanite-sillimanite gneiss with well-bedded quartzite; calcareous gneiss with some marble, quartzites, pegmatites and augen gneiss are exposed. The Tibetan Tethys Sediment consists of a thick fossiliferous succession of Late Cambrian to Cretaceous age. The lower part consists of a thick succession of impure limestone/marble with intercalation of phyllite, sandstone/quartzite, black shale, limestone and sandy dolomite. The upper part consists of highly fossiliferous limestone alternating with shales, slates, and sandstones.

Structurally, the study area is dominated by three major transverse faults along the Modi Khola, Mardi Khola and Seti River offsetting the Main Central Thrust (MCT) as well as other thrust sheets below. The upper contact of the Lesser Himalayan rocks within the study area is defined by MCT as in other parts of the Himalaya. The Higher Himalayan Crystalline is thrusted over the Lesser Himalaya along the MCT. The Higher Himalayan Crystalline rocks occur below the Tibetan Tethys Sediments. Previously, it was generally considered that the contact between the Higher Himalayan Crystallines and Tibetan Tethys Sediments was gradational and showed no structural break. But recently, a normal fault system called South Tibetan Detachment System (STDS) has been recognized (Upreti et. al., 1999).

INVESTIGATION RESULTS

Landslide is the down slope movement of soil/ rock mass and other materials under the influence of gravity, and resulted landform. Normally, the movement occurs when the shear stress exceeds the shear strength of the materials. Similarly, the landslide hazard is referred to as the probability of occurrence of a potentially damaging landslide within a period of time and in certain area. The instability of a slope is mainly governed by terrain parameters such as lithology and structural condition of the rocks, properties of overlying soil, slope gradients, vegetation, land use and human intervention acting on the ground conditions. The specific impacts of these causative factors can sometime be mixed among themselves making it very complex and difficult to differentiate.

PREPARATION OF FACTOR MAPS

The factor maps of various parameters such as landslide distribution, geology, slope, aspect and land use, which are generally used for the preparation of landslide hazard zonation map at regional scale were prepared after incorporating the available remote sensing and field data into GIS system. The relationship of landslide ratio to various classes of parameter maps was summarized and found to be associated with certain classes of different parameters and presented after statistical analysis (Fig.1).

ROLE OF REMOTE SENSING DATA AND GIS IN LANDSLIDE HAZARD STUDY

The remote sensing data and their integration with GIS system are rapidly becoming more popular in landslide hazard zonation studies due to the availability of appropriate data sets and powerful computer facilities. Obviously, Remote Sensing Data play a significant role during the evaluation of landslide susceptibility and the analysis of specific landslide events. Similarly, GIS has tremendous application potential and provides the users as a tool for effective and efficient storage of required data. Though the various concerned organizations are using different statistical methods for landslide hazard analysis, the present study was based on bivariate statistical method and deals with one of the dependent variable like landslide density and other independent variables such as geology, landuse, slope and slope aspect. The following formula was used (Van Westen, 1993); for the present analysis.

PREPARATION OF LANDSLIDE HAZARD ZONATION MAP

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

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

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

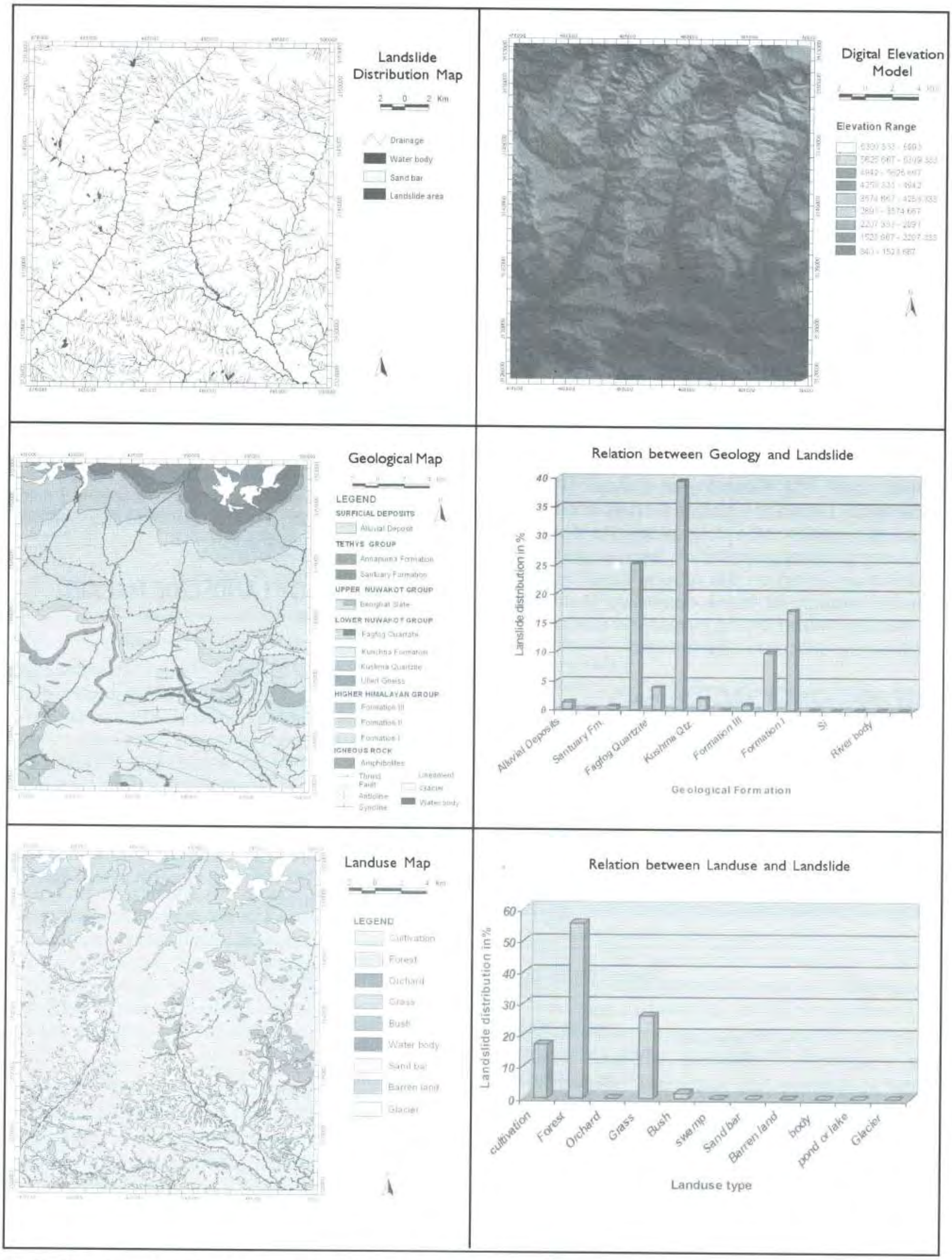
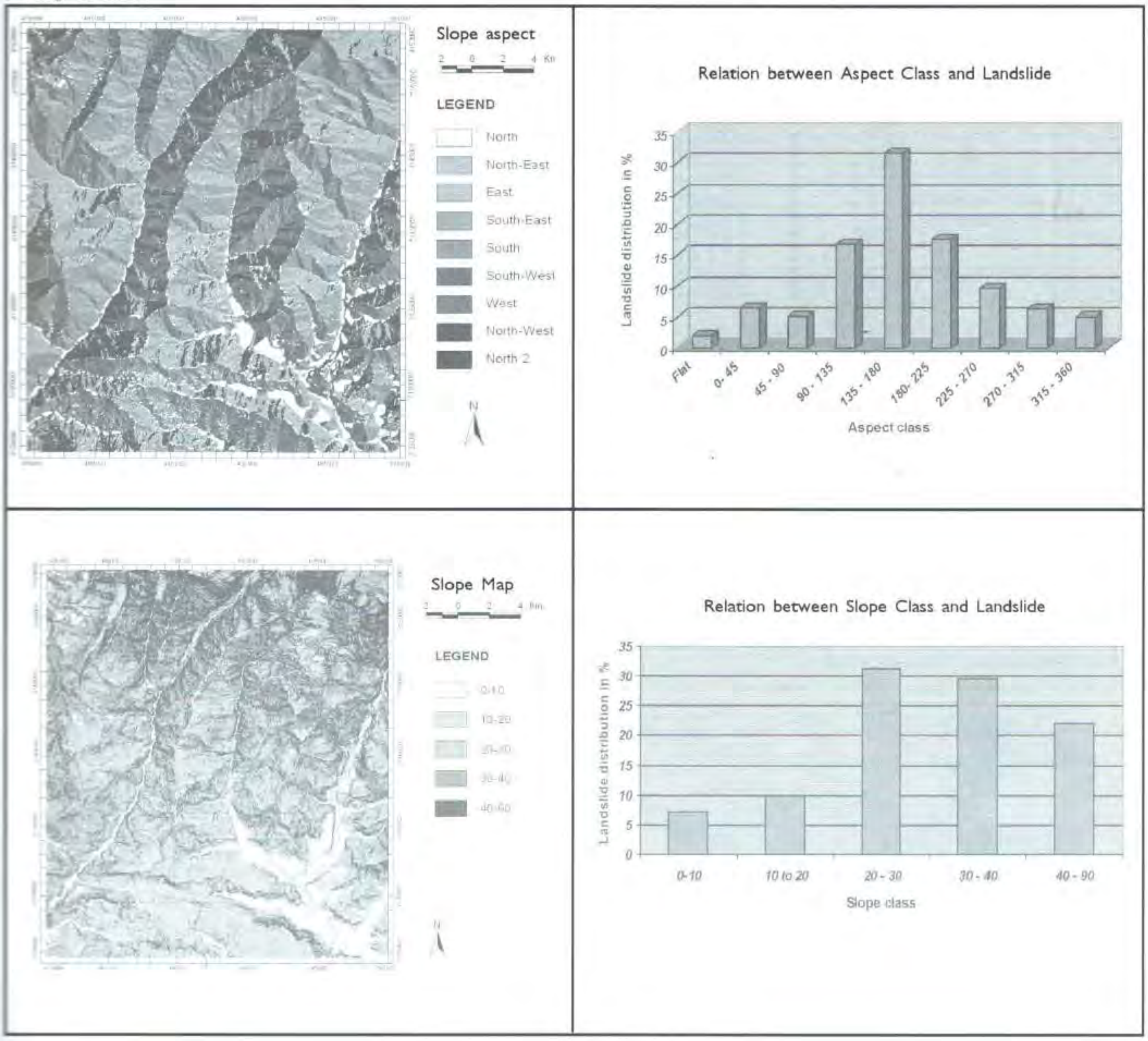


Fig. 1. The relationship of landslide ratio to various classes of parameter maps

(.... Fig.1 contd.)



RESULTS OF STATISTICAL ANALYSIS

The landslide hazard zonation map with low, moderate and high hazard zones was overlaid with the landslide distribution map and the landslide densities were calculated in order to checkout how much of the landslide area falls within the three different hazard zones. In this case, 87.30% of the landslides were found to be located within the high hazard zone; about 9.40% in moderate and only 3.30% in low hazard zone, indicating the satisfactory precision of the adopted statistical method for landslide hazard zonation mapping. Similarly the relationship between the area percentage of various hazard zones and other causative factors such as landuse, geology, slope and slope aspect were evaluated to identify the behavior of each factors. The following bar diagrams show the relation between hazard categories and various causative factors (Fig.3).

CONCLUSION AND RECCOMENDATION

The landslide Hazard Zonation map is mainly based on statistical and empirical evaluation of various causative factors related to slope instability and their relationship with existing landslide distribution within the area. The map totally relies on the surface information obtained by ground survey of accessible areas and data from aerial photographs.

Altogether sixty six 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 method itself.

The total weight values revealed from minus –13.353 to 2.345. About 87.30 percent of the landslides are found to be located within the high hazard zone, 9.40 percent

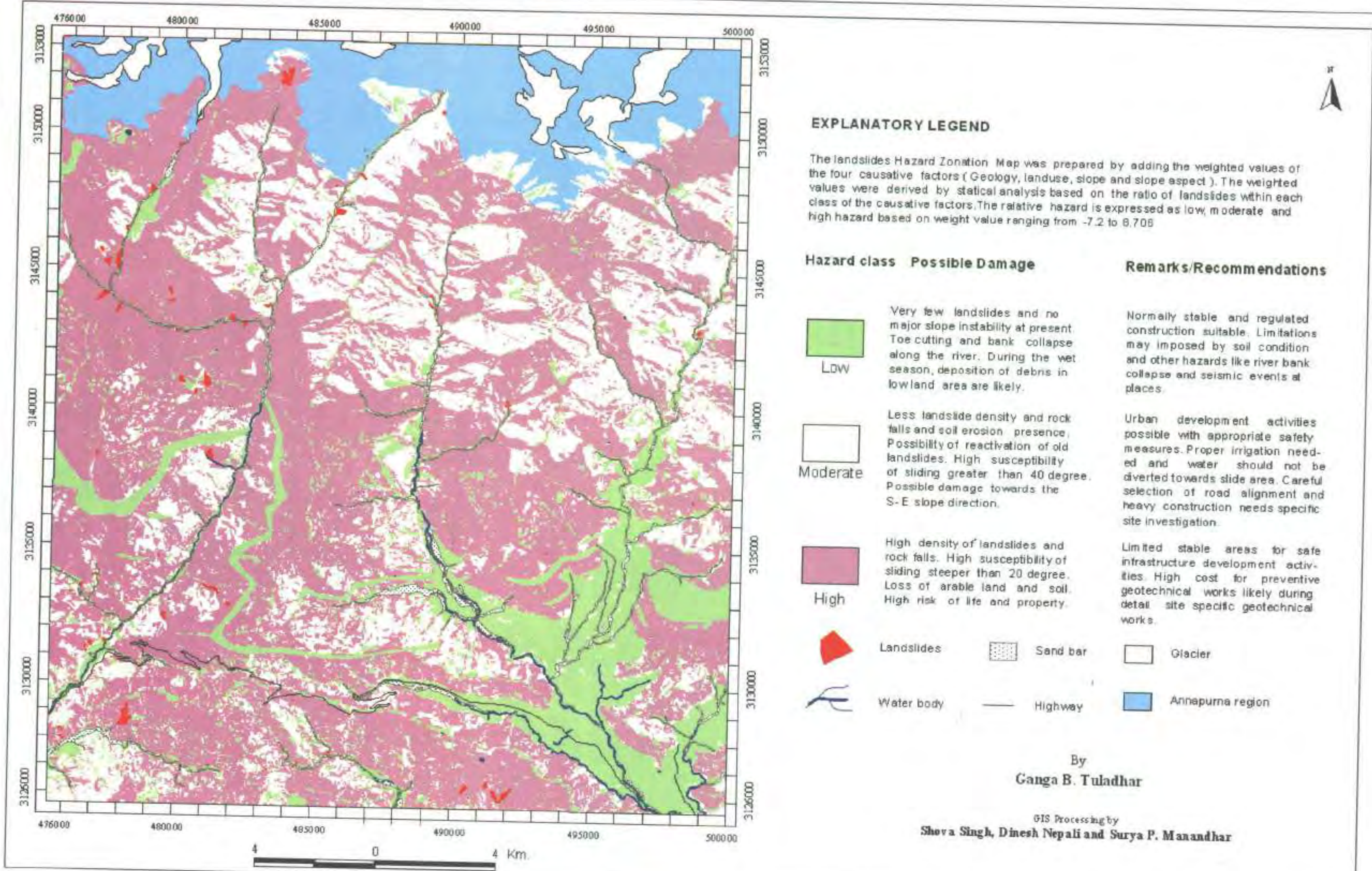
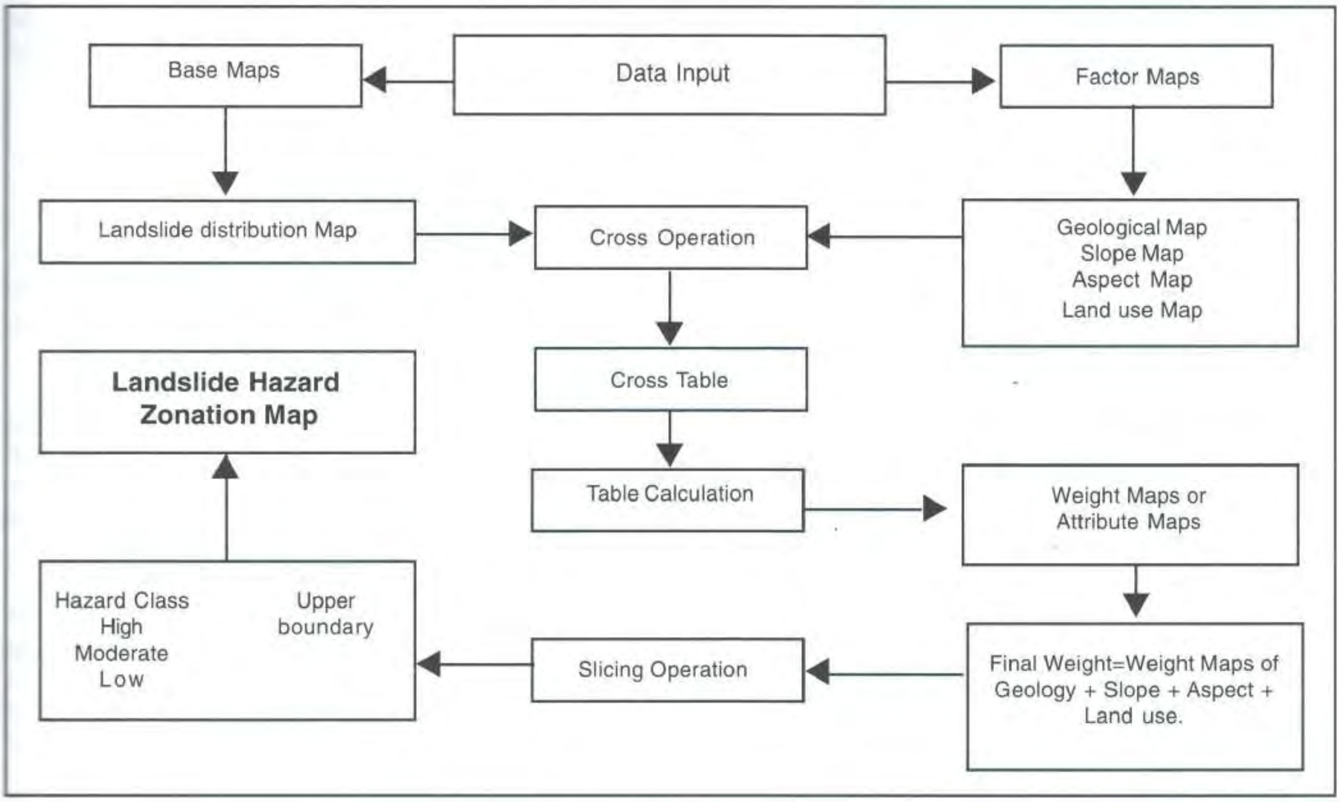


Fig 2. Landslide Hazard Zonation Map in Some Parts of Kaski, Myagdi and Parbat Districts



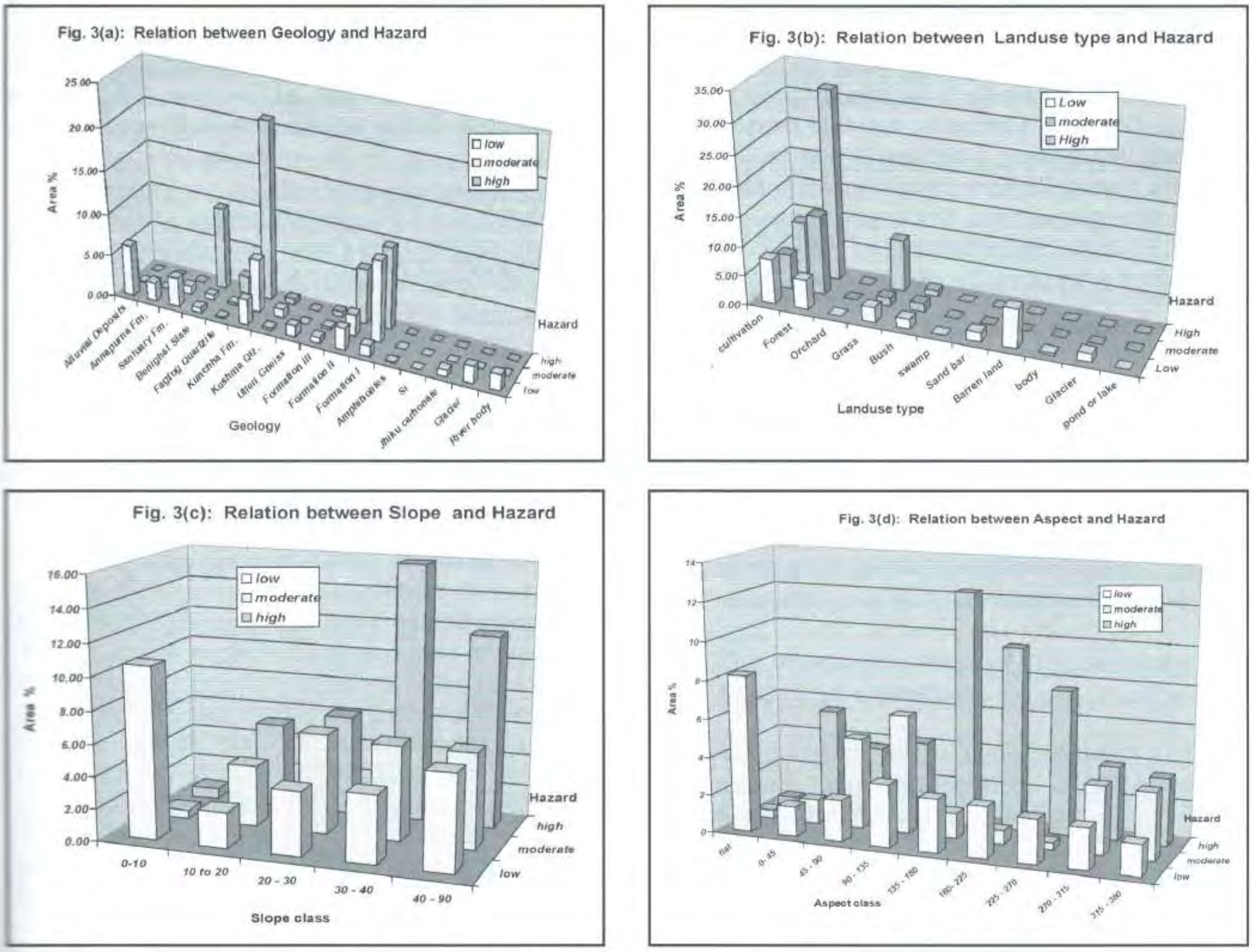


Fig. 3. Bar diagrams showing the relation between hazard categories and various causative factors

in moderate hazard zone and only 3.30 percent in low hazard zone.

The landslide hazard zonation map shows that about 344 sq. km. covered by highly unstable zone forming 50.76% of the total study area whereas about 22.28% area are on moderate hazard zone and the rest 26.99% in low hazard zone.

The landslide hazard zonation map provides a good geo-scientific base of the study area including some trekking routes around Annapurna sanctuary of national interest for the planners, policy makers and land developers in minimizing the risk of hazards and protecting the environment.

This map is exclusively intended for planning 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 failure.

ACKNOWLEDGEMENT

The author is grateful to Mr. N. R. Sthapit, former Director General, DMG for supporting the field program and guidance. My sincere gratitude is due to Dr. R. B. Shrestha, Deputy Director General for his keen interest and valuable suggestions. Sincere thanks are also due to Mr. K. P. Kaphle, Superintendent Geologist for valuable suggestions while going through the report. My sincere thanks are extended to the staff members of Remote Sensing Section and other sections of DMG for fruitful discussions and cooperation.

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Annual Report of Department of Mines and Geology, 2007, No. 4, pp. 61 - 69

Landslide Hazard Mapping in Some Parts of Kaski, Parbat, Syangja and Tanahun Districts, Western Nepal

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INTRODUCTION

Nepal is well known for its mountainous area of unstable nature. The steep slopes, complex geology, young mountains and intense monsoon rain combine to make it one of the most landslide prone areas in the world. Besides causing severe hazards to infrastructures, landslides cause loss of human lives and properties every year resulting disruption to the social and economic development of the country. Landslide disasters may not be stopped but efforts can be made to reduce their impact. Landslide hazard zonation mapping will help to find the ways of mitigating landslide disaster. In this context Department of Mines and Geology (DMG) has been conducting landslide hazard zonation mapping in different parts of Nepal.

This paper describes about the preparation of landslide inventory as well as other factor maps required for the preparation of landslide hazard zonation map in toposheet No.62P/16 covering parts of Kaski, Parbat, Syangja and Tanahun districts. The area is bounded by latitude 28°00'00" to 28° 15'00"N and longitudes 83°45'00" to 84°0000"E (UTM coordinates 3097832.6E to 3125632.6E and 475382.92N to 500032.92N). About 650 sq.km. area was covered. The main settlements in the area are Pokhara, Syangja, Naudanda, Bayerghari etc. Well known tourist city Pokhara lie within the mapped area. Siddhartha Rajmarg links Pokhara, Syangja and Southwestern parts of the mapped area passing more or less diagonally from Northeast to Southwest. The remaining portion is accessible by fair weather roads and hill tracks.

The study area lies in midlands of western Nepal. It consists of mainly rugged terrain with ridges and valleys. Pokhara valley is conspicuous in the North-eastern part. The hill slopes in general are moderate to steep. The lowest elevation is 510m. above msl. in the southeastern part of the area near Kalikot and the highest elevation is 2517m. above msl. at Panchasedanda in the northwestern part. River terraces are developed along the banks of Seti River in the northeastern part of the mapped area. Pokhara city is located in those terraces. Seti River forms deep river gorge along its course in the eastern part of the mapped area. River terraces are also developed along the banks of Andhi Khola and Seti Khola.

OBJECTIVES

The objectives of the present investigation are as follows:

- to prepare landslide distribution map.
- to check landslides identified in the air photos, satellite imagery and locate new ones.
- to register major landslides in 'Landslide inventory forms'.
- to integrate landslide distribution map with factor maps.
- to identify major causes and recommend possible remedial measures.
- to prepare landslide hazard zonation map.

METHODOLOGY

- Aerial photographs at 1:50,000 scale were studied for lithological contacts, landslides, erosional features, tectonic features etc.
- LANDSAT-TM scene of December 1992 was examined for tectonic features.
- The topographic maps of 1:25000 scale (No. 2883 16A, 2883 16B, 2883 16C and 2883 16D) were studied for existing landslides, landuse and they were also used as base maps for field work.
- The topographic maps of 1:50,000 scale were examined for landslides.
- The Land capability, Land utilization and Land system maps published by LRMP, 1994 were studied for infomation on landuse.
- Existing geological maps and reports of the investigated area were reviewed.

All the field investigation data and information were in 1:25,000 scale topographic base maps in conjunction with aerial photographs. Field verification of the landslides identified during desk study was also carried out. Landslides were studied closely as far as practicable. Detailed information for major landslides was recorded in landslide inventory forms. The measurements were carried out by using a tape whenever possible. Eye estimation is made when the size of the landslides is too big or too far from the observation point. The field survey include walkover in the valleys as well as along the ridges. Traverse along the ridges proved to be the most useful for landslide mapping. Trees and hill slopes obscured the view of the landslide while walking along the valleys. Besides recording landslides, erosional features and land use types were also recorded in the base map.

GEOLOGY

Geological map of some parts of Kaski, Parbat, Syangja and Tanahun districts (toposheet No.62P/16) compiled by B.M. Jnawali and G.B. Tuladhar (1999) and published by Department of Mines & Geology was used for the present study. Rocks of Lower Nawakot Group and Upper Nawakot Group are exposed in the mapped area.

Kunchha Formation is exposed in the northeastern and northwestern parts of the study area. It consists of greenish-grey, argillaceous, gritty quartzitic phyllites with occasional quartzite beds (Piuri Khola Members). Pokhara town and Phewa Tal are surrounded by this formation. Few anticlinal structures trending along E-W directions can be observed within this formation. Fagfog quartzite is distributed in elongated form from Northwest to Southwest portion of the investigated area. It comprises of white to palegreen ripplemarked orthoquartzites with Sidhane Green Phyllite Member. Some lineaments can be observed in this formation. Dandagaon Phyllite is represented by greyishgreen to silvergrey phyllites, slates with very subordinate white quartzite beds. Rocks are dipping mostly towards south in this formation. Nourpul Formation consists of grey, green and purple phyllites/slates, pure to impure arkosic quartzites, pink & buff coloured quartzitic dolomites to dolomitic quartzite. Ripplemarks and mudcracks present. Transverse faults displace it at places. Dhading Dolomite is composed of grey siliceous dolomites often with stromatolites. It occupies mostly southern part. Benighat Slates are exposed in the southern part only and consist of dark grey carbonaceous slates with minor Jhiku carbonates. Debris flow deposits are exposed in the northeastern corner of the investigated area and consist of calcareous conglomerates and breccia with unsorted clasts of limestone with subordinate schists and gneisses. Alluvial deposits consisting of silt, sand, gravel and conglomerates are distributed in the floodplains of Harpan, Andhi and Seti khola etc. Faults and thrusts separate the geological formations at many places. Many anticlinal structures can be observed in the study area.

PREPARATION OF FACTOR MAPS

Four types of factor maps e.g. geological map, land use map, slope map and aspect map were prepared along with landslide distribution map. Landslide distribution map was prepared from field work and aerial photo interpretation with field-verification. Land use map was prepared from LRMP map, topographic maps, digital data and field verification. Slope map and aspect map were prepared from digital data of topographic maps using GIS.

APPLICATION OF GIS AND REMOTE SENSING

Satellite data help in identification of changes in the landscape and surroundings due to landslides. GIS has tremendous application potential in landslide studies due to its ability in effective data storage in digital format, data overlay, and quick data retrieval.

Data on landslide distribution, geology and landuse were all transferred to a single toposheet of 1:50,000 scale for minimizing error during digitizing. This toposheet was then scanned. Individual layers on geology, land use and landslide distribution were extracted from this scanned topographic map using ILWIS 3.2 software. Thus geological map (Fig.1), landuse map (Fig.7) and landslide inventory maps (Fig.9) were prepared in digital form. Slope map (Fig.3) and aspect map (Fig.5) were prepared from digital contour data using ILWIS and DEM.

RELATION BETWEEN LANDSLIDE INVENTORY MAP AND FACTOR MAPS

In order to find out relation between landslide inventory map with different factor maps, landslide inventory map was crossed with factor maps. Map crossing results in cross tables. Percentage of landslides in different parameter class was calculated from cross-tables. Relation between landslides and different parameter class were presented in graphical forms with the help of cross tables. Fig.2 shows relation between landslides and geology. Most of the landslides are located in Kunchha formation. Similarly Fig.4 shows that most of the landslides favoured the slopes in between 20° and 40°. Fig.6 indicates that most of the landslides occurred in South facing slopes and Fig.8 shows that most of them have taken place in cultivated land.

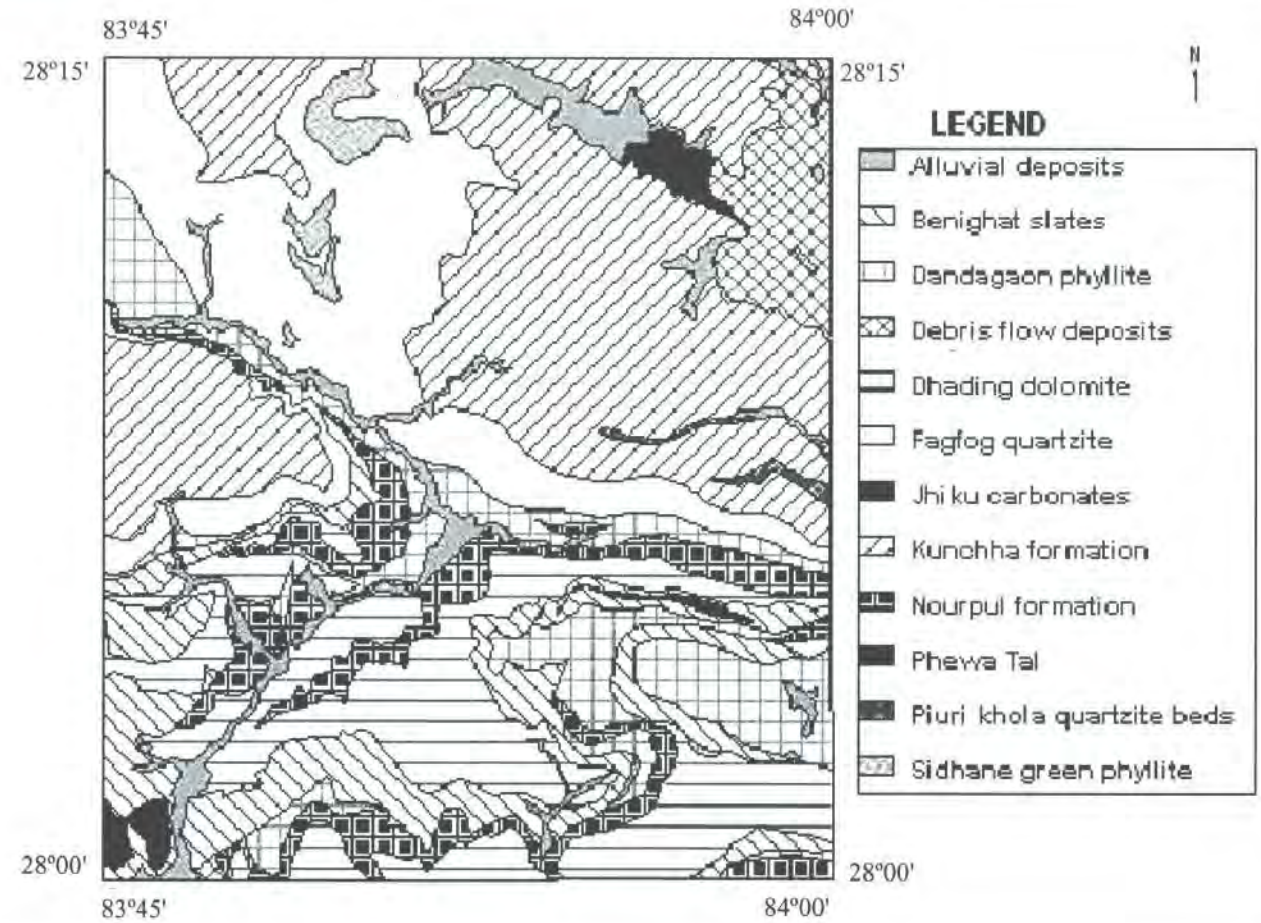


Fig. 1: Geological map of the investigated area

LANDSLIDE HAZARD ZONATION MAP PREPARATION

Landslide hazard zonation map was prepared using the GIS based bivariate statistical method (Westen, 1993) with quantitatively defined weight values. Weight value was obtained using landslide index method. The weight given to a certain parameter class was calculated by:

The crossing of landslide distribution map with four factor maps namely geological, land use, slope and aspect map using GIS results in cross tables as mentioned above. Hazard weight value (Wi) for a certain parameter class is calculated by cross table calculations using the expression as shown above. Weight value map or attribute map for each factor map was prepared based upon cross table calculations. All the attribute maps were combined and the landslide

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

Where,

W_i = Weights given to a certain parameter class

Densclass = Landslide density within the parameter class

Densmap = Landslide density within the entire map.

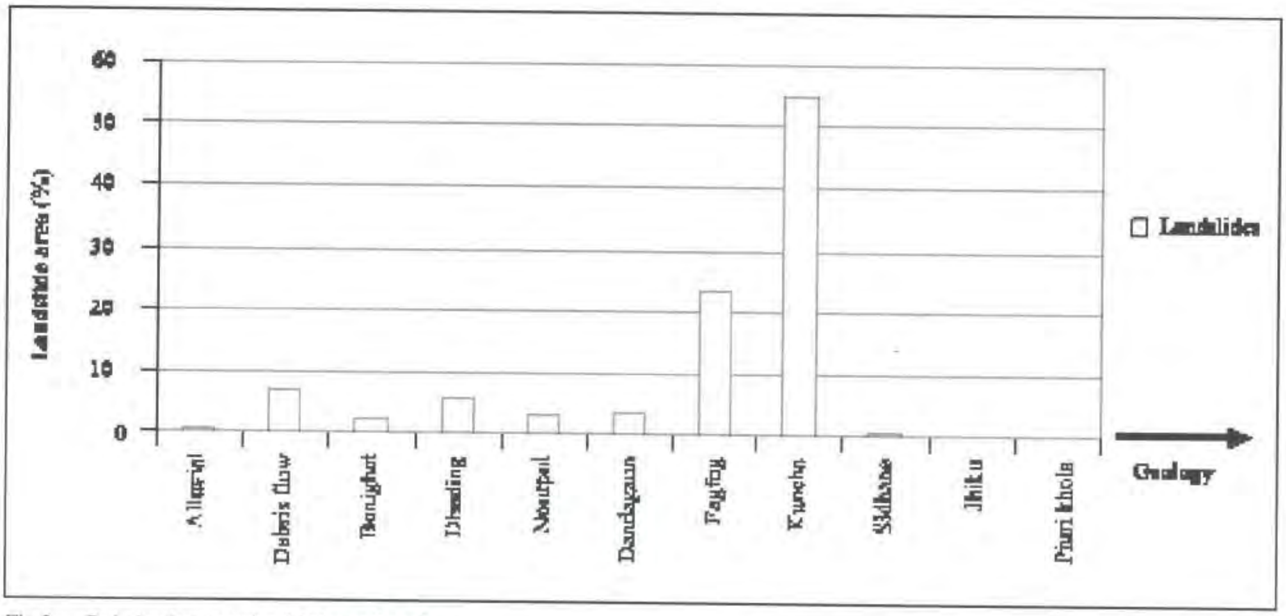


Fig.2: Relation between landslides and geology

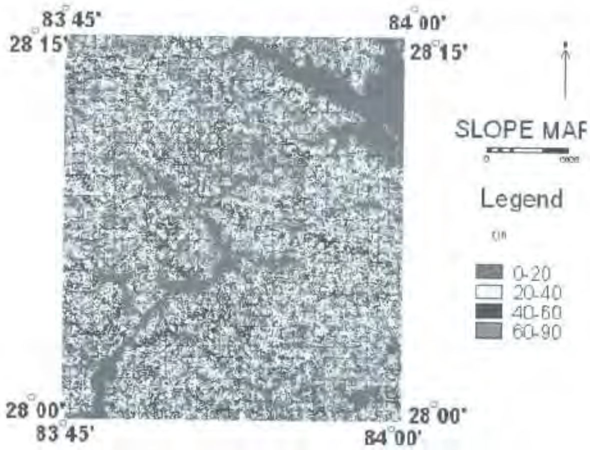


Fig.3: Slope map

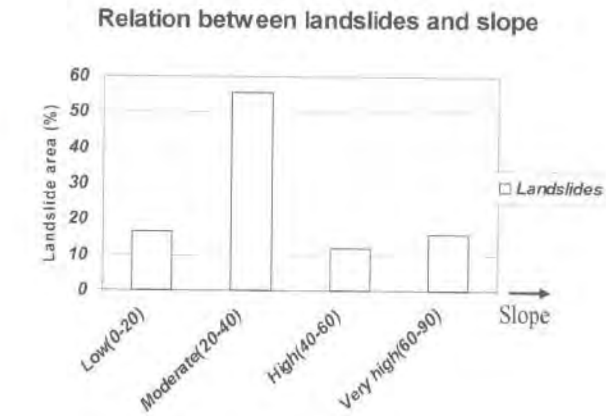


Fig. 4: Relation between landslides and slope

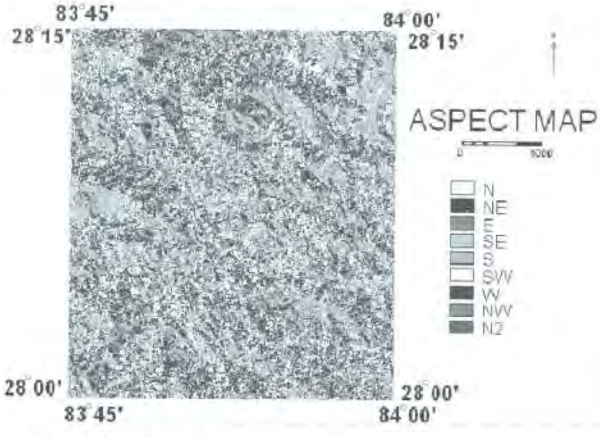


Fig. 5: Aspect map

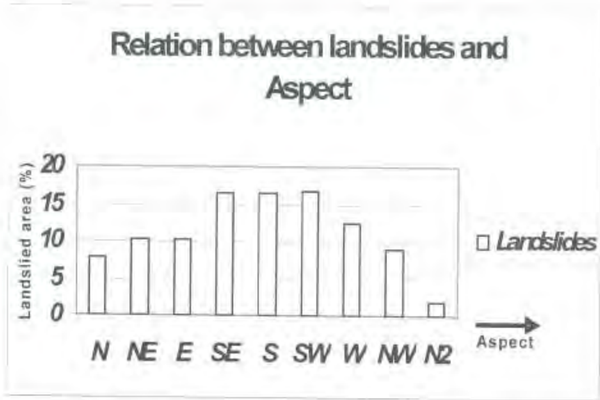


Fig. 6: Relation between landslides and aspect

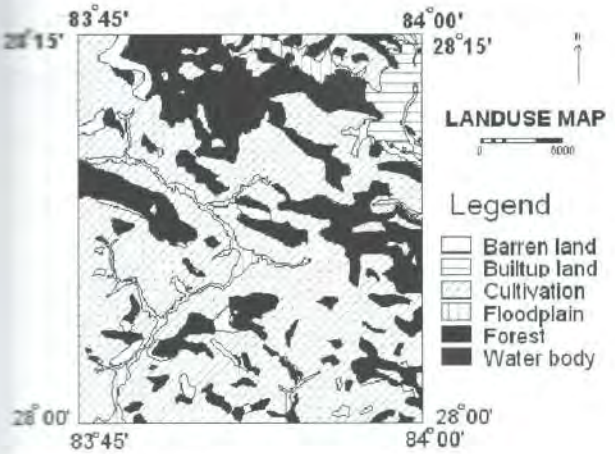


Fig.7: Landuse map

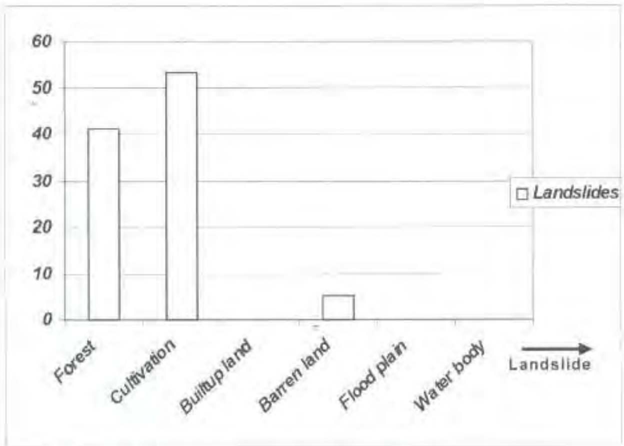


Fig. 8 Relation between landslides and landuse

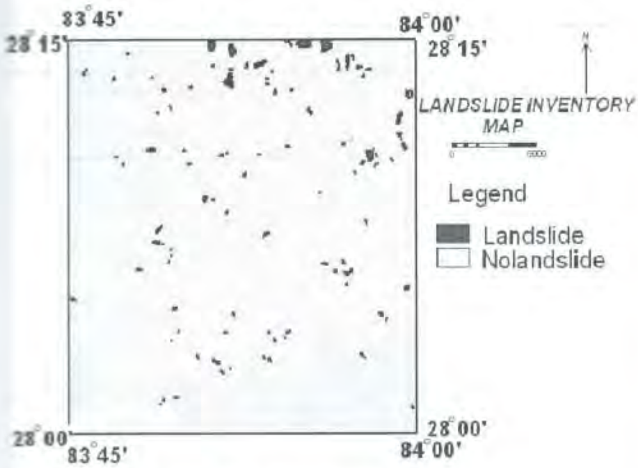


Fig. 9: Landslide inventory map

Fig.10: Steep slopes along Seti River

hazard zonation map was prepared (Fig.15) by classifying the final weight map into low, medium and high hazard zones.

RELATION BETWEEN LANDSLIDE HAZARD ZONATION MAP AND FACTOR MAPS

Landslide hazard zonation map was crossed with factor maps to find out the relation between hazard zones and different factor maps. Fig. 11 shows that most of the high hazard zones lie in Kuncha Formation, which consists of phyllites and quartzites. Lanslides take place easily in phyllites due to smooth joint planes and impermeable nature of phyllites. Silvery luster on the surface of the phyllite due to the presence of micaceous material makes the surface very slippery resulting in low friction of planes. Fig. 12 indicates that most of the medium and high hazard zones fall in the range of 20° to 40° slope. Fig.13 shows that almost all of the aspect classes lie in the medium and high hazard zones. Fig.14 indicates that most of the high hazard zones lie in the cultivated land. Trees root hold soil mass intact, whereas deforestation and subsequent cultivation leads to loose soil mass, high percolation causing high moisture content that resulting high erosion and more possibility of landslides.

RESULTS OF STATISTICAL ANALYSIS

Landslide inventory map was crossed with landslide hazard zonation map in order to find out the total area of landslides percent in different hazard zones. Cross table calculations indicate that more than 86.5% of the total area of landslides lies in high hazard zones, about 12.6% in medium hazard zone and less than 0.9 % lie in low hazard zone. It indicates reliability and precision of the adopted statistical method. Out of the total map area 8% lay in the low hazard zone, 45.7% lie in the medium hazard zone and 46.3% lie in the high hazard zone.

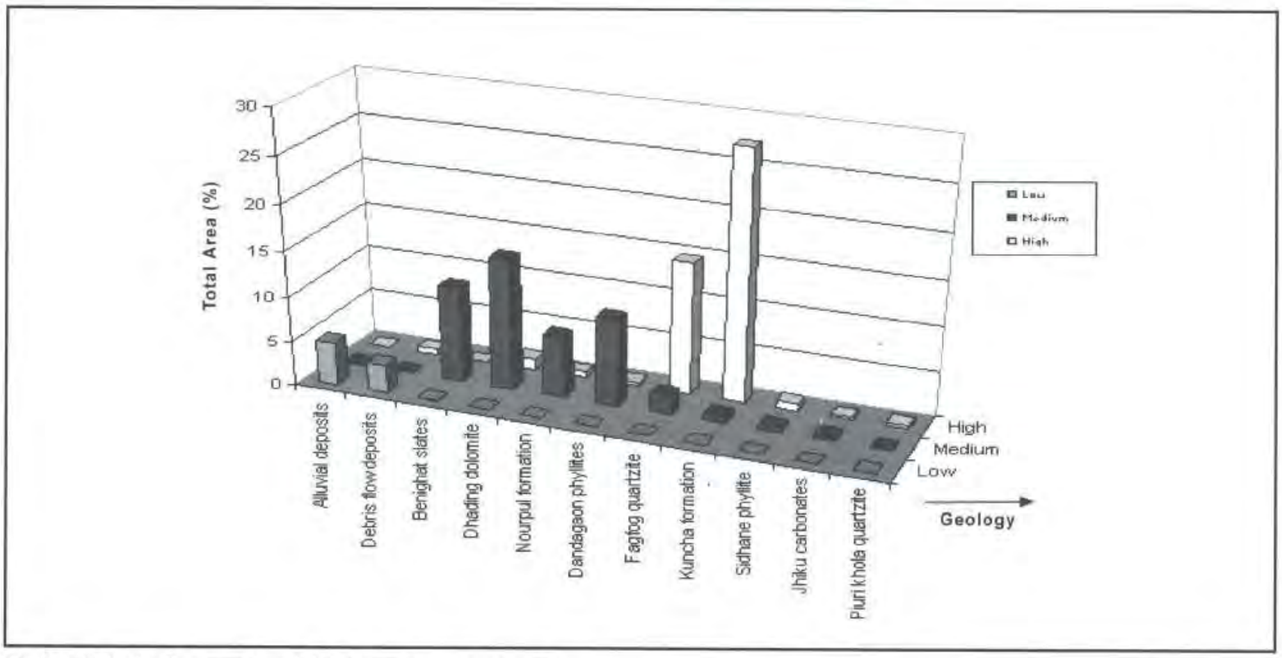


Fig.11. Relation between Landslide hazard zones and geology

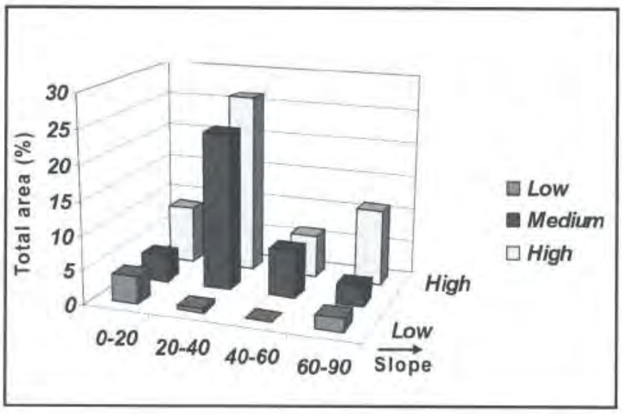


Fig. 12. Relation between landslide hazard zones and slopes

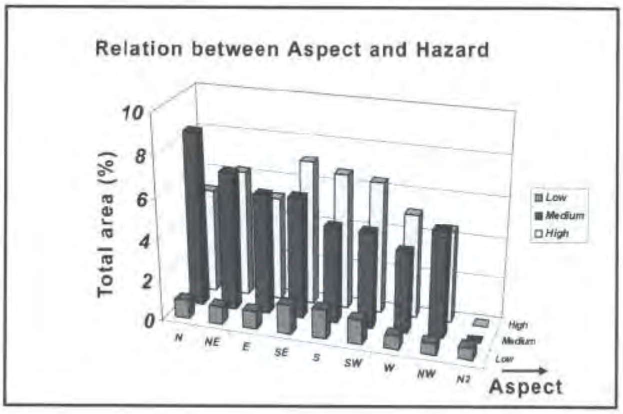


Fig.13. Relation between Landslide hazard zones and aspect.

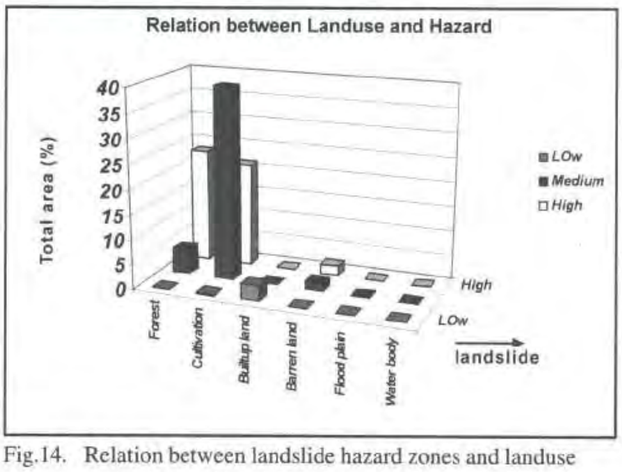
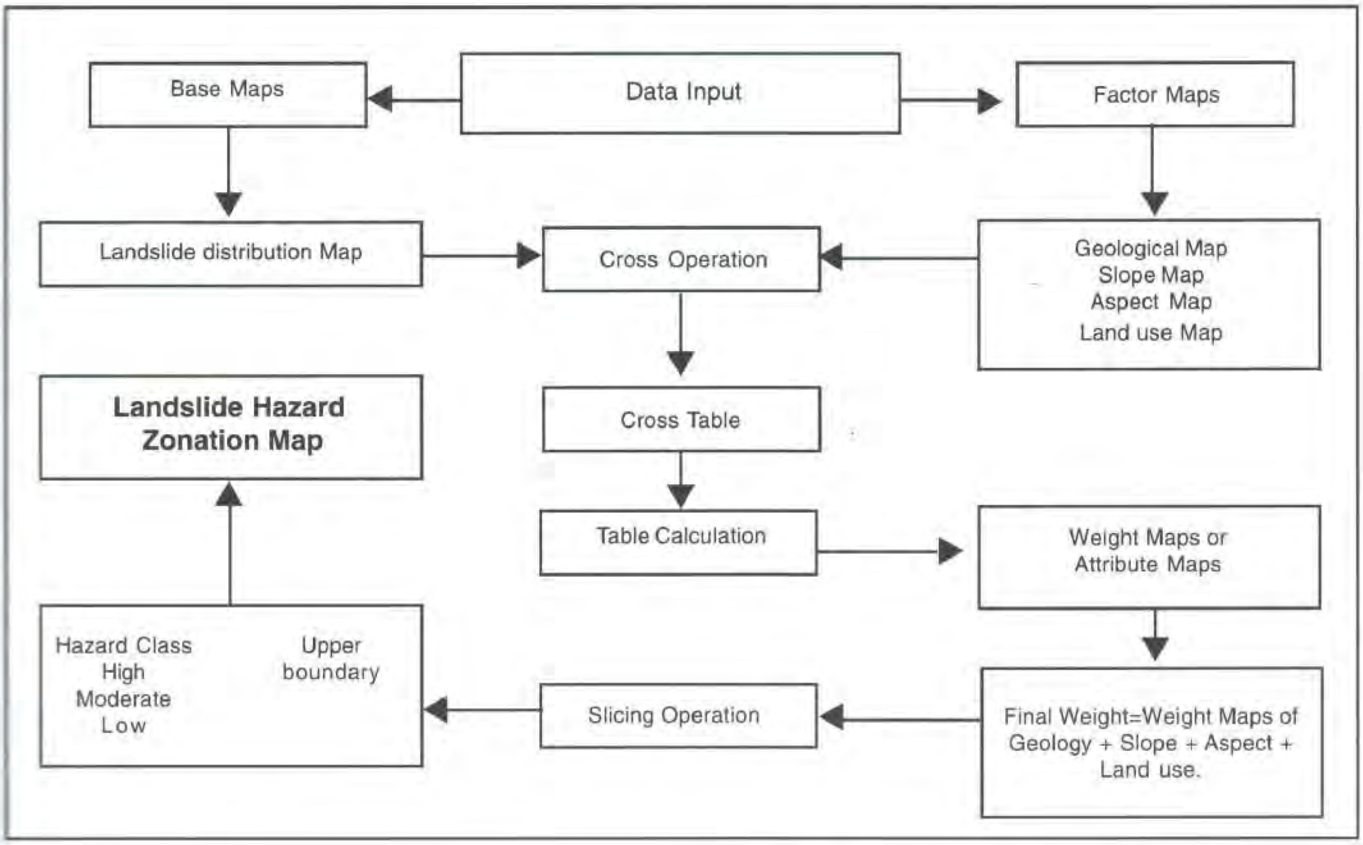


Fig.14. Relation between landslide hazard zones and landuse

FLOWCHART SHOWING PROCEDURE OF LANDSLIDE HAZARD ZONATION MAP PREPARATION



CONCLUSION AND RECOMMENDATION

Toppling failures and debris falls are common along the banks of Seti River.

Steep banks, toe undercutting and calcareous nature of the debris sediments are the main reasons behind failures along the banks of Seti River.

Most of the failures that took place in the mapped area fall in between 20° and 40° slopes.

South facing slopes seem to be more vulnerable to landslides as compared to North facing slopes. Rocks are dipping in different directions. So there is no clear relationship between dip direction and landslides. Detailed studies on joints may indicate the relationship between landslides and joint direction.

Kunchha formation is most prone to landslides in the mapped area probably due to smooth planes of phyllite planes, joints and impermeable nature of phyllites.

Most of the landslides have taken place in the cultivated land. Cultivation in hillslopes is generally carried out in loose and porous colluvial soil. Hence most of the landslides have taken place in this type of landuse.

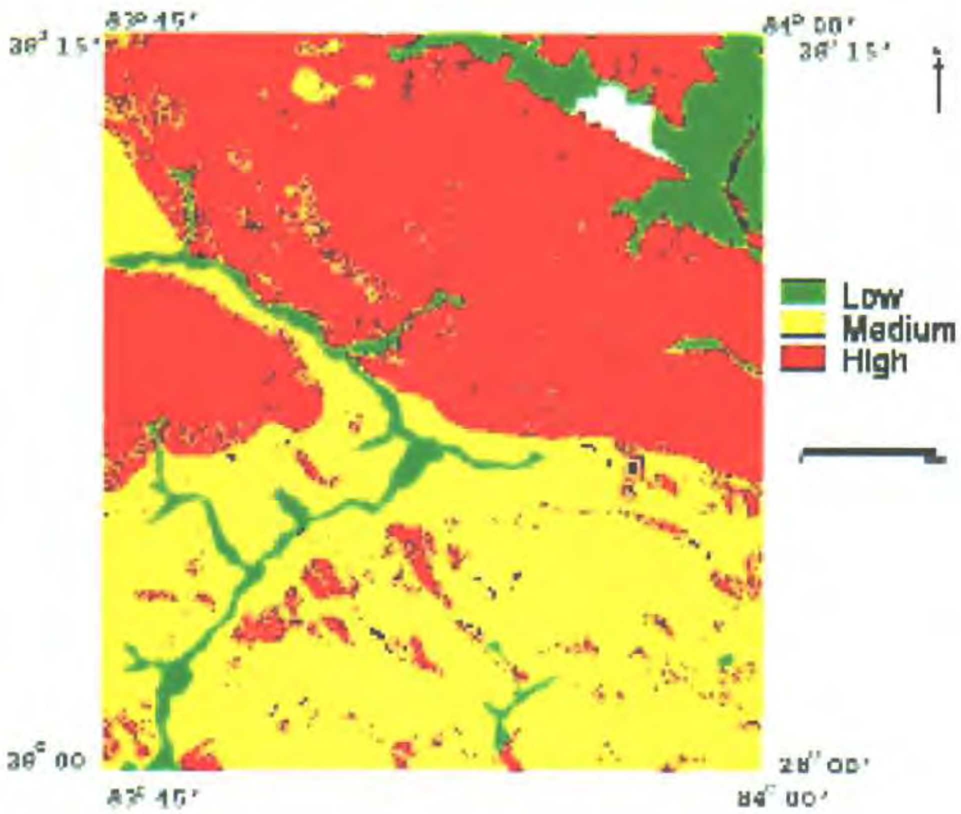
More than 86% of the area occupied by landslides fall within high hazard zone, which indicates reliability of this bivariate statistical analysis.

Landslides in the mapped areas occurred due to natural as well as man-made causes like deforestation, cultivation on colluvial deposits, improper hillslope cultivation, unfavourable discontinuity planes, high degree of weathering, toe erosion etc.

Since landslides are mostly triggered by rainfall, rainwater should be diverted from the landslide area by constructing catch drains and appropriate drainage system within the landslide zone.

Public awareness on the negative impact of deforestation, improper drainage, overgrazing, causes and impacts of landslides etc should be increased.

Landslide hazard zonation map will be useful for planners and decision makers for infrastructure development planning.



EXPLANATORY LEGEND

The landslide hazard zonation map was prepared by adding the weighted values of four maps (Geology, Landuse, Slope and Slope Aspect). The weighted values were derived by statistical analysis based on the ratio of landslides within each unit of the factor maps. The zonation classification in low, medium and high hazard is based on weight values ranging from -4.6 to 6.5.

Hazard class	Damage	Remarks and Recommendation
Low	Very few small landslides. River bank collapse and deposition of debris in low land area during wet season.	Usually stable, suitable for constructions on built up land. At present limitations may be imposed by soil conditions and other hazards like river bank collapse and seismic events.
Medium	Possibility of initiation of new and reactivation of old landslides. High susceptibility of sliding on cultivated land steeper than 20°.Magnitude of instability variable. Possible damage to infrastructure and cultivated land.	Urban development possible if appropriate safety measures are taken. Heavy construction needs detailed investigation. Proper irrigation required and water should not be diverted into slide areas. Proper selection of road alignment required. Natural and man made activities may cause slope instability.
High	High density of active and old landslides. High risk to human life and property, loss of soil and arable land likely.	Limited stable areas available for infrastructure

Fig. 15. Landslide Hazard Zonation Map.

ACKNOWLEDGEMENT

The author is grateful to Mr. P.L.Shrestha, Director General, DMG for all the facilities provided to the field activities and in the office while preparing the paper. I would also like to expres my sincere gratitude to Dr. R. B. Shrestha, Deputy Director General and Mr. K. P. Kaphle, Superintendent Geologist for their valuable comments while going through the manuscript. My sincere thanks are extended to all the members of Remote Sensing Section, Urban and Envoronment Geology Section, Geological Mapping Section and Engineering Geology Section for their fruitful discussions and cooperation.

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Annual Report of Department of Mines and Geology, 2007, No. 4, pp. 70 - 76

Geology and Natural Hazards Around Muktinath Area, Mustang District, Western Nepal

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INTRODUCTION

Muktinath Temple is located in Mustang district of Western Development Region (Fig.1). The temple is situated at an altitude of about 3800m. above mean sea level in Muktinath village. It was constructed in 1815 B.S. (Marashini, K., 2004). Jhon Khola (a tributary to Kaligandaki) is the main stream (Khola) in the study area. Thoron Khola, Madek Dumda Khola, Jhamlumba Khola and Tangarghiu Khola are the tributaries of the Jhon Khola. The lowest elevation in the area is 3444m. near Jharkot village and the highest elevation is 4663m. in the hill located to the south east of Muktinath Temple. The investigated area lies between latitudes 28º 45' 00" N to 28º 55' 00" N and longitudes 83º 50' 00" E to 83º 55' 00" E (Topo Sheet No. 2883 04 scale 1:25,000, Survey

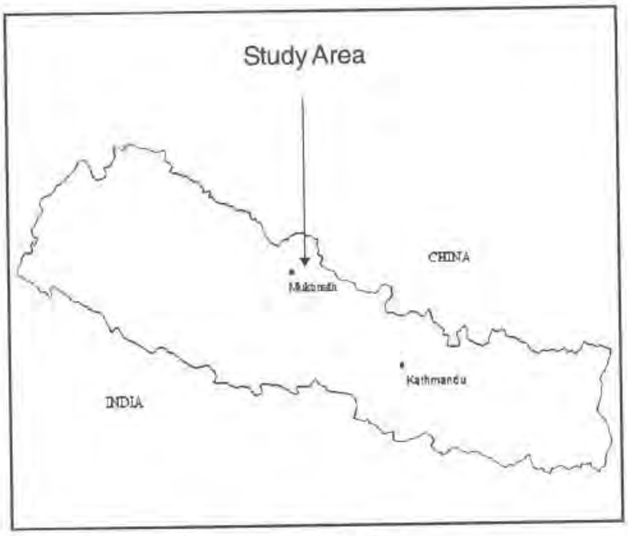

Fig.1. Location Map of the Study Area

Department, Government of Nepal). The slopes are mainly dipping due west to northwest near the temple. There is sparse vegetation and slopes with gentle to moderate steepness are cultivated. Major settlement areas are Ranipauwa, Chhyongur, Jhori and Jharkot. River bank erosion and slope wash processes are active. The area falls under the rain shadow zone Therefore the monsoon rain does not fall in the area. However, occasional rainfall occurs and the area remains dry in most of the time every year.

Mustang District Administration Office had reported the Department of Mines and Geology (DMG) about the severe slope failure processes and soil erosion around Muktichhetra in 2004. It had also requested to DMG to investigate the area and find out the reasons of soil erosion, mass movement and crack development in the temple premises and to recommend the appropriate remedial measures to minimize the effect of mass wasting in the area. In this regard, DMG investigated the area in the fiscal year (2005/06) under its annual program. Geological study was conducted around the Muktichhetra covering about 25 sq. km. area during the month of May 2006.

PREVIOUS WORKS

Geologically the study area lies within the Tibetan-Tethys Zone. Pioneering geological studies were carried out by Gansser (1964), Fuchs (1967), Hagen (1968), Colchen et. al. (1986) as mentioned in Gradstein et. al. (1992). These workers have provided stratigraphical framework of rock units of this area. Major tectonic structure known as the Thakkhola Graben, which extends in north south direction is located close to the Muktinath Temple. Upreti et al (2005) described the geology and natural hazards along the Kaligandaki valley including the Kagbeni-Muktinath section. This study had also revealed that the prominent cracks developed in the Muktinath temple premises were due to slow movement of the ground (creep). The feature was named as Muktinath Creep. Marashini, K. (2004) prepared a development plan for Muktichhetra and proposed for a geological study of the area to find out the causes and mitigation measures of the soil erosion in the area. Annapurna Conservation Area Project (ACAP) has prepared a draft report for Physical Planning for Environmental Improvement of Muktinath area. The maps include the present landuse pattern and proposed landuse for future planning.

OBJECTIVE

Main objectives of the present investigation were to:

- Prepare a geological map of the area in 1:25,000 scale.
- Identify the types of hazards, their causes and effects.

- Delineate the hazard prone areas and recommend preventive measures to the concerned authorities.
- Discussion with local authorities and concerned personnel from related offices like District Administration Office, District Development Committee and Soil Conservation office in Mustang district during field visit and suggested them to work together to mitigate the hazard in order to save the holy temple and surrounding area.

METHODOLOGY

Available literature on geology and other related topics on Muktinath area were reviewed prior to field verification. Topographical map of 1:50,000 scales were enlarged to 1:25,000 scales for the preparation of geological map of the area. Topographical map at the scale of 1:500 was acquired from the ACAP in Jomsom to know the detail about topographical and other features of surrounding area of Muktinath Temple.

A number of traverses were taken in and around the Muktinath Temple. Soil types, thickness of loose materials and constituent material were examined. Rock and soil units were identified and plotted on 1:25,000 scale topographical maps. Areas covered by more than 1m. thick loose sediments were mapped as Quaternary Deposit. Bedrocks are exposed only towards north, northeast and southeastern parts of the area (Fig.2). Bedrocks of the Spiti Formation are well exposed in the periphery of the temple (Figs.3 and 4).

GEOLOGY OF THE AREA

Quaternary sediments were derived from erosion of rocks and slope failure processes of the surrounding hills. The moraine deposits are distributed around Muktinath (Fig.2). The sediments derived from the hills are located to the eastern, southern and southwestern side of the temple. Such deposits are colluvial, glacial and or alluvial in nature. Bedrocks such as limestones, sandtones and shales are also present in the area. These rock units are of Lower to Upper Jurassic in age. They are named as the Quartzite Formation (qt) Jhomsom Formation (jm), Lumachelle Formation (lm) and the Spiti Formation (sp). However, these rock units have been named by Colchen et al. (1986) in Upreti and others, (2005) as Quartzite Formation (r), Jhomsom Formation (l), Lumachelle Formation (d) and Spiti Formation (m).

A. Quaternary Deposits

Colluvial Deposits (Co) are distributed mainly along the foot of the hill slopes (Fig.2). These deposits are composed of angular rock fragments derived from the nearest hills and almost all devoid of matrix. They are loose, highly porous and unstable.

Debris materials brought by melting glaciers were deposited along the river valleys as **Glacial Deposits** (**Gl**, Fig.3). This deposit consists of angular to sub-angular rock fragments of the catchment area. They are ill sorted, supported by sandy matrix and less permeable but more stable than colluvial deposits.

Glacio-lacustrine Deposits (Gll) are dominantly fine sediments consisting of clay, silt, sand with few boulder and gravel. These deposits are distributed near the banks of Jhon Khola (Fig.3). Deposition of finer sediments in this area seems to have taken place in the localized lacustrine environment.

Alluvial Deposits (Al) form river terraces by the sides of the rivers/streams (Fig.3). It consists of well-rounded rock fragments as boulder, pebble, sand and clay materials derived from the catchment area of the rivers. These deposits are matrix supported, but fairly permeable and relatively stable.

B. Bedrocks

Quartzite Formation (qt)

This Formation is of upper Triassic in age (Colchen et al. 1986 in Upreti and others, 2005). The Formation is composed of thick-bedded quartzite with interbeddings of grey shale. Rocks are exposed to the southeastern hills of the Ranipauwa village (Fig.3).

Jomsom Formation (jm)

Jomsom Formation of lower Jurassic age is represented by dark grey micritic and oolitic limestones interbedded with grey sandstone and black shale. These rocks are

Fig. 2. An overview of Muktinath Temple area viewed from Ranipauwa

well exposed on the hill to the southeast of Muktinath Temple (Fig. 2). Rocks are well bedded, highly jointed forming wedges. Such wedges on slope produce plenty of detached rock blocks, which slide down to the foot of the slopes forming colluvium deposits. Limestones of the Jomsom Formation are juxtaposed with the shales of the Spiti Formation along the east side of the normal fault of the Thakkhola Graben located to the east of the Muktinath Temple (Figs. 3, 4 and 5).

Lumachelle Formation (lm)

This Formation is of middle Jurassic (Upreti et al., 2005) in age. It is represented by dark grey, fine-grained limestone intercalated with shale. Rocks are well

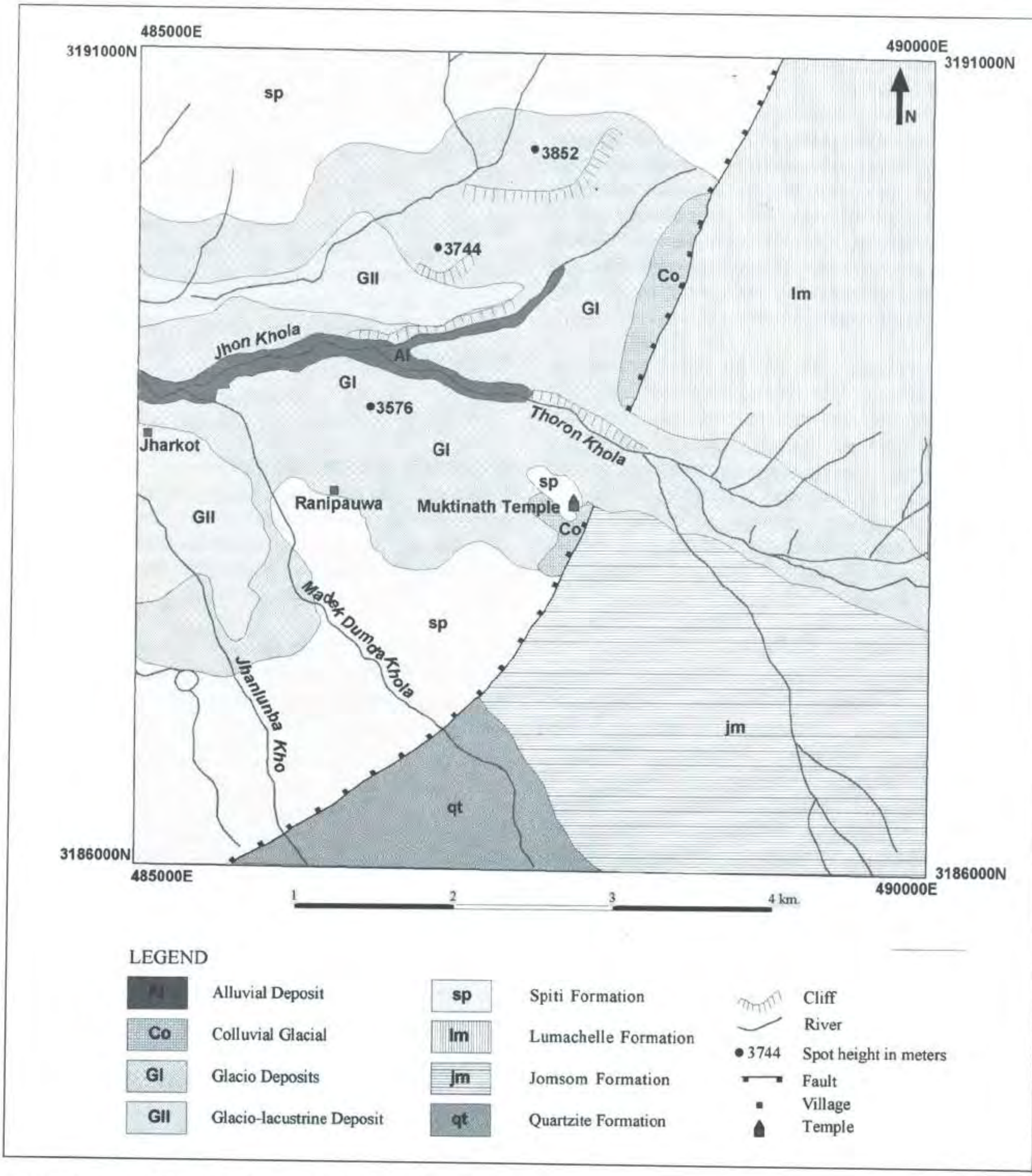

Fig. 3. Geological Map of study area (Modified after Upreti et. al., 2005)

exposed on the hill to the northeast of Thoron Khola (Fig. 3), a tributary to Jhon Khola.

Spiti Formation (Sp)

The age of this Formation is upper Jurassic. It is represented by pencil-cleavage splintery black shales with thin layers of dark grey limestone. Calcareous concretions of light yellow to dark brown colour are often aligned parallel to the cleavage plane. This formation is rich in ammonite fossils (Saligram in Nepali language). It is well exposed near the Muktinath Temple, Ranipauwa and Jharkot area (Fig.6).

NATURAL HAZARDS

Loose colluvial and glacial materials are distributed around the Muktinath Temple. The ground in the periphery of the temple is made up of about 1-2m. thick (Figs. 4 and 6A,) loose colluvial deposit underlain by black shales of the Spiti Formation (Fig. 6). There is a continuous inflow of surface water from the surrounding sources in the underground (Fig. 7) creating water-saturated condition. Some parts of the inflowing water come out in the low-lying areas and the remaining water is retained in the voids between the soils. The retained water is helping to deteriorate the bearing capacity of the substratum soil in two ways:

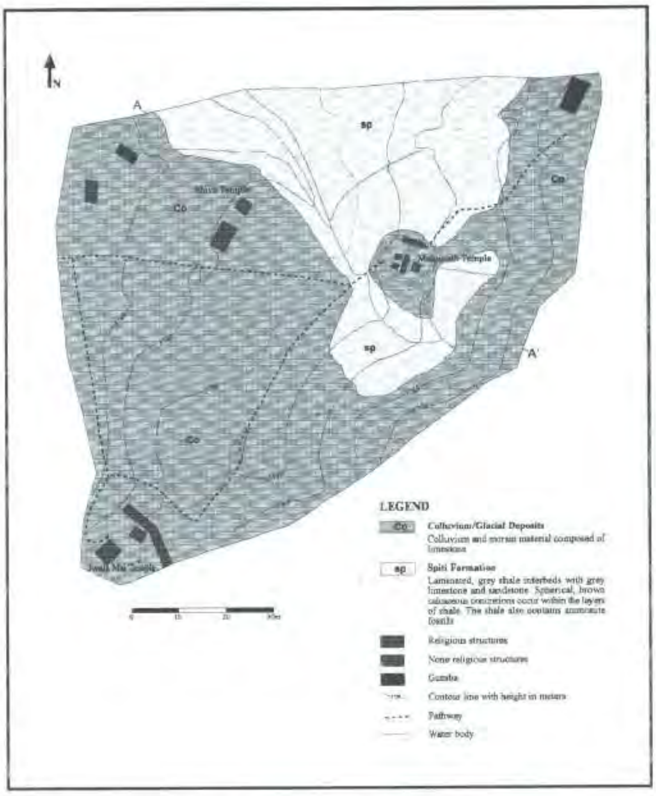

Fig. 4. Geological Map of Muktinath Temple area.

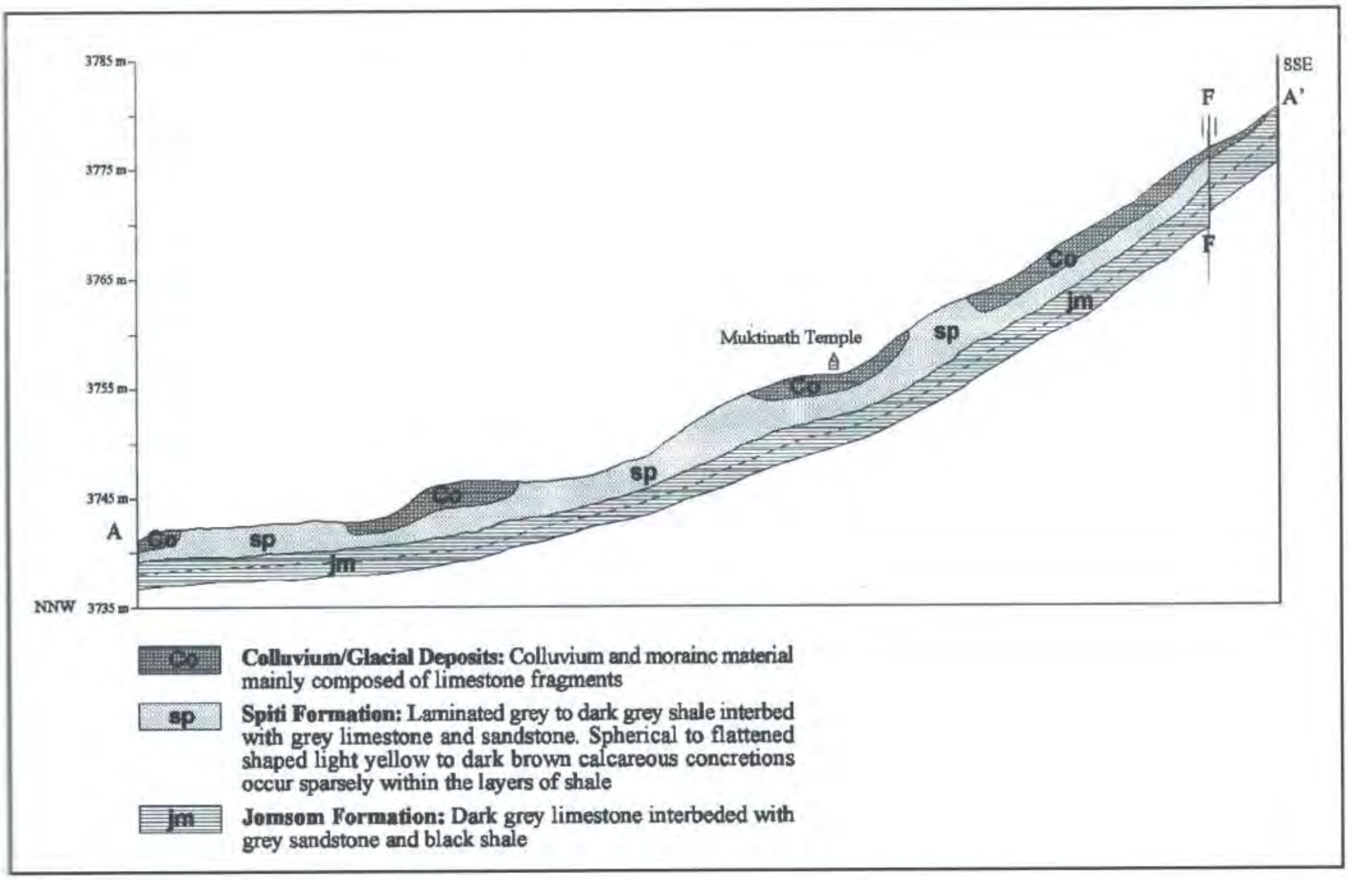

Fig. 5. Geological Cross Section along A-A'.

1. Increase and decrease in volume of retained water during winter and summer seasons due to freezing and thawing action by drastic climatic variations.

2. Reducing the bearing capacity of the soil by saturation.

The above mentioned process of freezing and thawing will ultimately create instability conditions by increase and decrease in volume within the soil mass that holds infrastructures such as temples or other buildings. As a result cracks are developed in such structures (Figs. 8, 9 and 10). This process is acting in the Muktinath temple area and the cracks are developed on the walls of the temple and other structures. According to Mr. Hira Bahadur Thakuri, Chief of Muktinath Monastery, prominent cracks were developed in the last ten years after the renovation of the temple. Existing clay lining at the base of the pond located behind the temple and other waterways were replaced by cement during the renovation. Infiltration of surface water seems to have been accelerated while replacing the clay liner and that could be another cause of crack development.

Surface water is also infiltrating into the underground in other locations of the Muktinath area such as near Jwalamai Temple, holy ponds located within the temple premises and septic tanks of the toilets.

Masonry walls being constructed in front of the Muktinath Temple may obstruct the out flow of ground water creating waterlogged situation in the foundation of the temple.

Construction materials such as blocks, boulders and aggregates are being excavated from the upper and lower slopes of the Muktinath Temple. Such activities will endanger the stability condition of the slopes. As a result landslides might be initiated in these areas causing severe slope instability and landslide problems in future.

CONCLUSION

The Muktinath Temple is founded on loose, highly permeable colluvium material, which is underlain by intensely fractured, impermeable black shales of the Spiti Formation. Infiltrating water accumulates within the soil mass creating unfavorable saturated condition for the stability of the ground.

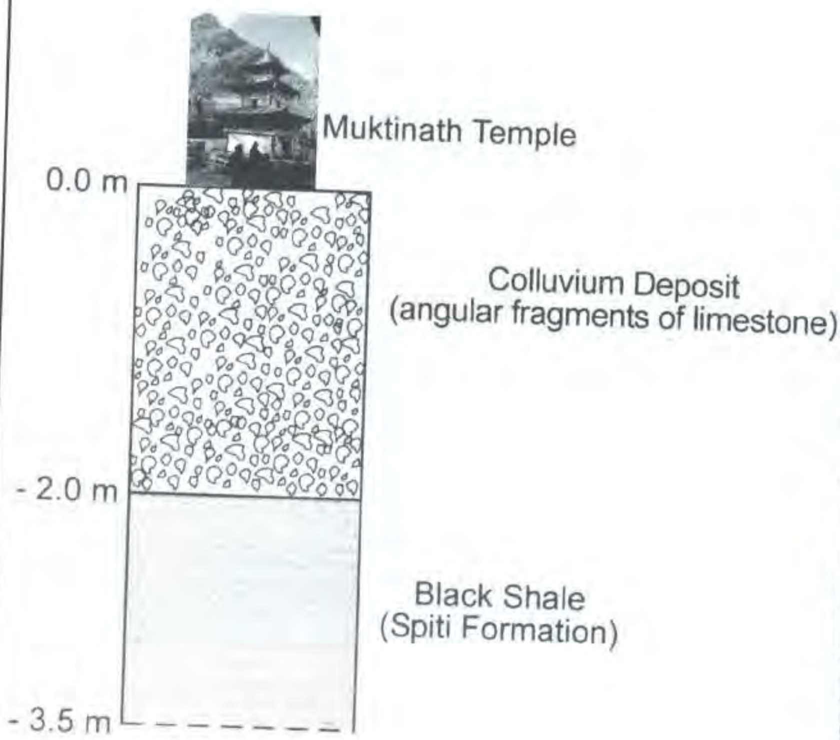

Fig. 6A. Soil Section observed in a trench in front of Muktinath Temple

Fig. 6B. Photographs of the section showing shales of Spiti Formation

Fig. 7. Perennial stream is flowing east to west near the Muktinath Temple.

Fig. 8. Close view of 108 holy spouts located behind the Muktinath Temple and diagonal cracks in the wall

Masonry walls constructed around the temple have no proper weep holes, which prevents water to flow out from the underground.

Excavation of construction material from the surroundings of the Muktinath Temple area is endangering the stability condition of the slope.

RECOMMENDATION

Soil erosion and other natural hazard processes endangering the stability condition of the temple area can be minimized by the following preventive measures:

- Excavation/extraction of stone blocks and aggregates from the nearby areas of the temple should be strictly prohibited. Stones can be taken by proper mining from the southern part of the helipad.
- Infiltrating water into the subsurface of the temple premises should be controlled by proper drainage such as horizontal drains and proper weep holes that allows the groundwater to flow out continuously.
- Leak proof surface drainage should be arranged from the temple premises to a distance of 50 m towards west to the natural river channel.
- Cracks in the temple premises should be sealed by cement to prevent from further infiltration of the surface water.

Fig. 9. Few mm. wide diagonal crack in the wall of the first entrance of Muktinath Temple.

Fig. 10. Damaged monument due to ground settlement located in front of the Muktinath Temple.

- Construction activities should be supervised by trained engineers/technicians and appropriate quality construction materials should be used.
- Proper drainage should be arranged to minimize the effect of percolating sewage water from the septic tanks of the toilets. All the septic tanks should be drained outside of the temple premises and properly managed to a distance of 500m in the down slope area.
- Small size trees should be planted to avoid disturbances in the underground soil by shaking of deep penetrating roots of large trees during strong winds.
- Surface water utilized for generating electricity is left uncontrolled on the surface of the slope below intake even if the plant is not operating. This could erode the ground and may trigger landslides in the long run. Therefore proper arrangement should be made to let the unused water to flow in its natural drain.

ACKNOWLEDGEMENT

The authors are grateful to Mr. N. R. Sthapit, former Director General, DMG for supporting the field program and guidance. Our sincere gratitude is due to Dr. R. B. Shrestha, Deputy Director General for his keen interest and valuable suggestions. Sincere thanks are also due to Mr. K. P. Kaphle, Superintendent Geologist for valuable suggestions while going through the report. We extend our sincere thanks to Mr. G.B. Tuladhar, Sr. Div. Geologist for his guidance. Our sincere thanks to Mr. Achyuta Koirala, Engineering Geologist for his creative suggestions.

We are thankful to Mr. Kashi Nath Marashini, Chief District Officer, Mustang District and Mr. Hira Bahadur Thakuri (Wangel Lama), Chief, Muktinath Monastery for their kind cooperation and valuable information. We are indebted to Mr. Kula Prasad Lamichane, Head, Primary School, Muktinath VDC, Ranipauwa and Ani of Muktinath Temple for their support during the field investigation. Our sincere thanks are extended to the staff members of Remote Sensing Section and other sections of DMG for fruitful discussions and cooperation.

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Annual Report of Department of Mines and Geology, 2007, No. 4, pp. 77 - 79

Geology of Dhulikhel - Sindhuli Road Section Between Bardibas - Dhungre Bhanjyang Area, Central Nepal

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INTRODUCTION

This field program was carried out in accordance with the annual field program of Petroleum Exploration Promotion Project/Department of Mines and Geology (PEPP/DMG) for the fiscal year B.S. 2061/62. The field program was scheduled to carry out geological investigation in the area and prepare geological section of a part of Bardibas - Dhungre Bhanjyang area of Banepa – Bardibas Road Section and adjacent areas Central Nepal. 50 line kilometer section measurements had been completed along the Pipal Bhanjyang road section and adjacent area.

The study area lies in the Sindhuli district and is bounded by 26° 58' 45" to 27° 16' 15" N latitudes and 85° 52' 30" to 85° 57' 30" E longitudes. It lies in the topo sheet nos. 2685 – 04B, 2785-12D, 2785-16B and 2785-16D published by the Survey Department, Nepal and the field investigation data were plotted on 1:25,000 scale Topo map.

Different Nepalese geologists have studied the area in connection with the regional geological mapping as well as mineral exploration work. Kayastha (1971) mapped the area in connection with the tracing of Phosphorite bearing horizon. Yadav (1984) traversed the area in connection with the radioactive minerals exploration in the Siwalik region. Subedi and KC (1994) studied the area in connection with geological section measurement and Petro geochemical sampling.

The study area is easily accessible and can be approached via East – West Highway from Bardibas. The Bardibas - Sindhuli road connects the East-West Highway at Bardibas and can also be approached from Banepa – Sindhuli Rajmarg.

OBJECTIVES

The objectives of the present investigation are:

- to prepare a geological map between Bardibas – Pipal Bhanjyang road section and adjacent area.
- to collect Petro- geochemical samples from the shale horizon to assess potential source, seal and reservoir rocks.

FIELD INVESTIGATION

METHODOLOGY

Geological mapping and section measurement was carried out using a topographic base map of 1: 25,000 scale. Traverses were made along the Sindhuli – Dhungre Bhanjyang section of Banepa - Bardibas road and adjacent area. Lithological units and structural features were identified. Geological section measurement was carried out using tape and Brunton compass. 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. The detailed study of the rock unit is to understand the source, seal and reservoir character of the formation. Samples were collected from the shale horizon of Lower Siwalik Formation as well as sandstone sample from the Middle Siwalik Formation for source and reservoir analysis.

GEOLOGY

The study area forms a part of Mahabharat range and Siwalik foot hills. The lower hill (Churia Range) forms an irregular terrain like ridge and valley consists of sandstone, shale, mud stone and siltstone etc. The higher mountain of the study area is Mahabharat Range of Lesser Himalaya and is composed of metamorphic rocks. The study area is drained by a number of rivers like Ratu Khola, Kamala Nadi, Gong Khola, Gadyauli Khola and Dhade Khola etc. The drainage pattern of the area is mainly dendritic.

The area under investigation consists of Siwalik Group and Metamorphic Group. The Siwalik rocks constitute the foothill Range of Churia Hill of Sub-Himalaya. The Metamorphic rocks constitute the Mahabharat Range of the Lesser Himalaya. The study area falls in the Petroleum Exploration Block No. 8, Rajbiraj (Fig.1).

The rock of Metamorphic Group is exposed in the northern part of the mapped area and thrusted over the rocks of Siwalik Group along the Main Boundary Thrust (MBT). The oldest rock of Metamorphic Group exposed in the study area consists of white massive quartzite, talcose phyllite, gritty phyllite interbedded with gritty quartzite.

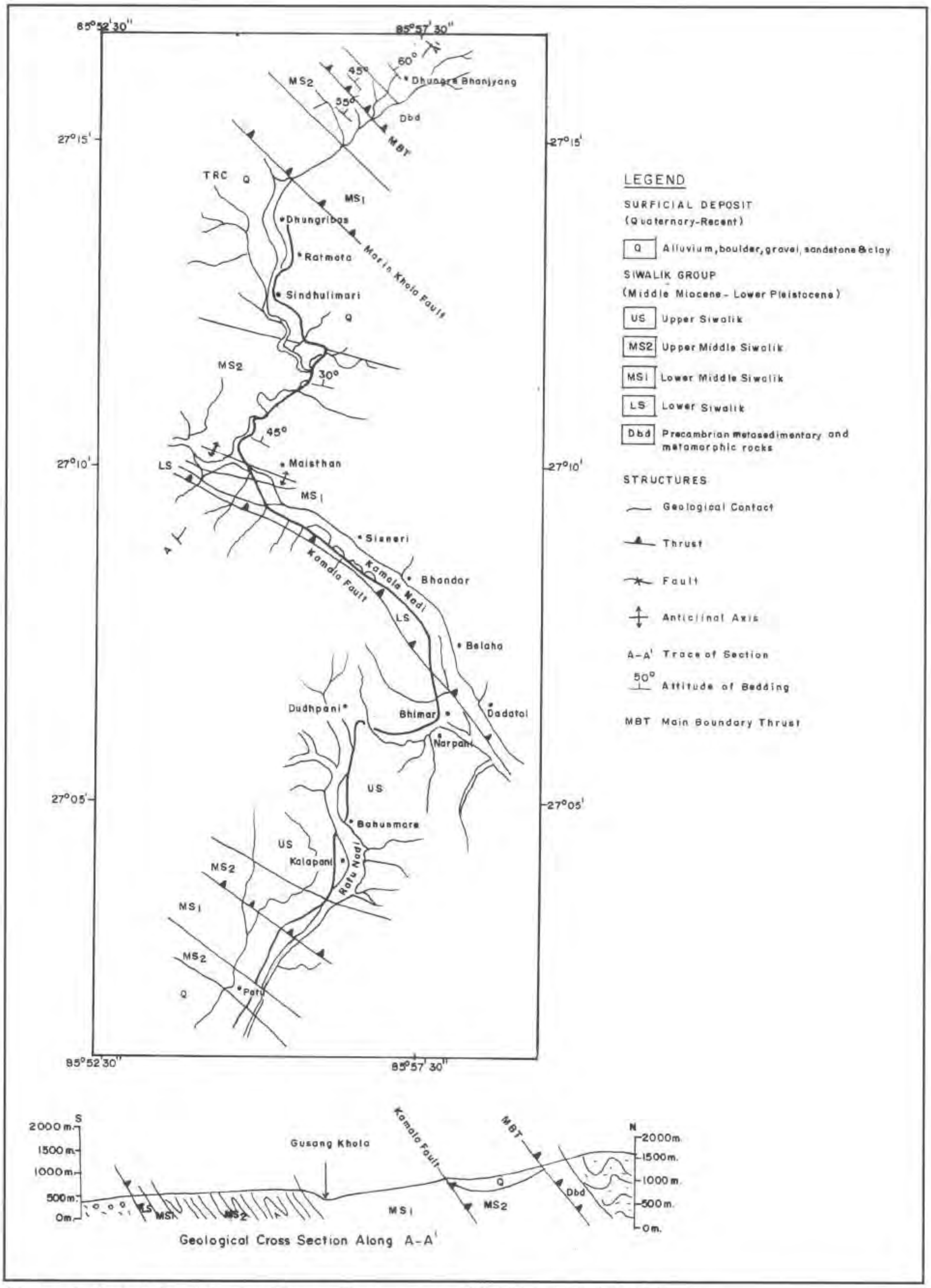

Fig. 1. Geological Map of Bardibas-Dhungre Bhanjyang Area of Dhulikhel-Sindhuli Road, Section.

The siliceous dolomite and argillaceous limestone are noted along the saddle of Dhungrebas and Hirapani Bhanjyang. The dark gray slaty phyllites are also noted with quartz lenses and veins along the foliation plane. The siliceous dolomite and argillaceous limestone are also interlayering within the phyllite and quartzite beds.

The youngest rock exposed in the study area is the rocks of Siwalik Group. This Group has been classified into three distinct units viz. Lower Siwalik (LS), Middle Siwalik (MS), and Upper Siwalik (US). Based on lithological character, the rocks of Middle Siwalik (MS) have 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. LS consists of fine to medium grained, light grey to grey sandstone, grey quartzitic sandstone and maroon nodular clay. MS1 consist of sandstone, mudstone, clay stone, siltstone and shale. MS2 is composed of grey to brownish grey arkosic sandstone, pebbly sandstone and claystone. US is composed of massive conglomerate, coarse grained micaceous pebbly sandstone and reddish brown clay. The rocks of Siwalik Group are bounded to the north by MBT and to the south by the Main Frontal Thrust (MFT) followed by Quaternary sediment.

In the study area, there are a number of major and minor folds and faults. The repetition of Siwalik bed observed in the study area is due to the folding and faulting nature of the formation. The major faults marked in the study area are Marin Khola fault and Kamala fault that causes the repetition of the Siwalik rocks. The general strike of the formation is NW-SE which is parallel to the general trend of the mountain chain and dip towards north east. At places the dip of the bed shows south westerly due to folding (Fig.1).

FINDINGS

Geological section measurement and petro-geochemical sampling was carried out in Banepa – Bardibas Section of Dhungre Bhanjyang – Bardibas area in the sedimentary rocks belonging to the Siwalik Group. The sedimentary rocks of the Siwalik Group are under the thick alluvium deposit in the south and separated from the rocks of Lesser Himalaya to the north by MBT. The metamorphic rocks are thrusted over Siwalik Group of rocks along the MBT.

Fifteen samples were collected from the shale horizon of Lower Siwalik Formation and sandstones from the Middle Siwalik Formation 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 Middle Siwalik were collected to evaluate the possible reservoir rocks analysis. Out of fifteen samples few selected samples are in process to be evaluated for hydrocarbon analysis.

CONCLUSION AND 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 sand stone beds to assess the sealing and reservoir potential in Siwalik rocks.
- Detailed geochemical and microscopic analysis is recommended to identify the source, seal and reservoir potential for the sample collected from the Siwalik Group.

ACKNOWLEDGEMENT

The authors are grateful to Dr. R.B. Shrestha, Former Chief, Petroleum Exploration Promotion Project for providing necessary facilities to conduct the field work. We would also like to thank Mr. Babu Raja Aryal, Project Chief, Petroleum Exploration Promotion Project, Mr. Krishna P. Kaphle, Superintendent Geologist, DMG and Mr. A.K. Duvadi, Senior Divisional Geologist, DMG for going through the manuscripts and valuable comments.

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Annual Report of Department of Mines and Geology, 2007, No. 4, pp. 80 - 84

Geological Section Along and Around Mirchaiya - Katari Road Between Mirchaiya - Patana Bhanjyang Ridge, Eastern Nepal

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INTRODUCTION

The field investigation was carried out in accordance with the annual field program of Petroleum Exploration Promotion Project, Department of Mines and Geology for the fiscal year 2062/63. Forty line km geological section measurements were carried out from Mirchaiya to Patana Bhanjyang Ridge. This study area lies in Dhanusha and Udayapur Districts and accordingly in exploration Block–8, Janakpur, Eastern Nepal. The study area had been covered by Topographic map of 1:25,000 scale of Survey Department, Government of Nepal. The area lies in sheet nos. 2686 02B, 2686 02C, 2686 06A and 2786 14D. The area lies in between latitudes 26°49'52" N to 27°02'30" N and longitudes 86°15'00" E to 86°25'00" E. The area is mountainous and exhibits rugged topography. The maximum altitude of the present study area is 998m. and minimum is 125m. from mean sea level. The area is mostly drained by one of the major river known as Kamala River. Tawa Khola and Maruwa Khola are the main tributaries of Kamala River. The main drainage pattern in the study area is dendritic type.

References for geological information can be made from the works of foreign and Nepalese geologists. Department of Mines and Geology have done regional geological mapping around the present exploration Block-8, Janakpur. Petroleum Exploration Promotion Project (PEPP). PEPP has completed the detailed geological section measurement and petrogeochemical sampling work in this area in various years. Hunting Geology and Geophysics (Pvt.).Ltd., (1984) had carried out photogeological as well as structural geological map of Terai, Churia and Lesser Himalaya. Petro-Canada International Assistance Corporation (PCIAC), 1989 has done seismic survey in the Terai plain of this area along the line 65. Pradhan, U.M.S. et al. (2004), have done the compilation of geological map of Petroleum Exploration block – 8, Janakpur eastern Nepal. Source and Seal study (1993) Project has also carried out geological study of Block–8 and also collected samples for the geochemical studies. Shrestha and Sharma (1993) had reported from the present study area the positive evidence of stratigraphic relationship between the Siwalik Group and pre–Siwalik rocks from the Sub-Himalaya.

OBJECTIVES

The main objectives of the present study area are:

- to prepare geological map and carry out geological section measurement of the investigated area.
- to collect the petrogeochemical samples from grey to dark grey shale horizon of Siwalik and Gondwana Groups

FIELD INVESTIGATION

METHODOLOGY

Geological Section Measurement was carried out using topographic base map of 1:25,000 scale. Traverses were made along Mirchaiya–Patana Bhanjyang ridge. Different lithological units and structural features were identified on the basis of field observations.

Brunton compass and tape Survey method (compass, measuring tape, hammer, chisel and altimeter) were used in the field to measure the road section. Rock sample were collected from the shale horizon of Lower Siwalik(LS), Lower Middle Siwalik (MS1) and the lower part of Charchare Formation of Gondwana Group.

GEOLOGY OF THE AREA

The study area comprised of sedimentary, meta-sedimentary and metamorphic rocks which can be divided into six different tectonic units as Terai (Quaternary sediments), Siwalik Group (Middle Miocene–Lower Pleistocene), Pre-Siwalik Group (Precambrian-Oligocene ?), Gondwana Group (Lower Carboniferous-Lower Cretaceous, (Pradhan et. al. 1998), Lakharpata Group (Pre-Cambrian to Early Paleozoic, (Kayastha, 1971) and Metamorphic Group (Pre-Cambrian), (Table-1).

Terai

Terai plain is the northern extension of the Indo- Gangatic Alluvium Plain. It extends from southern portion of Mirchaiya village to the Siwalik foot hills to the north. It consists of thick alluvium deposit derived from the higher

Table-1: Litho-stratighraphic succession of the area

Age	Group	Formation	Lithology
Quarternary – Recent			Alluvial, Gravels, Silt and Clay
Middle Miocene – Lower Pleistocene	Siwalik Group	Upper Upper Siwalik	Conglomerate claystone and mudstone
		Lower Upper Siwalik	Pebbly conglomerate, gritty sandstone and mudstone
		Upper Middle Siwalik	Medium to coarse grained sandstone, pebbly sandstone and siltstone
		Lower Middle Siwalik	Fine to medium grained sandstone, mudstone and claystone.
		Lower Siwalik	Fine grained sandstone, Siltstone, mudstone and nodular maroon Clay
Lower Carboniferous – Lower Cretaceous	Gondwana Group	Charchare Formation	Grey to dark grey carbonaceous slaty shale. Coating and occasional quartz vein.
Pre Cambrian – Lower Tertiary	Pre Siwalik	Pre-Siwalik	Purple shale, grey sandstone, quartzite and breccia.
		Gawar Formation	Grey Dolomite, cherty dolomite and grey shale.
		Ramkot Formation	Pink sandstone and quartzitic sandstone with purple shale.
Pre Cambrian – Early Paleozoic	Lakharpata Group	Dubbidanda Formation	Grey phyllite and white sericitic quartzite.
Pre Cambrian	Metamorphic Group		

mountains and deposited in the Terai plain. The alluvium sediment of Terai is considered to be of Quaternary to Recent age.

Siwalik Group

A thick succession of sedimentary rock of Siwalik Group is exposed along the road section. It consists of claystone, mudstone, siltstone, sandstone and conglomerates. On the basis of field relationship, Siwalik Group can be divided into Lower Siwalik Formation (LS), Middle Siwalik Formation (MS) and Upper Siwalik Formation (US). The Middle Siwalik Formation (MS) can be further differentiated into the Lower Middle Siwalik Formation (MS1) and the Upper Middle Siwalik Formation (MS2). The Upper Siwalik Formation can also be further sub divided into the Lower Upper Siwalik Formation (US1) and the Upper Upper Siwalik Formation (US2). The age of Siwalik Group is assigned as Middle Miocene-Lower Pleistocene. The Lower Siwalik Formation consists of claystone, mudstone, siltstone, purple shale, nodular maroon clay and fine grained sandstone. Sandstone of LS is thinly bedding and generally very fine to fine grained, light grey in colour. This formation is mainly exposed in Bhalu Khola, Katari Simla, Addakuna, and Phidi village. The MS1 consists of fine to medium grained sandstone with thin intercalation of grey to greenish grey siltstone, mudstone and claystone. The rock of MS1 in the study area is exposed in Churiya Mai, Badami Danda and Majhikharka. Its lower and upper contact is normal and gradational. The MS2 comprised of medium to coarse grained, grey, arkosic, pebbly sandstone with thin intercalation of grey mudstone, siltstone and claystone. Plant fossils are present in dark grey shale. Spheroidal weathering is present in greenish grey siltstone. It is exposed in Belsot Khola. Cross lamination is well developed. The US1 consists of grey, gritty sandstone, pipes and rod structure coarse grained sandstone, pebbly sandstone, conglomerates. Thick beds of yellow mudstone are found. Conglomerates are composed of rounded and subrounded pebbles and cobbles. It is well exposed in east of Belsot village. The US1 has normal contact with MS2. US2 overlies the US1. It consists of dominantly conglomerates with thin layer of micaceous sandstone. It is well exposed in east of Belsot Khola. Anticlinal structure is noted at Belsot village (Fig. 1). Its lower contact with US1 is normal and gradational. At some places the conglomerates contain earthy yellow matrix as cementing materials whereas in some places the conglomerates are much harder. The autochthon Siwalik Group is bounded to the north by the Main Boundary Thrust (MBT) and to the South by Quaternary or Main Frontal Thrust (MFT). MFT is concealed under the alluvium but on the sub surface it can be interpreted in the seismic section. The sandstone of Siwalik Group is medium grained, porous, permeable and could be of reservoir potential for hydrocarbon accumulation.

Gondwana Group

A thin exposure of carbonaceous shale has been reported in the north of the Lakharpata Group by earlier geologists and named as the Charchare Formation of Gondwana Group. The shales are slaty at places with a number of joints filled with calcareous materials. These carbonaceous shales are very soft and crushed. These rocks are presumed to be Lower Carboniferous – Lower Cretaceous in age (Pradhan et. al. 1998). The Para–autochthon comprising of sedimentary and meta-sedimentary rocks of the Gondwana Group are over thrusted along Gawar Formation of Lakharpata Group (Fig.3).

Pre-Siwalik Group

The pre-Siwalik sediments occur south of MBT in eastern Nepal. Pre-Siwalik rocks lying in direct contact below Siwalik sediments have been observed in the Katari area by the PEPP/DMG geologists during their 1992–93 field programs. These outcrops were visited by the source and seal study team. The outcrops contain red and grey clastic materials. There is a sedimentary contact of Lower Siwalik sandstones lying above stromatolite bearing carbonates of Gawar Formation of the Lakharpata Group. These carbonates (Shrestha, and Sharma, 1994) are first ever recorded south of the MBT. Herail and Mascale (1980) and Herail et. al. (1986) recorded sub Siwalik rocks at Kamala River which is not far from Katari. Cater (1989) has also observed sub Siwalik red, green and buff arkoses, shales and sandstones in the Katari area. Herail correlated these with Lower Miocene Murree. The Pre-Siwalik rock of Amtai Khola area is brought by a thrust passing along the Kamala-Tawa Thrust. The conglomerates consist of sub rounded to rounded pebbles of grey sandstone and banded quartzite at the base of LS.

Lakharpata Group

The Lakharpata Group is comprised of grey dolomite, pink sandstone, purple shale, green shale and grey limestone. This Group can be divided into two formations namely Ramkot and Gawar Formations in the present area (Kayastha et. al. 1971). The age of Lakharpata Group has been assigned as Upper Precambrian – Early Paleozoic (Pradhan et. al., 1998). In the northern part of the study area along Katari-Okhaldhunga Road from Haredanda to Patana Bhanjhyang ridge, this formation is faulted over Ramkot Formation. It consists of quartzitic sandstone, intercalation of purple shale (Fig. 2). Well

Fig.1. Anticline Structures in Lower-Upper Siwalik (US1) at Belsot Village

Fig.2. Pink quartzitic sandstone of Ramkot Formation of Lakharpata Group is exposed along the road section.

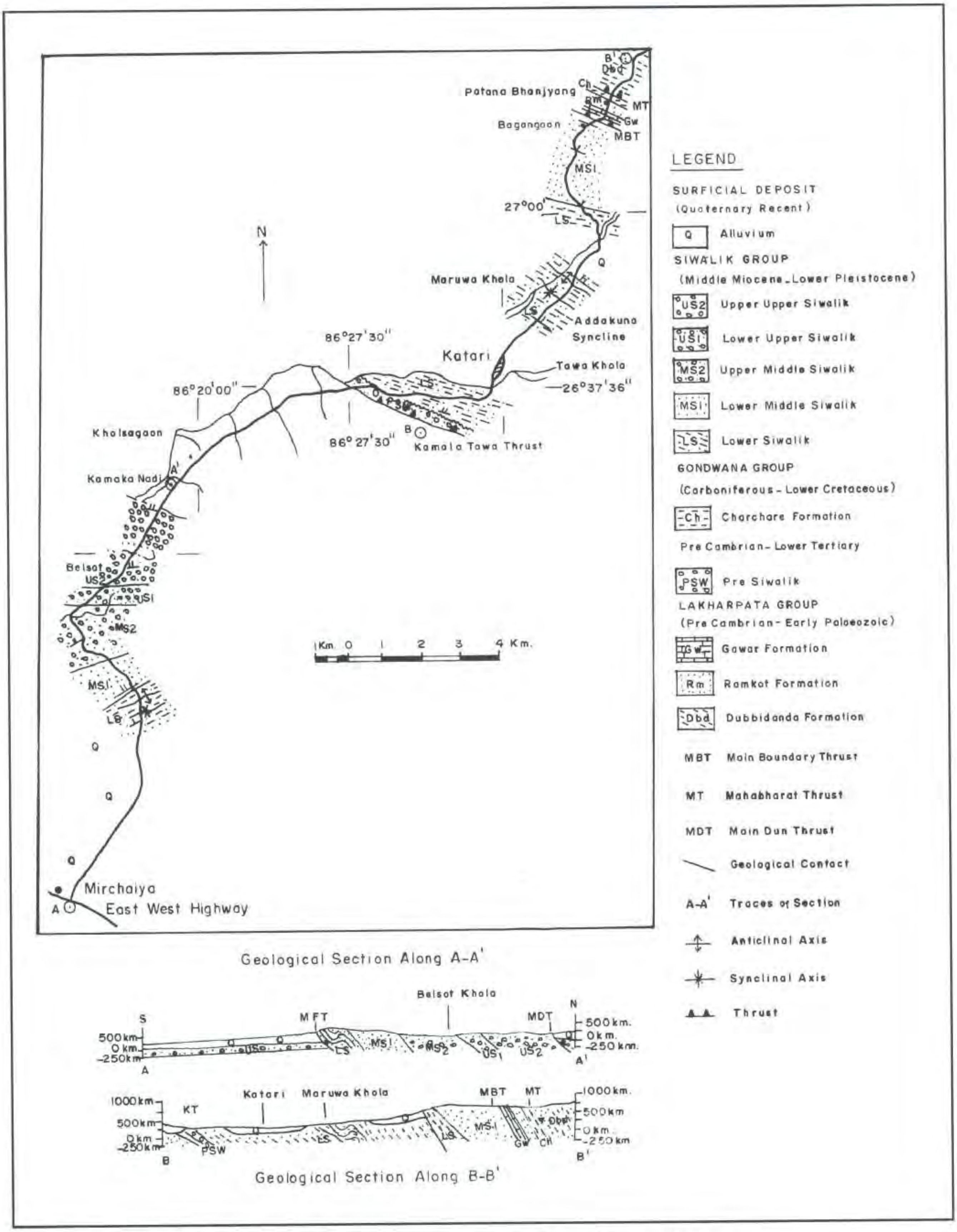

Fig. 3. Geological Map of a Part of Mirchaiya-Katari Road Between Michaiya and Patana Bhanjyang.

rounded quartz grains can be seen with naked eyes. Along the road section, variegated purple shale, pink quarzitic sandstone, pink limestone and dolomite are noted. Gawar Dolomites are of light grey to grey, well bedded and fractured. At places fine grained silicious dolomite is also noted. The para – autochthon comprising of Metasedimentary rocks of the Lakharpata Group is thrusted over MBT.

Metamorphics

The low grade Precambrian metamorphic rocks are exposed to the north of carbonaceous shales of Gondwana Group. The outcrops are mainly light grey to grey phyllite, chloritic phyllite, talcose phyllite, light grey to grey quartzite and sericitic quartzite? Mahabharat Thrust (MT) demarcated the boundary between Gondwana Group and overlying low grade metamorphic rocks of Dubbidanda Formation (Fig.3).

FINDINGS

Geological section measurement was carried out in the sedimentary and metasedimentary rocks belonging to Siwalik Group, Gondwana Group and Lakharpata Group. Siwalik rocks are fresh water molasse sediments. It is bounded by the MBT in the north and by the Terai Plain or MFT in the south. On the surface, MFT is concealed by the alluvium, but in the sub surface, this thrust can be interpreted in the seismic section. During Pleistocene time, the Siwalik sequence was folded and thrusted. As a result, Siwalik sediment is exposed repeatedly with folding and thrusting. The Precambrian and younger metamorphic rocks of the Lakharpata Group of Lesser Himalaya has thrusted over the Siwalik Group along MBT. However, in this area pre-Siwalik outcrop is exposed south of MBT lying within the Siwalik Zone (Herail et al. 1986, Bashyal et. al. 1989 and Shrestha and Sharma, 1994). The Lower Siwalik rock and the Upper Siwalik rock are brought together by the Main Dun Thrust (MDT). In the Katari Valley, the Lakharpata Group rocks are brought to the surface by the MDT and associated thrust (Bashyal et. al. 1989).

CONCLUSION AND RECOMMENDATION

- Coal from Lower, Middle and Upper Siwalik Group and Gondwana Group should be considered in order to study the relative maturity test.
- For the purpose of porosity and permeability measurements, oriented sandstones specimens for the reservoir studies of upper portion of Lower Siwalik (LS), Middle Siwalik (MS1) are recommended.
- Detail geological investigation is recommended to ascertain the major structures and thickness of potential source, seal and reservoir rock formations of Lakharpata, Gondwana and Siwalik Group.
- Palynological study of the sediment is needed to determine its stratigraphic position.
- Further follow up investigation should be carried out in order to evaluate the potential source, reservoir and seal rocks of Siwalik, Gondwana and Lakharpata Group.

ACKNOWLEDGEMENT

The authors are grateful to B.R. Aryal, Project Chief, PEPP/ DMG for his valuable suggestion in preparing the paper. The authors also would like to thank Dr. R.B. Shrestha (Former Project Chief, PEPP/DMG) for providing necessary facilities to conduct the fieldwork. The authors also wish their sincere thanks to Mr. Krishna P. Kaphle, Superintendent Geologist for going through the manuscript and valuable comments and A.K. Duvadi, Senior Divisional Geologist, DMG for his valuable suggestion.

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Annual Report of Department of Mines and Geology, 2007, No. 4, pp. 85 - 92

Soil Investigation of Proposed Bridge Sites Along Syafrubesi - Rasuwagadhi Road, Central Nepal

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INTRODUCTION

As per the bilateral cooperation ofGovernment of Nepal and the Peoples Republic of China, the proposed Syafrubesi - Rasuwagadhi Road is to be constructed by the Chinese Government under the grant assistantship to the Government of Nepal. For this, the Government of Nepal has to furnish the foundation design parameters of the bridges to be built. Therefore the Department of Roads (DoR) requested the Department of Mines and Geology (DMG) to carry out further detailed Soil Investigation of the proposed road.

For this purpose, the Department had formed a soil investigation team under the coordination of Uttam Bol Shrestha, Senior Divisional Mining Engineer. The soil investigation team carried out the required fieldwork from third week of November 2005 and completed it by second week of February 2006 respectively. Two reports viz. "Report on Engineering Geological Mapping" and "Detailed Soil Investigation" were prepared and submitted to the Department of Roads/Ministry of Physical Planning and Works during January and March of 2006. This paper deals with the exploration works carried out by the soil investigation team in brief.

The proposed Syafrubesi-Rasuwagadhi Road is 16km. long. It connects Syafrubesi to the south to Rasuwagadhi, the historic fort near China border to the north. Syafrubesi is approached via blacktopped road from Kathmandu to Trisuli and then by graveled hillyroad to Dhunche. It is located at 16km. north of Dhunche. Syafrubesi connects Rasuwagadhi by hilly foot track along the banks of Bhotekoshi River (Fig. 1). Starting from Syafrubesi, the road alignment follows the existing Trisuli - Somdang road for few hundred meters and then follows the right bank of Bhotekoshi till Chilime Khola. Then the road is aligned along the left bank of Bhotekoshi to the final destination Rasuwagadhi. There are two proposed alternative bridge sites to cross Bhotekoshi River at Syafrubesi. Another bridge to cross the Bhotekoshi River is proposed near the Chilime Khola. Rests of the proposed bridges are over the tributaries to Bhotekoshi River. Thus, there are altogether eight proposed bridges to cross Bhotekoshi and its tributaries.

OBJECTIVE

The Soil Investigation assignment along Syafrubesi – Rasuwagadhi Road comprises of "Engineering geological mapping" and "Detailed exploration with drilling boreholes" of 9 bridges.
The main objectives of the study are to:

- Prepare engineering geological maps of the bridge sites at the scale of 1: 1,000.
- Prepare geological profiles at HS 1: 500 and VS 1: 250.
- Determine the ground stratification of mentioned bridge locations.

Fig. 1. Location map of proposed bridge site with Borehole Numbers.

- Determine the strength parameters of the ground strata.
- Determine the bearing capacity of the stratum
- Find out the ground water quality.

INVESTIGATION METHODOLOGY AND WORK COMPLETED

Engineering Geological Mapping

The engineering geological mapping was carried out on the topographic maps of proposed bridge sites provided by DoR according to ISRM 1978 (Suggested Methods for Quantitative Description of Discontinuities in Rock Mass, International Society for Rock Mechanics, 1978). Schmidt Hammer was used to determine insitu rock strength. Engineering geological maps with geological profiles of nine bridge sites are prepared. Engineering Geological Map of proposed bridge site at K3+380 is presented in Fig.2.

Core Drilling

Boreholes were drilled by water flush rotary drilling method with double tube core barrels. Core barrels of Nx (2 1/8"- core size) and Bx (1 5/8"- core size) with respective casings were used. SPT/CPT values at 1.5m. interval were taken. Disturbed and undisturbed samples were collected. Four drilling machines were simultaneously run at four sites. Altogether 11 boreholes were drilled as tabulated below.

The completed boreholes were sealed by concrete pillars with inserted blank pipes. The borehole number is indicated in the sealing and nearby rock exposures. The recovered cores were stored in the standard core boxes. The soft and sandy materials were placed in the plastic sample bags before storing in the core boxes. Each run of drilling with in-situ test and core recovery is recorded in the core boxes. Each core box was properly marked with borehole numbers and depth covered.

Sampling

Disturbed Soil samples were collected from SPT tubes and sludge collection. Wherever possible, samples from adjoining scarps were also collected by trenching. Undisturbed soil samples were collected with the help of Ud tubes. Rock samples were collected from cores obtained from big boulders and bedrocks. Water samples were collected from the water level inside the cased borehole.

Borehole Logging

The rock cores, soil and sludge material obtained from the drilled boreholes were systematically logged. The borehole logs prepared give the information on the borehole location, drilled depth, ground elevation and date of start of the drilling etc. The logs were correlated with the drilled depth and the elevation of the ground. Logs were described according to BS 5930: 1981 for soil and ISRM 1983 for rocks. Core recovery, ground water level, permeability, depth and type of sample collection, type of penetration test and its value were given and the

Location	Chainage	Borehole	Depth m
Syafrubesi (Bhote Koshi)	K0+159	BHN KO+159LA* BHNKO+159RA*	30 35.45
Syafrubesi (Bhote Koshi)	K0+220	BHN KO+220LA1 BHN KO+220LA2 BHNK0+220RA1 BHN 0+220RA2	31.35 30.6 30.8 30.2
Chilime Khola	K0+330	BHN K3+380RA	30.2
Kalungkulung Khola	K5+873	BHN K5+873LA BHN K5+873 RA	23.7 21.65
Ghattekholo	K14+215	BHN K14+215LA BHN K14+215 RA	25.1 25.35
Total Drilled Depth	9 sites	11 Bore holes	314.4 m

*LA = Left Abutment, RA = Right Abutment lithologs were prepared for each of the boreholes drilled as shown in Fig.3.

Field Tests

Depending upon substratum soil, Standard Penetration Test/Dynamic Cone Penetration Test were carried out regularly at an interval of 1.5 m depth and recorded in the concerned borehole logging. SPT was driven in soft and sandy stratum where as for stiff and hard stratum CPT was driven and the values were correlated with SPT N. Water level in the cased boreholes was monitored twice a day, and water level found at the end of drilling borehole was noted in the concerned borehole log sheets. Permeability with variable head test method was carried out to determine the flow or infiltration through the subsurface stratum in all the boreholes.

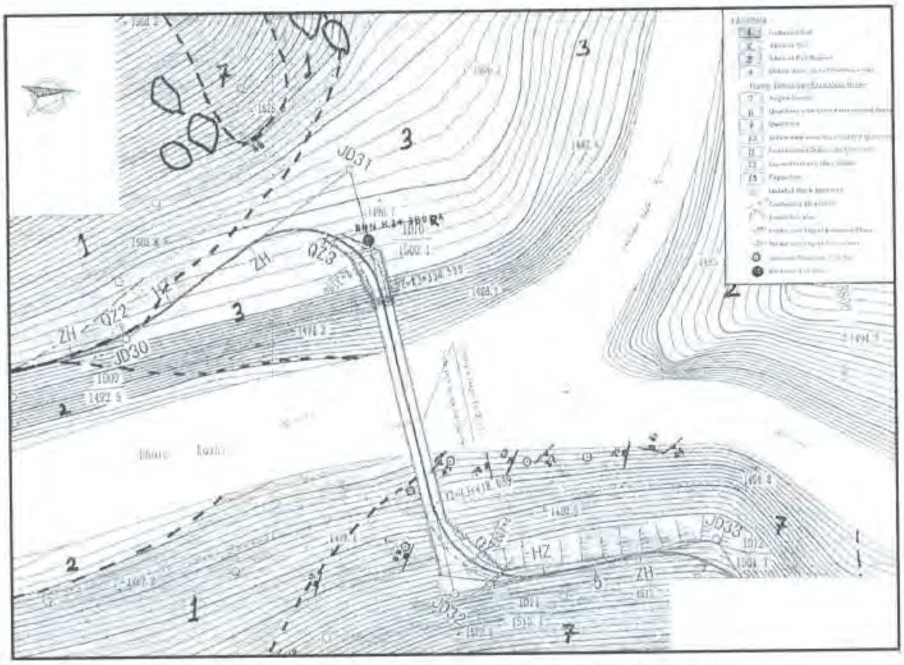

Fig. 2. Engineering Geological Map of proposed bridge site at K3+380

Laboratory Tests on Soil Samples

The collected samples were classified according to the Unified Soil Classification System (USCS) based on Japanese Geotechnical Standard (JGS). Different index properties such as Sieve analysis/Hydrometer tests, liquid limit and plastic limit, moist density, dry density tested and specific gravity were tested. Direct shear tests and angle of repose on soils were tested on the basis of British Standard (B.S.). All the soil samples were tested under the supervision of Mr. Suman Manandhar, Lab. In-charge in the Laboratory of Central Department of Geology, Tribhuvan University, Kathmandu.

Laboratory Tests on Rock Samples

Densities and unit weights of 59 rock samples were determined according to ASTM, 1996: a suggested method for determining the rock material densities. Unconfined Compressive Strength of 11 samples was determined according to ASTM, 1996: suggested methods for determining the Unconfined Compressive Strength of rock specimen. Moduli of elasticity for all these tested samples were also calculated. Point Load Test of 54-core rock specimen was carried out according to ISRM, 1985. Rock samples were tested in Department of Mines and Geology, Lainchaur, Kathmandu and Soil Test (P). Ltd., Balaju, Kathmandu.

Water Quality Tests

11 water samples from the boreholes were tested for their physical and chemical parameters. The results were compared with limits for assessing the aggressiveness of water on standard types of concrete according to the

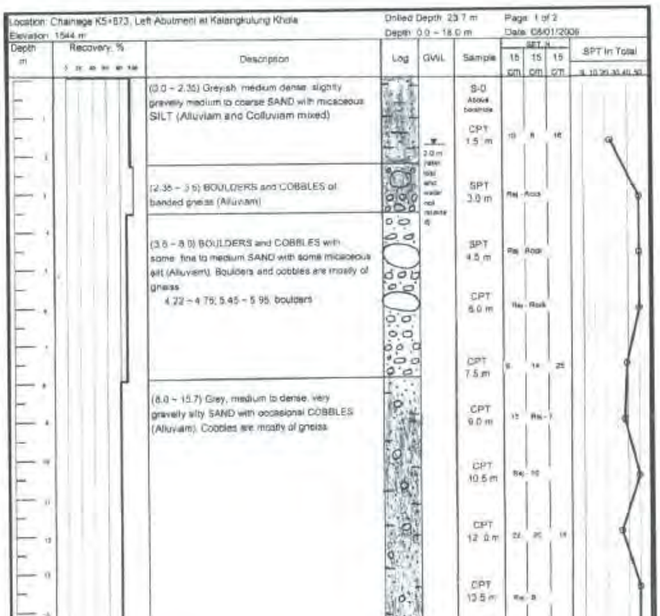

Fig. 3. Litholog of the borehole at BHN K5+873LA, Kalungkulung Khola

GERMAN Standard, DIN 4030. Its corrosive nature is found out based on Langelier Saturation Index. The different parameters tested comprises of pH values, Total Alkalinity, Bicarbonate, Total Acidity, Sulphate, Ammonia, Magnesium, Iron, Carbon dioxide and Langelier Saturation Index (LSI). Water Quality was tested in CEMAT Water Lab. (Pvt.) Ltd., Bijuli Bazaar, Kathmandu.

Correlation between SPT-N and soil properties

The bearing capacity of granular soil depends upon the unit weight, relative density and the angle of internal friction of the soil, both of which vary primarily with the relative density of the soil. The relative density of granular soils in-situ is generally determined by standard penetration tests or dynamic cone penetration tests. They are correlated as shown in the Table-1 (Teng, 1988). The bearing capacity of different subsurface stratum was calculated basically depending upon the corrected SPT-N values only.

Bearing Capacity Calculation:

Equation 1 gives the ultimate bearing capacity for open foundation on granular soils (Teng, 1988) and equation-2 gives net allowable bearing pressure for maximum of 40 mm allowable settlements (Terzaghi and Peck, 1967) in psi.

$$q_{ult} = 2\,N^2B\,Rw + 6\,(100 + N^2)\,DRw' \;\ldots\ldots (1)$$

$$q_a = 1.6\times720(N-3)\left(\frac{B+1}{2B}\right)^2\left(1+\frac{D}{B}\right)Rw' \;\ldots\ldots(2)$$

where,

q_{ult} = net ultimate bearing pressure, psf

q_a = net allowable bearing pressure in psf for max settlement of 40 mm

N= Adjusted standard penetration resistance value

B = Width of footing, ft

D = Depth of footing, ft

Rw and Rw' = Correction factor for position of water table

FINDINGS

The proposed road from Chainage K0 + 000 to Chainage near K3+500 passes through steeply dipping Lesser Himalayan Metasediments (LHM) represented by phyllite, quartzite, schist and marble, alluvial and colluvial deposits. Bridges proposed at Chainage K0+159, K0+220 and K3+380 lies in this section. Rest of the road alignment passes through Higher Himalayan Crystalline Zone (HHCZ) represented by schist, gneiss and quartzite with some granite and pegmatite at places, terraces, fans and the colluvial deposits. The Main Central Thrust (MCT) lies near Chainage K3+500 at Chilime Khola. The results of the study at each of the proposed bridge sites are dealt separately below.

Bridge at K0+159 (Syafrubesi)

- Its left abutment is on nearly 20 meters high flat alluvial terrace comprised of sandy gravel with well rounded boulders and cobbles while the right abutment is in the area deeply eroded by Bhotekoshi River and later filled by alluvium and colluvium derived from active landslide located just on the upper part of the slope. Bedrocks are found at distant only.
- Both the boreholes BHNK0+159LA and BHNK0+159RA drilled at its abutments revealed that the subsurface strata are dominated by very coarse (boulders and cobbles) material with coarse-grained (gravel, gravelly sand, sand and sand with some silt) matrix. Bedrocks are found in BHN K0+159RA at 33.75m and below the depth of 17m (Fig. 4) in BHN K5+873LA.

Table-1: Relationship between Relative Density, Penetration Resistance and the Angle of Internal Friction of Granular Soils (W. C. Teng, 1988).

Compactness	Very loose	Loose	Medium	Dense	Compactness
Relative density, D_r Standard penetration resistance, N = No. of blows per 300 mm	15% 4	35% 10	65% 30	85% 50	100%
f (degrees)*	28<	30	36	41	
Unit weight: moist submerged (kN/m³)	580 < 350	550 – 725 320 - 375	635 - 750 350 - 405	640 - 810 380 - 490	> 750 > 435

** Increases 5 degrees for soils containing less than 5% fine sand and silt.*

- The allowable bearing pressure at left abutment is 116 t/m^2 at 6 m foundation depth. The safe bearing capacity obtained by reducing the allowable bearing pressure by 50% for terrain consideration results the safe bearing capacity more than the load 50 t/m^2 to be imposed on the structure. Hence, the foundation depth found is at 6m. The calculations are shown in the Table-2.
- The allowable bearing pressure at right abutment is 127t/m^2 and 84t/m^2 at 4.5m. and 6m. foundation depth respectively. The safe bearing capacity obtained by reducing the allowable bearing pressure by 50% for terrain consideration respectively gives the safe bearing capacity 63t/m^2 and 42t/m^2. Hence the foundation depth in between 4.5m. to 6.0 is appropriate. The calculations are shown in the Table-3.
- The water from both boreholes is found free of acid and base but slightly corrosive in nature.

Bridge at K0+220 (Syafrubesi)

- This bridge is considered as an alternative to above bridge site as this bridge will be quite longer than the above. There are two piers at each abutment. The lower pier at left abutment lies within the river course, while the upper pier lies near the toe of a huge dormant landslide. The lower pier at right abutment lays aside the river course with alluvial soil, while the upper pier lies on colluvial soil. The slopes at right abutment are stable at present condition.
- All the boreholes BHNK0+220LA1, BHNK0+ 220LA2, BHNK0+220RA1 and BHNK0+ 220RA2 drilled at its abutments revealed that the subsurface strata are dominated by very coarse (boulders and cobbles) material with coarse-grained (gravel, gravelly sand, sand and sand with some silt) matrix. Bedrocks are found in BHN K0+159RA below the depth of 33.75 only.
- There was an outflow of hot water without smell and odor from the drilled borehole BHNK0+ 220LA1at a death of 8 m to 9 m . This hot water flow is attributed to old landslide situated only at few meters above the borehole location (Fig.5).
- Foundation depths with safe bearing capacity are 9m at BHNK0+220LA1, 6.0 to 7.5m. at BHN K0+220LA2, 4.5 to 6.0m. at BHNK0+ 220RA1 and 6.0m. at BHNK0+ 220RA1.

Table-2: Bearing capacity calculation results of BHN K0+159LA

Depth of Foundation, m	Ground Water Level, m	Corrected SPT, N-Value	Allowable Bearing Capacity Based on Ultimate Strength, t/m^2	Allowable Bearing Pressure Based on 40 mm s ettlement, t/m^2
3.0	9.60	33	184	70.0
4.5		25	136	60.0
6.0		50	559	116.7
7.5		50	578	110.0
9.0		50	572	100.3
10.5		50	591	100.3
12.0		50	643	109.4

Table-3: Bearing capacity calculation results of BHN K0+159RA

Depth of Foundation, m	Ground Water Level, m	Corrected SPT, N-Value	Allowable Bearing Capacity Based on Ultimate Strength, t/m^2	Allowable Bearing Pressure Based on 40 mm s ettlement, t/m^2
3.0	14.3	19	67.4	37.2
4.5		50	534.9	127.6
6.0		30	250.0	83.8
7.5		46	668.0	150.0
9.0		50	819.0	160.0
10.5		22	192.0	66.5
12.0		50	839.0	148.8
13.5		50	812.0	137.5

Fig. 4. Core box containing rock samples recovered from borehole BHN K5+873 LA at depth of 17m.

- Water from all the boreholes is reported neutral and free of any strong acids and base. Except the water from BHNK0+220RA1, water from other boreholes are not aggressive and corrosive to concrete. Based on Langelier Saturation Index, water from BHNK0+220RA1 is found to be slightly corrosive in nature though there are no strong acids and base.

Bridge at K3+380 (Chilime Khola Confluence)

- Its left abutment is (BHN K3+380 LA) on Augen gneiss bedrock (>200 MPa) where as the right abutment is in thick alluvial fan deposit of Chilime Khola, hence differential settlement of the piers may be possible. At right abutment except rock falling/ and toppling of isolated blocks due to randomly located discontinuity planes, no other slope stability problems are anticipated.

- BHN K3+380 RA drilled to the depth of 30.2 primarily comprises of alluvial soil consisting of very coarse-grained material with matrix of finer material (sand and silt).

- Foundation depths of 4.5m. to 6.0m. are calculated for left and right abutments of the bridge.

- The water is neutral and free of any strong acids and base.

Bridge at K4+624 (Wangal)

- The bridge is proposed across a dry incised gully. There is no problem for foundations as both the abutments lie on the jointed and folded schist interbedded with quartzite (medium strength, > 50 MPa). In this area, the slopes are though found stable at present, the one at right abutment may pose problem during road cuttings due to presence of prominent unfavorable joint set (270°/43°) dipping toward slope direction.

Fig. 5. Drilling of borehole BHN K0+220 LA1 aside the Bhotekoshi River

Bridge at K5+873 (Kalungkulung Khola)

- The proposed bridge site has been flooded and washed out during a flash flood of 2005. Hence,the investigation is carried for a bridge of 38m. span, which is recommended by the investigation team and accepted by DoR. Its left abutment is on a mixed soil composed of alluvial and colluvial origin, where as the right abutment is on alluvial terrace of Bhotekoshi River. There exists an active landslide aside the left abutment and the abutment area seem to be just in equilibrium condition.

- The borehole BHN K5+873 LA shows subsurface strata dominated by very coarse (boulders and cobbles) material with coarse grained (gravel, gravelly sand, sand and sand with some silt) matrix up to depth of 17.05m. and then bedrock of highly foliated and fractured garnet mica schistose gneiss is encountered. Borehole in right abutment, BHNK05+873 RA comprises of only very coarse material with coarse-grained matrix.

- The foundation depth found at the left abutment is 4.5m. and at right abutment is 7.5m.

- The water from both the boreholes is strongly aggressive and corrosive to concrete based on the chemical analysis of the water samples.

Bridge at K8+435 (Below Phewalin)

- Both abutments are on intensely folded and interbedded slightly weathered to fresh quartzite and schist bedrocks. There shall be no foundation problems as the rocks are very strong (quartzite = 200 MPa, schist = 100 MPa). However the detached blocks of quartzite due to westerly dipping along the hill slopes must be taken care off during road construction.

Bridge at K9+074 (Phenlung Khola)

- Both abutments are in intensely folded, medium to strong; slightly weathered garnetiferous mica schist. There shall be no foundation problems as the rocks are very strong (80 to 120 MPa). The rolled down and precariously hanging huge blocks of rock in the vicinity of proposed bridge and road in this section if rolled down may inflict serious damage to the proposed bridge as well as to the road. Hence due consideration must be given during construction work for their stability.

Bridge at K9+889 (Dalphedi Area)

- The left abutment is on a presently stable but detached rock mass caused by pegmatite intrusion into the garnetiferous mica schist. Foundation is not a problem (80 to 120 MPa) till the rock mass remains stable. However, due care must be given not to disturb the interlocking surfaces during excavation work. The right abutment lies on a slight to moderately weathered, medium to strong (120 MPa) jointed mica schist.

Bridge at K14+215 (Ghattekholo)

- Ghattekholo is a very young staged perennial snow fed tributary of Bhotekoshi River. Both abutments lie on the alluvial fan deposit of Ghattekholo itself and comprises of very coarse (boulders and cobbles) material with coarse-grained (gravel, gravelly sand, sand and sand with some silt) matrix. Its thickness is more than 30 meters. There are some scattered huge boulders of gneiss.

- Foundation depth of 4.5 to 6m is found for both the abutments.

- The water is strongly aggressive and corrosive.

CONCLUSION AND RECOMMENDATION

Between the two alternative Bridge sites to cross the Bhotekoshi River at Syafrubesi, bridge at Chainage K0+220 seems to be safer than the one at Chainage K0+159. However, care should be taken not to disturb the adjoining dormant landslide by excessive toe cutting during foundation excavation.

Differential settlement of the load bearing piers of the bridge at K3+380 may be possible. To avoid such conditions due consideration must be taken during foundation design.

The landslide area near bridge site at K5+873 should be treated for its stability. Otherwise the active landslide may create problem for the stability of road and bridge in this area.

The proposed bridge at K8+435 has major joint sets dipping towards the hill slope in its left abutment, hence extensive care should be taken to avoid excessive excavation for roads and bridge foundations.

Though the proposed bridge at K9+074 is located over the bedrocks, necessary precautionary measures should be taken to avoid detachment of isolated rock blocks. Similar is the case with proposed bridge site at K9+889.

Foundation depths for safe bearing capacity of 50 t/m2 based on the allowable settlement of 40mm. are calculated, and the piers should be founded at appropriate mentioned depth.

If the actual settlements to be occurred at the bridge sites are required, it is recommended to carry out the Plate Load Tests during construction.

Water from the boreholes at Chainage K5+873 and K14+215 is aggressive and corrosive to concrete. Suitable construction material must be used to take care of these effects.

ACKNOWLEDGEMENT

The author is grateful to Mr. N. R. Sthapit, former Director General, DMG for supporting the field program and Mr. P.L. Shrestha, Director General for providing all the facilities to use existing informations in the Department. My sincere gratitude is due to Dr. R. B. Shrestha, Deputy Director General and Mr. K. P. Kaphle, Superintendent Geologist for their valuable guidance while working in the field and later going through the manuscript and valuable comments.

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Annual Report of Department of Mines and Geology, 2007, No. 4, pp. 93 - 98

Inspection and Monitoring of Operating Mines in Different Parts of Nepal

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INTRODUCTION

Department of Mines and Geology (DMG) is the sole governmental organization to issue prospecting and mining licenses. DMG has the obligation and authority to inspect, monitor and regulate the mining and exploration activities all over the country. District Development Committee (DDC) issues license for ordinary construction materials such as sand, gravel and stone quarries. However, DDC acquires technical approval from DMG before issue of such license. The issue of prospecting/ mining license and monitoring of mining activities are carried out by Mining Regulation and Administration Sub-Division of DMG. Out of 57 existing mines, the inspection and monitoring were carried out in 27 different mines. In addition to those 27 mines, monitoring were also carried out on the mining activities of 'Ordinary Construction Materials' the license of which were issued by DDC because there is no reports of DDC monitoring the mining activities the license of which were issued by DDC itself. In the fiscal year 2062/ 63B.S. the inspection and monitoring works were carried out by three different teams. Each team consisted of a mining engineer and or a geologist assisted by a surveyor or a mines sub-inspector. The targeted frequency of monitoring one mine is three times in a year. But due to unavoidable situations, these operating mines were inspected one to three times as per the annual inspection schedule. This report is based on the inspection and monitoring of different operating mines in Lalitpur, Dhading, Makwanpur, Sindhuli, Udayapur, Jhapa, Tanahun, Kaski, Dang, Dolakha, Kavrepalanchowk and Sindhupalanchowk Districts.

OBJECTIVES

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

- to inspect and evaluate the exploitation and mining activities carried out by the lease holder 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 last inspection visits were followed or not .
- to check whether the royalty is paid as per the production and also to collect production statistics.
- 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 mining methods in an environment friendly manner in compliance with the existing mineral laws and regulations of Government of Nepal. and
- to take further actions if the previous suggestions/ directives were not followed by the license holders

METHODOLOGY

To judge the overall mining operation, all the three inspection teams adopted the same inspection methodology developed by DMG. Taking into consideration of the technical (mine plan, mining method, mining parameters etc.), environmental (physical, biological and socio-economical) and legal (Mines Rules and Regulations) parameters, the team inspected all those mines, mining activities, monitoring of environmental impact due to mining and gave necessary suggestions and directions to the mine operators / lease holders.

STATUS OF INSPECTED MINES AND DIRECTIVES GIVEN

The regular field inspection reports submitted by the teams of all the mines/ quarries mentioned above are categorized in three different groups based on the types of mineral commodities.

ORDINARY CONSTRUCTION MATERIALS

Inspection and monitoring of mines of ordinary construction materials (sand, gravel, boulder, slate, raw stone) were carried out along the Prithivi Highway (Kathmandu – Malekhu sector), Araniko Highway (Barabise – Tatopani sector) within Kathmandu valley and at Bahundangi, Jhapa.

Along the Araniko Highway a number of illegal slate mining were in operation improperly. They were operating in a very unsafe manner. DDC has been directed to immediately stop all those improper mining activities. Local administration has also been requested to stop all the improper mining activities.

Similarly, most of the sand and raw stone quarries operating within the Kathmandu valley and at Dhadhing district were in operation without forming the benches and not in environmental friendly manner. Some of the sand and raw stone quarries are running under unsafe condition with bench height of 25 m or so. All these licensees were directed through the concerned DDC to work by making small benches from top to bottom and to follow safety measures by providing safety boots and helmets to the workers as a prime care and to do the mining in environmentally friendly manner.

The boulder quarry owned by Deurali International Mines (Pvt.) Ltd. in the eastern region of Nepal has done almost nothing except collecting gravel and boulder from the cultivated land and paddy field where abundant gravel and boulder are found. Gneiss, Schist, Marble, Sandstone are the major types of rocks found in this periphery. Gravel and boulder derived from those rocks by the streams are collected. The volume of such materials seems to be around 3000 cubic feet in FY 2060/61B.S. only. Deurali International Mines was allowed to export 2000 cft. Gravel to India via Rani Custom Office, Biratnagar in the FY 2060/61B.S. It has exported only 161 Cu ft of stone boulders till 25 Ashwin 2061B.S. There is no immediate environmental and technical problem in mining activity. However, over extraction / mining of such gravels, boulders may cause river bank erosion and collapse of river sides and finally the fertile cultivated land. It was directed to initiate production immediately at optimum capacity by environment friendly manner.

NON-METALLIC INDUSTRIAL MINERALS

Limestone

Seven limestone quarries were inspected by the teams. Only three of them were in production after rainy season whereas the rest have produced limestone in the last six month of the fiscal year 2061/62B.S.

Out of the seven limestone quarries, Hetauda Cement Industry Limited (HCIL)'s two quarries at Bhainse (Fig.1) and Majuwa (Okhare) and at Udayapur Cement Industry Limited (UCIL)'s quarry at Sindhali were operated with mechanised mining method. Other limestone quarries of Agri-lime Industry Limited (ALI), Ajay Raj Sumargi, and Maruti Cement Industry were operating under manual method of extraction. Similarly, Annapurna Quarries (Pvt.) Ltd. is operating with semi-mechanised mining method.

The limestone quarry owned by Agri-lime Industry Limited at Jogimara in Dhadhing district has just undergone the development work on uphill side of Prithivi Highway. Tension cracks are developed in that area as a result there is possibility of rock slide or debris flow. The quarry site located right on the right bank of Trishuli River has the waste management problem.

The limestone quarry owned by Annapurna Quarries (Pvt.) Ltd. at Jawang Khola in Dhadhing district was in production at the time of inspection. Regular maintenance of approach road, clearing of quarry faces, maintenance of machineries were found in order. The production was from the two quarry sites (1) east of Jawang Khola and (2) west of Jawang Khola. Production of limestone on the east of Jawang Khola was carried out without making proper benches and the limestone is transported through the high natural chute to the lower level. Therefore there is high risk for the labour in the working area due to high slopes. On the other hand in the quarry sites to the west of the Jawang Khola, the leasee has tried to maintain the proper benching system on the slopes of the hill. But the loose debris and soils were deposited haphazardly on the slope of the mine. Jawang Khola flowing through the quarry area has not been canalized. However, there were not much negative effects on water and air quality.

Bhainse limestone quarry owned by Hetauda Cement Industry Limited (HCIL) was in operation. It has developed the benches from the western quarry site with the help of heavy equipment. Drilling and blasting in benches with 7 m. bench height, hole diameter of 100 mm, the hole spacing of 2.5 m. were in process at the time of inspection. Limestone extracted from this quarries is blended with those having high CaO content to produce

Fig. 1. Bhainse Limestone Quarrry (Hetauda Cement)

cement. It was found that the waste disposal site was improperly maintained around the quarry hill slope. However, there was little effect on water and air quality. There was least concern of safety of workers.

Okhare limestone quarry of HCIL was not in operation due to road collapsed in rainy season. Therefore the mining was carried out on the southern hill slope called Majuwa. Limestone deposit located in this area is generally mined in the winter when the water level at Samari River is quite low. There is high overburden in the western part. Rocks are dipping on opposite side to the natural slope. Manual and mechanical excavations are in practice for mining. Open Chute along the natural drainage is a means of transport of limestone from the excavation point. HCIL has hired contractors for mining who are malpractice mining methods that are not at all suitable for safety. Excavation should be strictly under the guideline of mining methods rather than contractor's convenience. Adverse effect of unplanned waste disposal by the mining can be seen in local streams and rivers.

There is no significant environmental impact in the quarry owned by Ajay Raj Sumargi at Pandrang, Makwanpur. He used to collect limestone boulders from the khola and calcite from limestone veins. The mines remained closed most of the time. The opening and closure of mine for a long time in different periods were not informed to DMG. The production data record system was not properly maintained. Since there were no mining activities, not much of environmental problems were noticed.

The limestone quarry owned by Maruti Cement Udhyog (Pvt.) Ltd. at Kakur Thakur of Sindhuli district was in operation at the time of inspection. Limestone was mined by opencast manual mining method without developing benches. Limestone was collected from the broken rock mass that was slided down to khola level. Mine development work has yet to be done. There were few landslides near the quarry area which has to be stabilized.

Sindhali limestone deposit owned by Udayapur Cement Industry Limited was running with mechanized opencast mining method. Drilling and blasting in benches with bench height of 6 m, hole diameter of 65 mm and spacing of 2.5 m was adopted to exploit the limestone. In the absence of blasting, rock breaking machine was used to break limestone. Mine development and operation was found satisfactory. Environmental degradation due to mining was not significant.

The production figures of raw limestone from different quarries in different periods in FY 2061/62 B.S. are given in Table–1.

During the mine inspection, the professionals of DMG gave suggestions and directive to the owner of all the inspected mines. Agri Lime Industry was directed to make an assessment of the limestone deposit on the highway side whether continuous mining on that area is possible or not in an environment friendly and safe manner. Annapruna Quarry (Pvt.) Ltd was instructed to maintain the benches properly to have minimum environment

Table-1: Production of limestone from different quarries in FY 2061/62 B.S.

S.No.	Name of Lease Holders	Quarry site	Production in MT	Remarks
1	Hetauda Cement Industry Limited	Bhaise,Makawanpur	9,309	Total production upto Baishak, 2062 for the last 10 months.
2	Hetauda Cement Industry Limited	Okhare(Majuwa), Makawanpur	45,926	Total production upto Baishak, 2062 for the last 8 months.
3	Agri-lime Industries Ltd.	Jogimara ,Dhading	7,170	Total, production upto Baishak, 2062for the last 10 months.
4	Annapurna Quarries (p) Ltd.	Jawang Khola ,Dhading	18,040	Total, production upto Jestha, 2062 for the last 11 months
5	Maruti Cement Udhyog Ltd.	Kakur Thakur,Sindhuli	11,495	Total, production upto Jestha,2062for the last 7 months.
6	Ajaya Raj Sumargi	Pandrang, Makawanpur	850	Total, production upto Jestha, 2062 for the last 5 months.
7	Udayapur Cement Industry Ltd	Sindhuli,Udayapur	1,24,566	Total, production upto Baishak, 2062for the last 10 months

impact and erosion problem, to canalize the Jawang khola, to have proper waste management and do the excavation and production of limestone under the supervision and guidance of mining engineer.

Bhainse quarry should be well managed and strictly disposed all the mining waste at waste disposal site. HCIL must apply safety majors for workers. Improvement in bench development is still required. To mine the limestone at Majuwa, HCIL was directed that excavation should be carried out as per mining scheme and benches should be developed from the top of hill for long term sustainable mining. It was also instructed that mining should be carried out with coordination of locals to maintain the basic amenities like drinking water supply, road. It was also directed that previous directives and instructions should be followed.

The inspection team also instructed Ajay Raj Sumargi, the owner of limestone quarry at Pandrang to report DMG about the closure and re-open of mine timely. It was also directed to maintain proper recording of limestone production and to follow the instructions and directives given by DMG in the previous inspection visits. Maruti Cement Udhyog was directed to develop the benches properly and also to take safety measures for workers as well as machinery. UCIL was suggested to run the quarry at full capacity and to submit the environment report including mitigative measures.

Sarada limestone deposit at Purandhara, Dang under the lease holder of Dang Cement P. Ltd. was inspected to have cross verification of the mining scheme that was submitted to DMG to get approval of mining scheme. Based on this field visit, it was recommended to approve the mining scheme submitted by the leasee that was designed to produce limestone at the rate of 1200 tons per day.

Marble

DMG has issued three mining licenses for marble quarry. During inspection visit, only the marble quarry licensed to Godawari Marble Industry (Pvt.) Ltd. was in operation. This quarry is situated at Godawari, Lalitpur. The remaining two quarries were not in production of marble blocks. Laxmi Lime Product has been issued a license to operate marble quarry at Sukaura, Makwanpur and Everest Marble and Allied Industry (Pvt.) Ltd. has been issued a license to operate marble quarry at Jaishithok, Kavre.

Godawari Marble Industry has developed proper benches and is exploiting the marble blocks by semi-mechanized method. Everest Marble Industry is having technical problem to have marble block production and it is producing only the stone aggregates. The Laxmi Lime Product is having the problem of insecurity as reported by the lease holder. However, it has established marble slab cutting machine at Hetauda Industrial Estate. So far, it has done only the trial production of the marble blocks collected from river beds. The commercial exploitation of the deposit has not yet been started. However, it has started to construct the approach road to the quarry.

Godawari Marble Industry has maintained the environmental issues rose by DMG and to some extent, has followed the DMG directives. It was directed to continue maintaining the environmental mitigation measures so far done and to submit the operating quarry area map in the scale of 1:500 for the purpose of verification of mined marble blocks. The rest two marble quarries were directed to produce marble blocks as per the approved mining scheme.

Talc

Out of the 5 talc mines inspected in different parts of the country, three of them were in operation and two were not in production. All the operational talc mines are working with manual method of open cast mining.

Mines owned by Gautam Khanij Udhyog (Pvt.) Ltd at Manapang, Tanahun, Dig Bijaya Products (Pvt.) Ltd. at Phulping Katti, Barhabise, Sindhupalchok Nepal Orind Magnesite (Pvt.) Ltd. at Kharidhunga, Dolkha were in production. The total production of talc from these operating mines are 150 MT (up to Falgun 2061); 292 MT (up to Chaitra 2061) and 724.44mt. (up to Ashwin 2061) respectively. Dust Nepal (Pvt.) Ltd at Phirphire, Tanahun and Singh Khanij Udhyog (Pvt.) Ltd at Pumdi Bhumdi, Kaski were not in operation due to the unfavorable security situation as reported by the lease holder.

Some of these quarries were doing bench development activities and others had already developed production benches. Due to poor waste management there was erosion and siltation problem nearby quarry areas in all these mines. It was also noticed that safety measures were also not adopted for the labours.

It was also noticed that most of the lease holders were not following the directives given by DMG. The lease holders were therefore, instructed to have effective dumping and waste management system to minimize the impact on erosion and siltation. They were also directed to develop benches properly, to adopt safety measures for the labours, and to work under the direction and supervision of technical experts. The license holders of the mines which were closed were directed to bring the quarry into operation. They were also directed to manage the mine waste, erosion and siltation problem.

Red Clay

The red clay quarry at Pachkhal VDC, Kavre district lies under the lease of government owned Himal Cement Industry. This quarry is not in operation for the last few years due to closure of the factory itself and hence there was no environmental problem in the worked out areas.

The red clay quarry under the lease of Udayapur Cement Udhyog Ltd. (UCIL) at Aapsota, Udayapur was in operation. Mechanized excavation of red clay was in progress. Stripping was carried out by loaders from benches of different heights varying from 3m. to 6m. and was directly loaded to the dumper. The production of this quarry was 6128m^3 up to Baishakha, 2062. Another quarry under the lease of Udayapur Cement Udhyog Ltd. at Manohara was not in operation at the time of inspection. However, the production of this quarry upto Marg 2061 was 7189 m^3.

In the last fiscal year, the UCIL was advised to minimize the deforestation and start plantation in the work out area. As it was not found to follow the earlier directives issued to them, they were therefore issued the same directives again. They were also directed to pay the government royalties regularly.

FUEL MINERALS

Coal

Most of the coal mining licenses are issued in Dang, Sallyan, Palpa and Rolpa districts. In this year inspection and environmental monitoring was done in two operating coal mines (Fig.2) and one coal prospecting area of Dang district. It was not possible to visit other operating coal mines in the region due to unfavorable security situation. However, the inspection team was able to visit the corporate offices of eight operating mines situated in Ghorahi and Tulsipur, Dang district and collected and verified the coal production data as well as checked the production record system. The coal mines leased by Dinesh K. Dangi, Ram Gopal Jajodiya and Bageshwori Coal Industries in Dang district were inspected. During the visit it was noted that the lease holders were following only few directives given by DMG. Coal mining was carried out with board and pillar system of underground manual mining method. The ventilation system was not good enough at Tosh coal mine of Ram Gopal Jajodiya. These mines also require proper support at the weak zones (underground). The total coal production in the last 3 months was 703 metric tons and 468.5 metric tons from Dinesh K. Dangi and Ram Gopal Jajodiya's coal mines respectively as reported by the end of Magh in this FY. The total coal production from the eight operating coal mines of Dang in the last 3 months was 3498 metric tons by the end of Magh in this FY.

The inspection team directed to the lease holders to provide proper support in weak zones, to have proper ventilation for the workers working underground and maintain adequate safety measures to protect from any mine accidents. They were also directed to manage the waste in a dump yard outside the adit and to provide safety equipments to the miners. They were also instructed to keep proper and up to date production records.

Besides the regular inspection of the operating coal mines, the team also visited one coal prospect that was in the process to obtain mining license. During the visit the field verification of the mining and environment report was carried out. Finally it was recommended to approve the mining scheme submitted by Subhas C. Yogi for mining of coal deposit at Saigha, Dang at the proposed production rate of 20 tones per day under the terms and

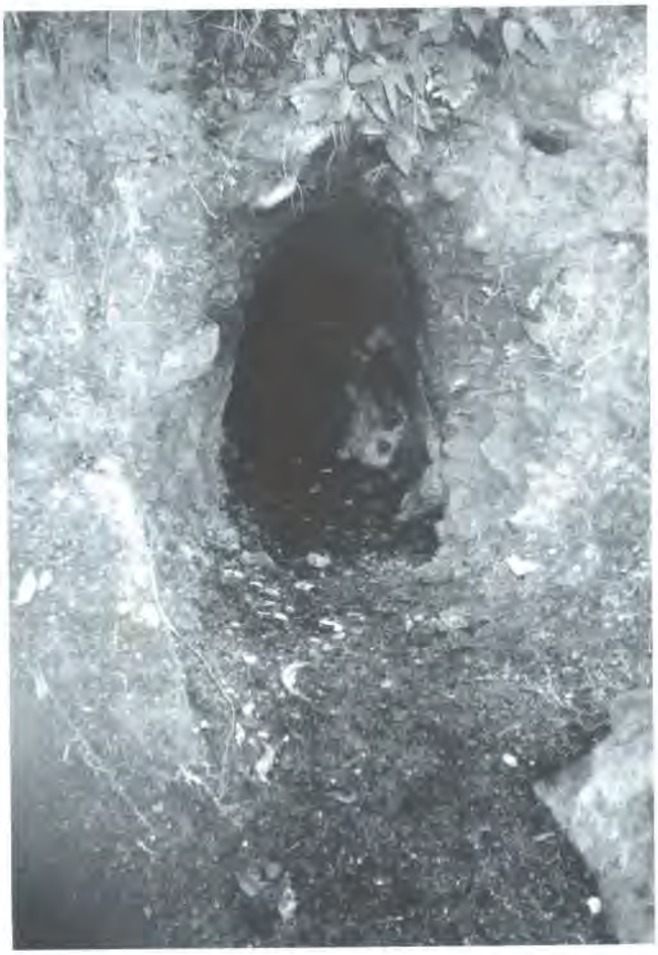


Fig. 2. Coal Audit (Coal mine) in Dang.

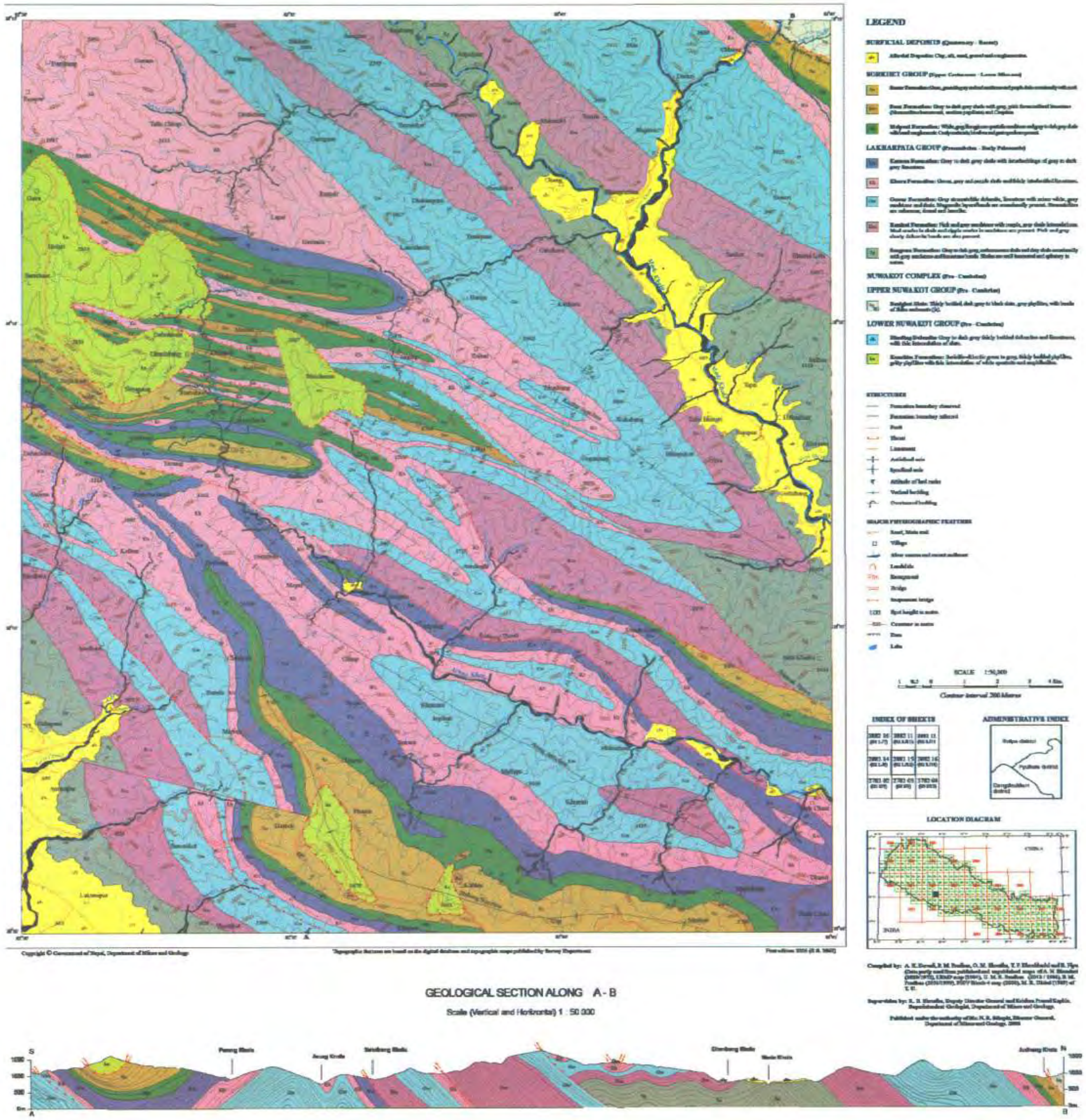
conditions like proper management of ventilation, waste disposal, safety aspect of the workers, machineries and materials while exploiting the coal.

CONCLUSION

- Presently operating 27 mines in different parts of Nepal were inspected/ monitored basically for their mining activities and environmental impact due to mining. These operating mines were inspected one to three times as per the DMG's annual inspection schedule.
- During the inspection, it was recorded that safety aspect of man and machineries had been poorly dealt with.
- Most of the mines were not following the directives given by DMG previously. It is therefore necessary that these inspected mines should continue their operation according to the suggestions and directives given by DMG from time to time. Hence regular inspection of all the mines is necessary.
- During the visit, most of the mines were not in operation. Some of them were in operation at very low rated capacity and rests were operating but not in full capacity. The insurgency had negative impacts on mine operation and production as reported by the lease holders.

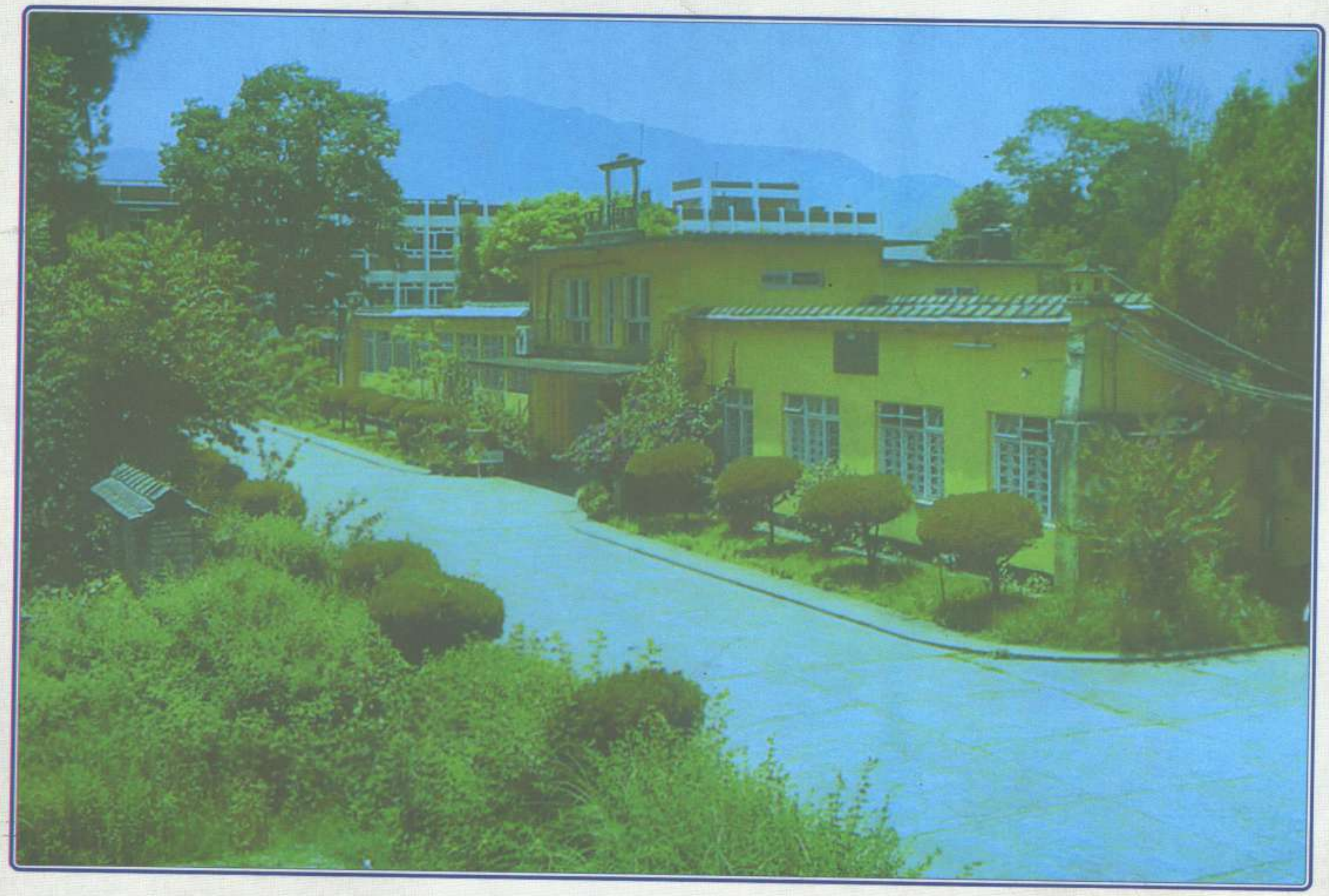
RECOMMENDATION

- Inspection should be carried out more frequently and effectively.
- DMG should force the lease holders to follow the directives given by the inspection team to achieve the goal of mineral production with minimum environmental effects.



GEOLOGICAL SECTION ALONG A - B

Scale (Vertical and Horizontal) 1 : 50 000



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