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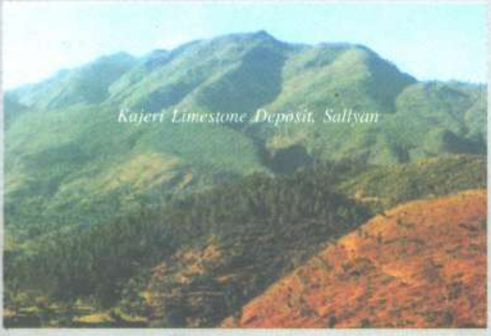
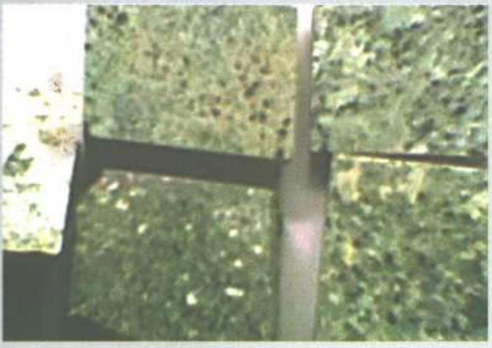


DEPARTMENT OF MINES AND GEOLOGY



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FOREWORD

The Department of Mines and Geology is the only responsible government organization to conduct all types of geoscientific researches and carryout mineral exploration, evaluation of mineral resources including petroleum and natural gas and also promotion of mineral based industries in Nepal. All these activities are successful not only to find a number of mineral deposits/prospects and promotion of some mineral based industries in the country but also to deliver the geoscientific information/data to the potential users. All these activities directly or indirectly are contributing in the national economic development. To make the people aware of the DMG activities it has started to publish regularly the DMG Annual Reports in addition to Mineral Resources of Nepal, DMG Newsletter, DMG Précis, different types of Geological Maps, Engineering and Environmental Geological Maps, Geo-Hazard Maps, Mineral Resources Maps, Earthquake Epicentre Map, Brochures, Information Booklets etc. since 2004.

In this regard the Department of Mines and Geology is pleased to publish the Annual Report No.3 as a part of DMG Annual Program of FY 2062/63. In this volume, nine papers on Geology, Mineral Exploration, Engineering and Environment Geology, Mines Inspection and Environmental Supervision and Petroleum Exploration are included. I am sure that this Annual Report will be successful to deliver the geoscientific information and disseminate the outcome/ achievement of all the field activities and laboratory investigations carried out by DMG mainly during the FY 2061/2062 and before. I would like to request the concerned people, engineers, planners, university/college teachers and students to make maximum use of the information for their respective works.

I would like to thank and appreciate the hard work of all the members of Editorial Board and cooperation of authors of the papers and necessary helps of the concerned DMG staff to bring out this Annual Report No. 3 in time.

Nanda Ram Sthapit
Director General

EDITORIAL

The Editorial Board is very much pleased to bring up this publication 'Annual Report, Number 3' of the Department of Mines and Geology (DMG). The purpose of publication of annual report is to disseminate geoscientific information to the concerned people and agencies and contribute in fulfilling the objective of the department.

The Editorial Board is formed to published annual activities of the department in the form of 'Extended Summary' of technical report of geological investingation, mineral exploraton and mining survey activity programs of the department conducted during the fiscal year 2061/062 in particular as well as articles on technical reports of the previous years also to facilitate the publication of scientific researches conducted by the department even before the initiation of Annual Report publication.

The Editorial Board would like to extend its appreciation and express thanks to all the geoscientists and staff of the department who have contributed directly or indirectly in bringing up this volume as well. Especially, the tedious efforts made by the Drafting Section of the department in the preparation of various maps and figures is highly appreciated.

Dr. Rajendra B. Shrestha
Chief Editor

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Annual Report of Department of Mines and Geology, 2006, No. 3, pp 1– 8

Geology of Gurja Khani - Dana Area, Myagdi and Mustang Districts, Western Nepal

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INTRODUCTION

Geological mapping of the study area has been carried out according to the departmental programme of the fiscal year 2055/056 B.S. The study area lies in the topo-sheet no 62 P/2, P/6 and 62P/10 (scale 1"= 1 mile) of Survey of India. The area of investigation is bounded by latitude 28º 30' 00" to 28º 37' 30" N and longitude 83º 10' 00" to 83º 45' 00" E (Fig.1).

Vaidya (1971) mapped the eastern part of the study area which is represented by relatively less disturbed and north dipping low grade metamorphic rocks in the south and high grade metamorphic rock in the north. Joshi (1971) mapped the western part of the study area. Except north-eastern corner of the map, where high grade muscovite biotite schist occurs, rest of the area is found to contain only meta-sedimentary rocks, dipping toward north-east. Western (15%) part of study area has not been covered by any detail geological mapping programme. Kaphle and Khadka (2005) did follow up gold exploration along Kaligandaki valley and prepared a geological map (section) of that area and reported alluvial gold occurrences in the recent as well in the old river terraces. Pradhananga (2000) carried out the geological mapping of the area and divided the rocks of the area into northern Crystalline Complex and southern Nawakot Complex.

OBJECTIVE

The main objective of the field study was to carry out geological mapping of the southern part of toposheet no 62 P/2, P/6 and 62P/10 in some parts of Myagdi and Mustang districts to compare the litho-stratigraphy of the present study area with that of the Central Nepal and publish the updated geological map.

GENERAL GEOLOGY

The liltho-stratigraphy of meta-sedimentary rocks of the investigated area in general is found to be compatible with the liltho-stratigraphy of Central Nepal. But there are some differences in the characteristic features present in the rocks of Nawakot Complex from that of Central Nepal. For example, Benighat Slates of this area are slightly more metamorphosed and thickness of Dhading Dolomite is smaller compared to those occurring in Central Nepal and other parts of Western Nepal. The metamorphism of Benighat Slate may be due to its proximity to Main Central Thrust zone. The Main Central Thrust (MCT) separates the Higher Himalayan rocks from the Lesser Himalayan rocks. The study area falls around MCT and consist of meta-sedimentary rocks of Nawakot Complex in south overlain by high grade crystalline rocks to the north of MCT (fig.1). The rock units of the Nawakot Complex present in this area are Dandagaon Phyllite, Nourpul Formation and Dhading Dolomite of Lower Nawakot Group and Benighat Slate of Upper Nawakot Group. The crystalline rocks in north consist of garnetiferous gneiss, kyanite gneiss, schists, calc-schists and marbles. Unlilke Lesser Himalayan geology of other parts of Nepal, this area is less complicated with few truncation, repetition or omission of beds. All the beds are almost uniformly dipping toward north without any folding. MCT is swinging to the south in eastern part of the map area. Metasedimentary rocks of Nawakot Complex occupy more than 50% of the map area in western part and gradually pinches towards east (fig.1).

Nawakot Complex

The rocks of Nawakot Complex occur in the southern part of the map area. Its thickness attains 14.5km in western part and pinches towards east. Nawakot Complex is divided into Lower Nawakot Group and Upper Nawakot Group by Stocklin and Bhattarai (1977).

Lower Nawakot Group

In this area the Lower Nawakot Group is represented by argillaceous Dandagaon Phyllite, calcareous Dhading Dolomite and argillo-calcareous Nourpul Formation.

Dandagaon Phyllite

Except in the Kaligandaki valley, the southern boundary of the area starts with green Dandagaon Phyllite with bands of quartzite. It has pinching and swelling nature and thins out toward east. About 4000m thick pile of Dandagaon Phyllite is exposed in Simudar Khola, in western part of the map in Kaligandaki valley. This Formation consists of greenish grey to dark green, generally fine grained phyllite with bands of quartzite. Two types of phyllites are recorded as: (a) Argillaceous

Table.1 Litho-stratigraphic Succession of the area

Complex	Group	Formation
Crystalline Complex		Garnetiferous gneiss, Kyanite gneiss, Biotite-garnet schists, Calc-schists with marble.
	MCT	
Nawakot Complex	Upper Nawakot Group	Benighat Sslate
	Disconformity	
	Lower Nawakot Group	Dhading Dolomite (dh)
		Nourpul Formation (np)
		Dandagaon Phyllite (da)

green fine-grained phyllite and (b). Laminated phyllite. The argillaceous phyllite contains intrusions of high density of quartz veins. Quartz veins are impregnated at the spacing of 2-5 cm of green phyllilte. The laminated phyllite is composed of 1-2 mm thick light green to yellowish brown argillaceous and calc-silicious layers of phyllite. Bedding planes are smooth and wavy.

Dandagaon Phyllite contains 1 to 80meter thick quartzite bands. These quartzites are medium to thick bedded, fine to medium grained and generally greenish grey in color. However, at places some white quartzite bands are also recorded. Occasionally, these quartzite bands contain green chloritic partings and chloritic phyllite intercalations. At Dare Khola, a 3m thick yellowish grey to greenish grey limestone band is present. The limestone band contains green chloritic partings and some phyllite intercalations. Many copper ores are present in Dandagaon Phyllite. Many old working adits for copper were found to be driven in Dandagaon Phyllite. It is the oldest formation in this area and it is conformably overlain by Nourpul Formation.

Nourpul Formation

The sequence of argillaceous Dandagaon Phyllite transitionally passes into Nourpul Formation with appearance of colored argillaceous, calcareous and arenaceous rocks. At places, it is difficult to draw the exact contact between Dandagaon Phyllite and Nourpul Formation due to dominance of argillaceous rock in both the formations and lack of purple slate in Nourpul Formation in this area. Beginning of Nourpul Formation is recognized with the presence of greenish grey colored slate, shaly slate, quartzite with ripple marks and colored dolomite contrary to phyllilte and pyllitic slate in Dandagaon Phyllite. Thick piles of Nourpul Formation reaching 5000m thickness, occurs in western part of the area, in upper reaches of Simudar Khola and Phi Khola. This formation gradually pinches toward east to 1500m in central part and moves south of the map area, east of Bagar Khola. A small inlier of Nourpul Formation occurs in central part of the map area. In general, the rocks of Nourpul Formation occur in southern part of the map area with a general trend of E-W and dipping toward North with an angle of 30-50°.

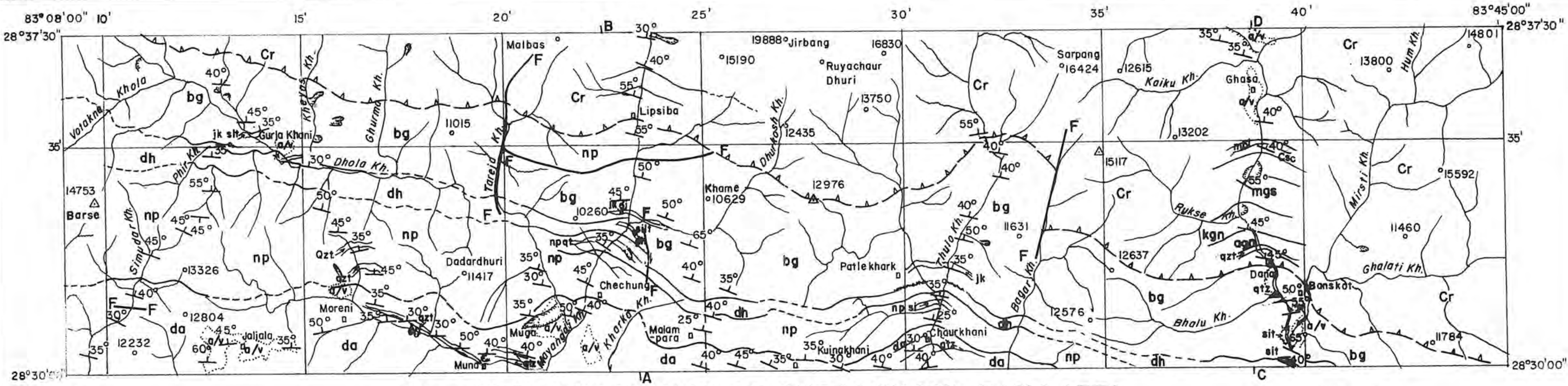
Nourpul Formation consists of greenish grey shaly slate, light grey to light bluish grey shaly slate, very often dark grey or black slate, light greenish grey fine grained sandstone, white grey fine grained quartzite, light grey and milky white to pink dolomite and dolomitic limestone. These dolomites, quartzite and phyllites occur as thin lamination or intercalations to hundreds of meters thick band. Generally, argillaceous unit is dominant compared with siliceous and calcareous units. Ripple marks are quite common in quartzites of Nourpul Formation.

Dhading Dolomite

Nourpul Formation is conformably overlain by Dhading Dolomite which mainly occurs in the western part and gradually extends towards south in eastern part of the map. About 1000m thick dolomite pinches to 350m in eastern part of the map area. Like other formations it has also general trend of E-W, dipping toward N at an angle of 30°- 50°. Lithologically Dhading dolomite consists of light grey, light bluish grey to dark grey fine grained, medium to thick bedded dolomite with intercalations of dark grey to black slate. The dolomites occurring near the Benighat slate are found to be more darker in colour and those occurring toward south i.e. away from Benighat slates are lighter in color. At places, the dolomite bands are argillaceous to siliceous in nature and stromatolitic structures are developed e.g. in Dhola Khola, Myagdi Khola and Malampara Khola. In this area,

Fig. I

Topo.sheet No. 62P/2,6,10



GEOLOGICAL MAP OF GURJAKHANI–DANA AREA
MYAGDI-MUSTANG DISTRICTS

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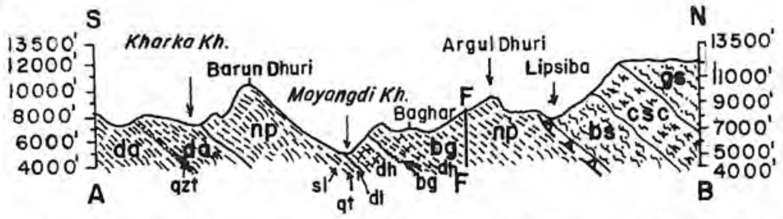

Schematic Cross-Section along A-B (Mayandi Khola)

Schematic Cross-Section along C-D (Kaligandaki Area)

LEGEND

Group	Formation		Dominant Lithology
	a/v	Alluvial deposit	
	Nawakot	Complex Rocks	
Upper Nawakot	bg / jk	Benighat slate with Jhiku limestone	Dark grey to black graphitic phyllite, Carbonaceous slate with intercallation of limestone and dolomite bands. (jk)
		Transitional to Discomformable Contact	
Lower Nawakot	dh / slt	Dhading dolomite	Light grey to dark grey, fine grained, med. to thick bedded dolomite with intercallation of dark grey to black slate (slt) stromatic structures present.
	np / dl / sl / qt	Nourpul formation	Light greenish grey shaly slate (sl) light greenish to white grey quartzite (qt), light grey milky white to pink dolomite, dolomitic limestone (dl). Dolomites, quartzites and slate as thin laminations to tens of meter thick bands.
	da / qzt	Dandagaon	Greenish grey to dark green, fine grained phyllite, laminated phyllite with bands of quartzite (qzt). Quartzite contains chloritic partings. Argillaceous phyllite contains high quartz vein intrusions. Some carbonate laminations and layers are present.

Group	Formation		Dominant Lithology
		Main Central Thrust	
	agn	Augen gneiss	Garnetiferou augen gneiss with qartz feldspar, muscovite, biotite and garnet
	bsc	Banded schist	Alternate bands of silica (quartz, feldspar) rich, light grey band and mica (biotite-muscovite) rich dark grey band.
	kgn	Kyanite gneiss	Kyanite, quartz, biotite feldspar gneiss with bands of schists.
	mgs / gs	Mig-schist & gneiss	Migmatitic garnet, biotite schist interbeded with migmatitic gneiss. At places, non migmatitic gneiss and schist interbeded (gs)
	csc / mbl	Calc-schist	Light bluish grey to dark grey garnet biotite calcschist with bands of bluish grey to milky white coarse crystalline marble bands (mbl)
	cr	High grade crystalline rocks.	

45°	Strike and dip of inclined strata
	Geological contact
	Inferred contact
	Disconformity
	Boundary between alluvial deposit and geological formation.
(Cu)	Ore occurrence/old working, (cu)-copper ore
	Landslide,
	Anticline
	Drainage
	Syncline
	Suspension bridge
/0 10275	Height in feet
▫	Village / locality name
F——F	Fault
	Thrust (MCT)

reworked pelletal dolomite and bluish grey chert lenses are absent and thickness of the dolomite is also small as compared to other areas.

The contact of Dhading Dolomite with overlying Benighat slate is found to be transitional (in Malampara Khola) to abrupt disconformity (in Thulo Khola). In upper reaches of Malampara Khola, the dolomite with bands of dark grey to black slates passes into slightly argillaceous dolomite to dark grey to black slate with small bands of light grey dolomite and calc-slate, whereas, in Thulo Khola area, though, the dolomite is conformably overlain by Benighat Slate, the contact is very sharp and contains yellowish brown weathered zone. The weathered zone contains 4cm to 10cm thick yellowish brown silty soil.

Benighat Slate

Benighat Slate occurs in the north-western part and in south-eastern part of the map area. The bed slightly swings toward south from west to east. It is the youngest formation of Nawakot Complex. Its thickness varies due to pinching and swelling nature. The maximum thickness of 6500m is found to occur in Thulo Khola area, whereas the thickness in Gurja Khani area is 4500m and in Kaligandaki valley is only 3800m. It has a general trend of E-W to NW-SE and dip toward N with an angle of 30° to 50°.

Benighat Slate is represented by dark grey to black carbonaceous slate, shaly slate, graphitic phyllite, greenish grey to lead grey phyllite with intercalation of some carbonate and quartzitic bands. In this area, in Benighat Slate, phyllite dominates over slate and shale, where as slate is dominant in western Nepal. The phyllites of Benighat Slate in eastern part of the map area also contain few garnets as found in the up stream of Thulo Khola near MCT zone and in Kaligandaki valley, north of Tatopani area. As in other areas, white salt coating on fresh outcrop of Benighat Slate is also found in this area. South of Gurja Khani 1 to 1.5cm pyrite cube (mineralization) is found in Benighat Slate. In this area, around one meter thick magnesite band and 24m thick grey to black argillaceous dolomite bands are present. Limestone up to 2.5m thick interbedded with phyllite occurs at least in two horizons of the Benighat Slate. The limestone and phyllite interbedding is 40 m thick. Quartz veins intruded along the foliation plane are quite common in the area.

High Grade Crystalline Rocks

Augen Gneiss

In northern part of the map area, high grade crystalline rocks are brought over the rocks of Nawakot Complex by MCT. Just north of MCT the high grade rock starts with a band of garnetiferous augen gneiss. Its thickness varies between western and eastern part of the map area. In western part, in upper reaches of Myagdi Khola the gneiss is only about 100m thick, whereas, in Kaligandaki valley in eastern part it is more than 2km. thick. The gneiss is composed of quartz, feldspar, muscovite, biotite and garnet. The augens of feldspar are 1cm to 3cm in diameter.

Thickly bedded white grey siliceous gneiss occurs in Kaligandaki valley, around Dana area, immediately north of MCT. The gneiss is composed of 1-3 cm thick siliceous band alternating with 1-2mm green chloritic schist. It contains medium to coarse grained pink feldspar. 1cm to 6cm thick light bluish grey chert lenses are present in the gneiss. The siliceous gneiss is overlain by garnetiferous muscovite biotite gneiss. The gneiss contains yellowish grey to bluish grey, medium bedded quartzite with biotitic schist. This quartzite band is about 100m thick. The gneiss is slightly calcareous and some calc-migmatitic rock is also present. In the upper part, the gneiss is interbedded with dark grey schist bands.

Banded Schist

In Myagdi Khola section, the Augen gneiss is overlain by banded schist. The banded schist is composed of interbeddings of silica rich light grey schist band and mica rich dark grey schist band. Thickness of the band varies from 5cm to 20cm. The schist consists of muscovite, biotite, quartz and scattered fine grained garnets. At places, 20 to 30 cm thick schist bands with medium to coarse grained garnets are present. Some bands contain mainly micas, which are relatively very soft, where as other schists are very hard, and compact. These schists are generally non–calcareous. Some augen like structure and a 25cm wide pinkish green quartzite is found in the schist. The banded schist in Myagdi Khola is overlain by a band of calc-schist, which further north is again overlain by garnetiferous schist and gneiss bands. The garnets in the schist and gneiss are medium to coarse in size.

Kyanite Gneiss

Towards north, the garnetiferous gneiss is overlain by kyanite bearing gneiss. The gneiss consists of alternate layers of 0.2- 0.5cm thick muscovite-biotite layer and 0.5 to 1cm thick quartz-feldspar layer. At places, the gneiss is interbedded with fine-grained muscovite- biotite schist. Kyanite crystals are generally bluish grey in color and 0.2 to 0.5cm wide and 1 to 3 cm long. Around the confluence of Rukse Khola and Kaligandaki River, salt and pepper like textured garnetiferous migmatite bands are present. In the rock, the size of garnet reaches up to 4cm in diameter. These large size garnets are slightly elliptical in shape and often form augen structure in gneiss. Highly disturbed pegmatite bodies are also present in this area. The pegmatites contain books of micas of 3-4cm wide and up to 2cm thick. Both muscovite and biotite are present but muscovite flakes are larger than biotites. Black tourmalines up to 3cm long size are present.

Migmatitic Gneiss and Schists

From Rukse Khola confluence to Talbagar (Mustang-Myagdi border), the area is represented by hard, tightly packed, slightly migmatitic garnet-biotite schist interbedded with hard and compact migmatitic gneiss. The schist is composed of fine to medium grained garnet, biotite, muscovite and quartz. The gneiss is composed of garnet, biotite, muscovite and feldspar. Though in most of the places gneisses are very compact and migmatitic but at few places 2-3m wide, comparatively less compact, very coarse grained gneiss bands are also recorded. Kyanites are generally developed in such coarse grained gneiss. Few calc-schist bands are also present in them.

Calc-Schist

North of Talbagar there exist the bands of light bluish grey, dirty (yellowish brown) grey to dark grey calc-schist. At places these are interbedded with yellowish grey to white grey marble. The calc-schist mainly consists of greenish grey carbonate mineral, biotite, and medium to coarse grained reddish brown garnets. The marbles are thickly bedded coarse crystalline, bluish grey to milky white in colour. The interbedding of calc-schist and marble bands ranging from 5cm to 60 cm are common. Generally calc-schist is the dominant rock type. Calc-schist in the outcrops looks like laminated, with carbonate rich layer and biotite rich layers. Fine-grained kyanites are also developed in some bands. Calc-schist is also present in upper part of Myagdi Khola but here it is only about a kilometer thick but in Kaligandaki valley, it is more than 10 km thick.

GEOLOGICAL STRUCTURE

Most of the rock formations in this area have general trend of E - W direction and dip toward north at an angle of 30° to 50°. Major geological structure in the area is Main Central Thrust, which brings the high grade crystalline rocks of the north over the meta-sedimentary rocks of Nawakot Complex in the south. Generally, a clear and undisturbed thrust contact cannot be seen in the area. However by observing the out crop pattern in the vicinity of the thrust, it can be inferred that the thrust has a general trend of E - W and dip toward north at an angle of 45° to 50°.

In the upper part of Thulo Khola, there is an outcrop gap of 50 to 70m in MCT zone. It is presumed that due to pressure and thermal effect of the thrust, medium to coarse grained garnets were developed in black phyllite of the Benighat Slate. In Kaligandaki valley, MCT passes more or less along the Ghatte Khola.

As described above, the contact between Dhading Dolomite and Benighat Slate is found at some places to be transitional with interbeddings of slate and dolomite at the contact where as at places the contact is disconformable. Such disconformity is seen in the upper reaches of Rahughat Khola.

FINDINGS

Main Central Thrust brings the high grade crystalline rocks over the meta-sedimentary rocks of Nawakot Complex. Benighat Slate in the area is relatively more metamorphosed with appearance of some garnet at places, due to its proximity to Main Central Thrust. Transitional to disconformable contact of Dhading Dolomite and Benighat Slate shows that the basin after the deposition of Dhading Dolomite was partially exposed for erosion. Though, some pyrite minerals are found in Benighat Slate, Dandagaon Phyllite is the mineralized formation in the area with up to 30cm thick mineralized bands. There are a number of limestone bands (Jhiku carbonate) within Benighat Slate. Coarse crystalline marble bands of calc-schist of high grade crystalline rocks could be exploited as polished or decorative stones, once the Mustang district is connected by country's road network in near future.

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Annual Report of Department of Mines and Geology, 2006, No. 3, pp 9 – 24

Exploration and Assessment of Thoshe Iron Deposit in RamechhapDistrict, Central Nepal

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INTRODUCTION

Thoshe Iron deposit lies in between latitude 27° 33' 00" to 27° 35' 00" North and longitude 86°16' 00" to 86° 17' 30" East. It extends from Singate in southeast to Arubote and Danga Dinger village in northwest in Thoshe VDC, Ramechhap district, Central Nepal. The elevation of the deposit site varies from 8500ft at Arubote to 9600ft above msl. at Singate. The area can be accessed from Jiri to Thoshe Megchan by rough seasonal road and from Thoshe Megchan to Singate on foot. Jiri is linked with Kathmandu by a 198km black topped road. The nearest airport is in Manthali, the District Headquarter of Ramechhap. A small airstrip and helipad also exist at Jiri.

Jhingran (1951) prepared the first technical report on hematite of Thoshe area. Upadhyaya (1956), Suwal (1965) and Manandhar (1963) described about the old workings in Thoshe iron deposit. Weise (1960) prepared the mining scheme. Good (1963) recommended for mine development. Rana (1965) did preliminary feasibility study for 600 tons finished iron per year. Talalov (1972) did reconnaissance geological survey for the first time and concluded that it is not of commercial value. Poudyal & Shrestha (1977) carried out regional geological mapping of the area. From all these information it is known that Thoshe and its surrounding area is represented by low to high grade metamorphic rocks. Hematite mineralization occurs within gently dipping chloritic mica schist overlain by calcareous schist and siliceous marble with some quartzite and underlain by sericitic chlorite mica schist

Kaphle and Khan conducted Preliminary investigation and Follow up exploration and assessment of Thoshe Iron deposit in FY2051/52 and FY2052/53 respectively. They prepared regional geological map of 100sq km area covering Thoshe and surrounding regions in 1:63,360 scale, semi detail geological map of Thoshe Iron prospect and adjacent area in 1:16,000 scale and a detail geological map of 2sq.km area of Thoshe iron deposit in 1:2500 scale. Northwest – southeast extending two hematite mineralization bands were traced by outcrop mapping and trenching/pitting, which has helped to find out their extension length and thickness. 50 chip, 15 bulk and 30 grab samples were collected from the ore body and analyzed to find the iron content in them. Similarly 35 rock samples from various rock units were collected for petrographic and mineralogical studies. Few old mine pits (old workings) were cleaned up and examined. Field investigations were successful to trace 1 - 3m thick (combined) and about 4km long hematite ore body at Thoshe. The grade of iron ore varies considerably from 22.5% to 66% iron in them. Follow up geochemical stream sediment survey covering the same 100sq.km was able to trace minor one copper and two zinc anomalous bodies but none of them deserved further investigation. This paper is based on these field investigations and their results.

Old Mining and Ore Processing Activities

From the available literatures/reports and local miners it is known that small-scale domestic mining of Thoshe iron deposit was started as early as in 1865 (1922 BS) and continued till 1966 (2022 BS). Smelting of mined ores was continued till 2028 BS. In those days, 15 mines (Fig.1) in Thoshe e.g. (1) Singate East (2) Singate West, (3) Ghyang Danda (4) Barappu (5) Kuwako Pakha (6) Sallyani (7) Bhosbhose (8) Pokhari, (9) Jhoreni (10) Pahare (11) Kopu (12) Patale (13) Arubote (14) Dangadinger (15) Sotre), other three mines in (16) Majuwa Khani and (17) Soleban Khani in Priti and one mine in (18) Ghunsa were in operation. In early days the annual production was around 50 tons and later increased up to 150 tons ore per day. It is learnt from old miners that they use hand to crush the ore materials to minus 20 to 40 mesh size fraction and wash them in a slow running water with the help of wooden vessels to get the clean concentrate and upgrade the ore for smelting. The concentrated ores were used to smelt in 29 smelting places (Affars) located near by. Charcoal prepared from Khashru, Phalant, Banset, Gurans, Angari, Bulu and Uttis trees were used for smelting in which red clay was used as flux. It is also known from them that smelting procedure use to take 12 – 16 hours to smelt about 250kg ore into 100 to 125 kg sponge iron depending on the quality of the ore. Blacksmiths used to make various agricultural tools like spade, axe, knife (Khukuri), sickle (ansi), phali, hammer, nails, chains and cooking vessels like Tapke, Dadu, Paniyo etc. from the sponge iron. In those days, based on Thoshe iron, the government had also established a small gun factory at Thoshe Megchan, which was capable to produce nine barrels of the gun every day. The factory closed after 2007 BS but its remnants still exist in the school compound at Thoshe Megchan. The mining activity was closed in 2022 BS due to government's new policy, shortage of fuel wood, technical difficulty in mining at depth and easily availability of finished iron in the free market.

OBJECTIVE

- Compile the existing information, carry out Preliminary and Follow up investigation and quick assessment of the deposit.
- Prepare regional geological map of 100sq.km. area in 1:63,360 scale, semi detail geological map of 10sq.km. area in 1:16,000 scale, Detail geological map of 2sq. km. in 1:2500 scale and trace the hematite mineralization bands in different sections and find out their thickness, lateral extension, the grade and also roughly estimate the Tonnage of the ore deposit (i.e. geological reserve).
- Excavate few trenches and open old mining pits to expose the mineralization bands to collect chip, bulk and grab samples for petrographical, mineralogical studies and chemical analysis.
- Make overall assessment of the prospect/deposit.
- Recommend for further detail investigation to exploit the ore in near future.

FIELD INVESTIGATION

Existing data were compiled and a quick field assessment of Thoshe iron deposit was carried out in 1995. A Regional Geological Map of 100sq.km (scale 1:63,360) and Semi Detail Geological map of Thoshe Iron prospect area covering over 10sq.km in 1: 16,000 scale (Fig.1) were prepared. Follow up stream sediment survey covering the same 100sq.km area at a sample density of 1 sample/sq.km. and heavy mineral concentrate sampling with a sample density 1 sample/ sq.km. were carried out. In 1996 a detail geological map of 2sq.km area of Thoshe iron deposit in 1: 2500 scale (Fig. 2A & 2B) was prepared. The mineralized horizons were traced by shallow trenching. All together 50 chip, 15 bulk and 30 grab samples from the ore bodies, 35 rock samples from different rock units, 102 stream sediment samples and 20 heavy mineral concentrates from different streams were collected for laboratory investigations and chemical analysis (Table–2). All the chip, bulk and grab samples were analyzed for iron content and some selected samples analyzed for Cr, Ti, Ni and Ag content in them.

METHODOLOGY

- During field investigation/survey a topobase map was used to locate the outcrops, samples and other features.
- Geological maps were prepared with the help of Brunton Compass and tape survey and identified the rock types, host rocks and trace the ore bodies.
- Survey compass, tape and altimeter were used to carry out the survey of the deposit and detail mapping.
- Chisel, hammer etc. were used to take the chip and bulk samples from the ore body.

REGIONAL GEOLOGY AND STRUCTURE

Poudel and Shrestha (1977) prepared the regional geological map of this area. Kaphle and Khan (1995) had also mapped some parts of Thoshe and Khimti Khola area. This area is represented by low to high grade metamorphic rocks which is broadly divided into three main Litho-Tectonic Units (Complexes) e.g. Low grade metamorphic rocks of (A) Nawakot Complex and High grade metamorphic rocks of (B) Central Crystalline (Crystalline Complex, Table-1) separated by Main Central Thrust (MCT) and (C) Lesser Himalayan Crystalline Gneiss (Ulleri gneiss ?) which occurs towards southern part of the investigated area (Fig.1). It is separated from Nawakot Complex by another thrust. Three transverse faults as Khimti Khola fault, Kuthme fault and Singate fault are traced in the field. Part of the Khimti Khola is controlled by Khimti Khola fault. There exists a Dorje Khola anticline (Fig.1). The general trend of the rock units is NW – SE direction and dip $11^{\circ} - 40^{\circ}$ towards north except in Khimti Khola gneiss that occurs towards southward of the area and dips towards south. Hagen (1965) had correlated these two groups of rock with Waling Schist and Darjeeling Gneiss respectively. Poudyal and Shrestha (1977) had divided the rock into two zones as (1) Carbonaceous and Argillaceous zones with calcareous horizons and (2) Schistose and Gneissic Zone. Present authors compiled the various litho-tectonic units as follows (Table-1).

Lesser Himalaya Gneiss (Ulleri Gneiss ?)

Coarse to very coarse grained Khimti Khola augen gneiss is possibly the part of crystalline nappe. It is similar to Ulleri type gneiss in its texture and mineral composition.

Nawakot Complex

It is represented by low to medium grade metamorphic rocks like (1) Sericitic white quartzite (2) Gray to greenish gray phyllite and Carbonaceous phyllite (3) Chloritic quartz mica schist with hematite followed by Calcareous schist and silicified Marble and (4) Chloritic garnet mica schist and calc mica schist.

Crystalline Complex

It is represented by (1) Kyanite bearing garnet mica schist and micaceous quartzite (2) Quartzo feldspathic garnet mica schist, gneiss and banded gneiss and (3)

Table.1: Litho-tectonic units in Thoshe and surrounding areas.

Complex	Formation	Lithological description
Higher Himalayan Crystalline Complex	VII. Lumsa Formation	Medium to coarse grained garnet mica schist, Quartzofelspathic schist, augen gnaiss, migmatites and granite bodie.
	VI. Mélange Formation	Medium to coarse grained biotite rich quartzofelspathic mica schist, garnet mica schist, gneiss, and banded gneiss.
	V. Dhunge Khola Formation	Medium to coarse grained kyanite bearing garnet mica schist occasionally with micaceous quartzite, kyanite schist and gneiss bands.
	MCT	
Nawakot Complex (?)	IV. Yalung Khola Formation	Medium to coarse grained chloritic garnet mica schist, calc schist and silicified marble bands.
	III. Dorje Khola Formation	(B) Fine to medium grained gray to light greenish gray chloritic biotite schist, calcareous schist with crystalline dolomite (marble) bands at the base. At few places small irregular Amphibolite bodies. Hematite bands located at the base of crystalline dolomite. (A) Fine grained gray to dark gray carbonaceous slaty phyllite and greenish gray chloritic sericitic phyllite and chloritic mica schist.
	Thrust	
	II. Thoshe Megchan Quartzite	Fine to medium grained sericitic white quartzite. At places feebly calc. quartzite bands and silicious magnesite/dolomite with talc lenses
	Thrust	
Lesser Himalayan Gneiss	I. Khimti Khola Gneiss (Ulleri Gneiss ?)	Coarse grained porphyroblastic augen gneiss with quartzofeldspathic schist and quartzite bands

Garnet bearing quartzo-feldspathic schist, gneiss and migmatitic augen gneiss.

GEOLOGY OF THOSHE IRON DEPOSIT

Kaphle and Khan (1995) prepared a fairly detail geological map (scale 1:16,000, Fig.1) of the Thoshe and surrounding area. Thoshe area is a part of Lesser Himalaya. It is represented by low to medium grade metamorphic rocks of Nawakot Complex (?). High grade metamorphic rocks occur further north (beyond the present investigated area) and separated from low to medium grade rocks of Nawakot Complex by a prominent linear structure that is know as Main Central Thrust (MCT). The rocks of Nawakot Complex are represented by fine grained sericitic quartzite, fine to medium grained gray to light greenish gray chloritic mica schist and quartzite. At places minor amphibolite bodies are also recorded in the area. Various lithological units are given in Table-1 and briefly described below.

Thoshe Magchan Quartzite

This unit is separated from Khimti Khola gneiss by a prominent thrust. The rock unit is a part of Nawakot Complex (?). It is very well exposed right at the suspension bridge site in Thoshe Magchan at the confluence of a small tributary coming from the right side of Khimti Khola (Fig.1). It is a fine to medium grained, poorly foliated

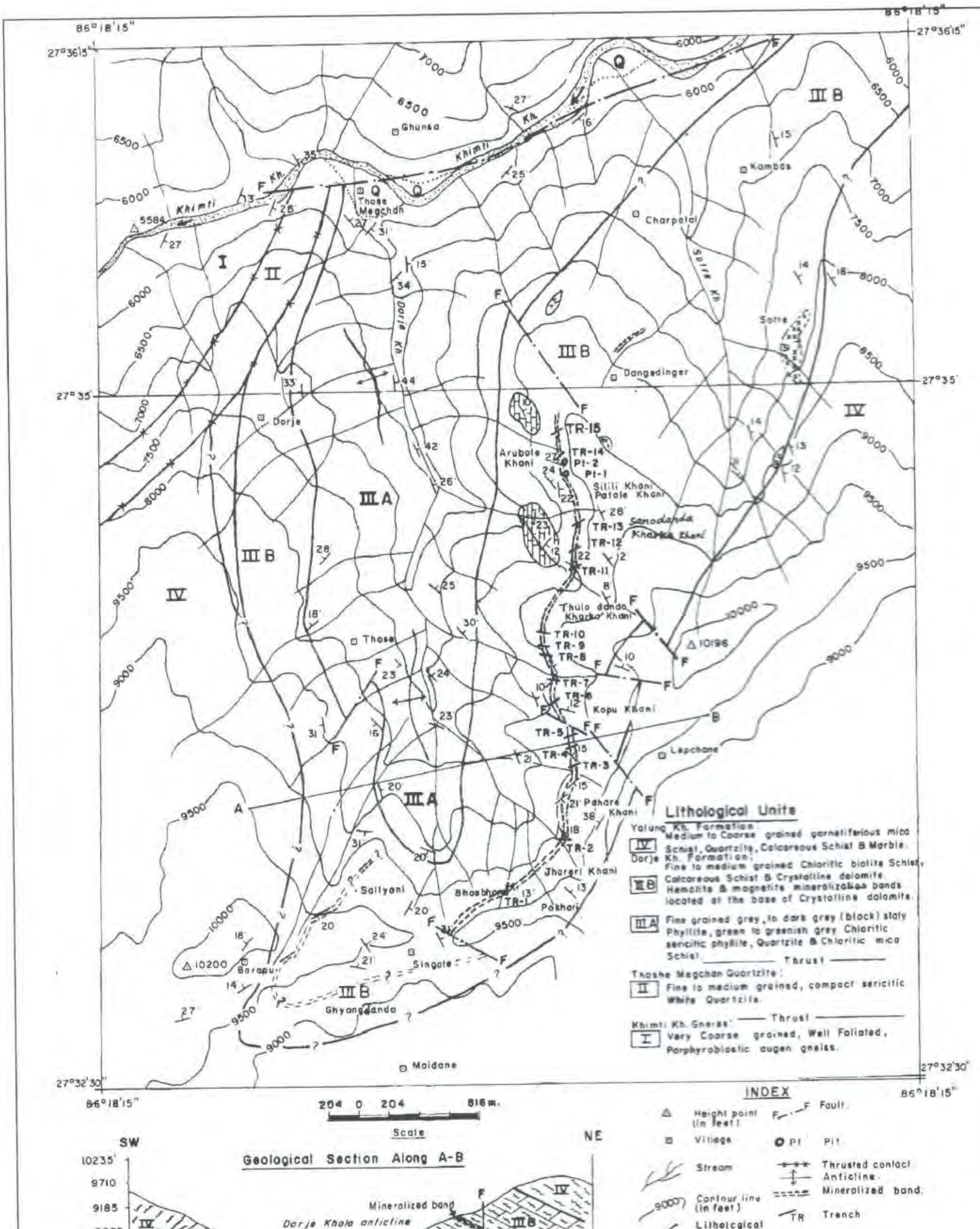

Fig. 1 Map of Thoshe Iron Prospect Ramechhap Dist.

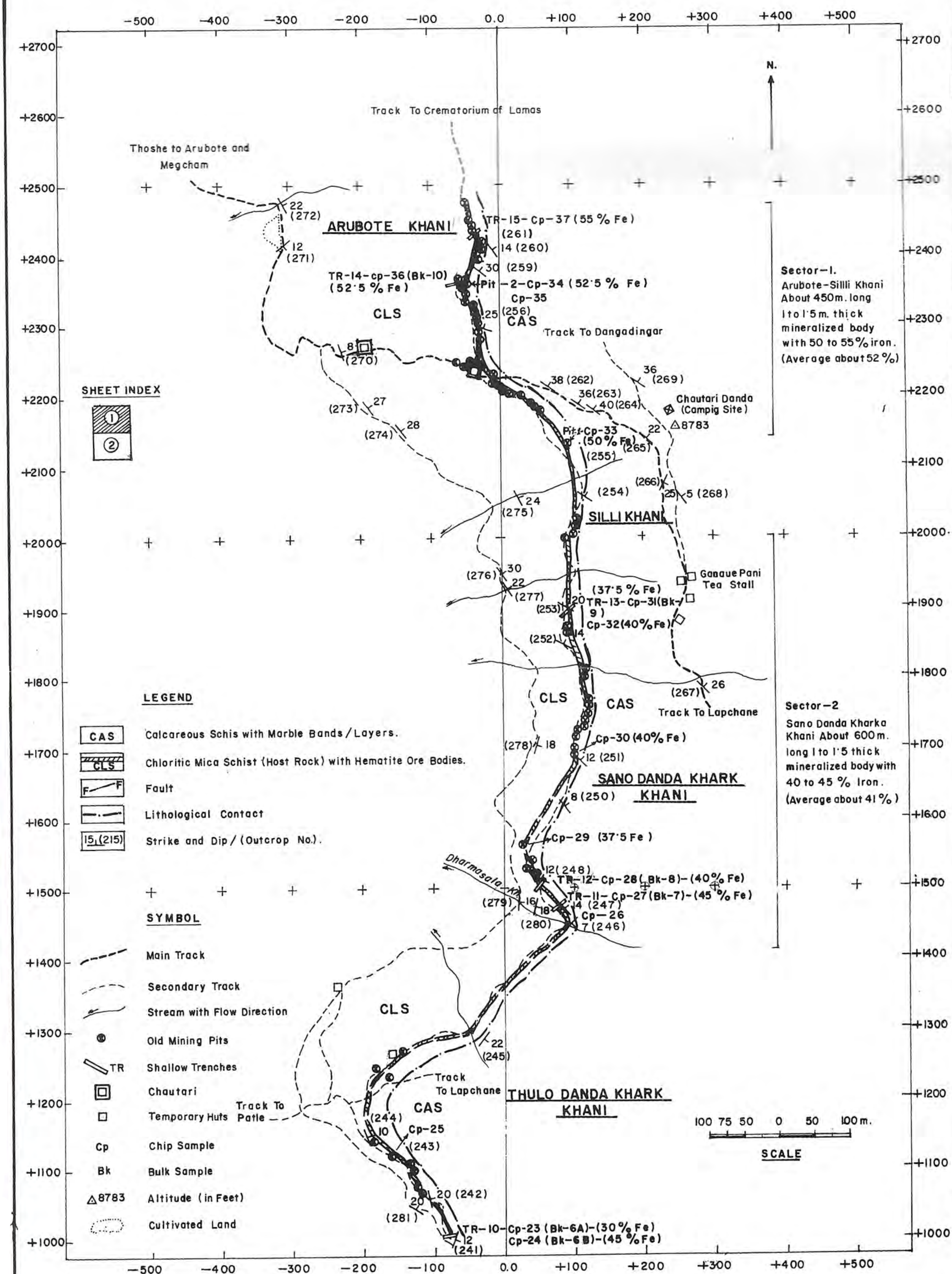

Fig.2A GEOLOGY OF THOSHE IRON DEPOSIT, RAMECHAP DISTRICT

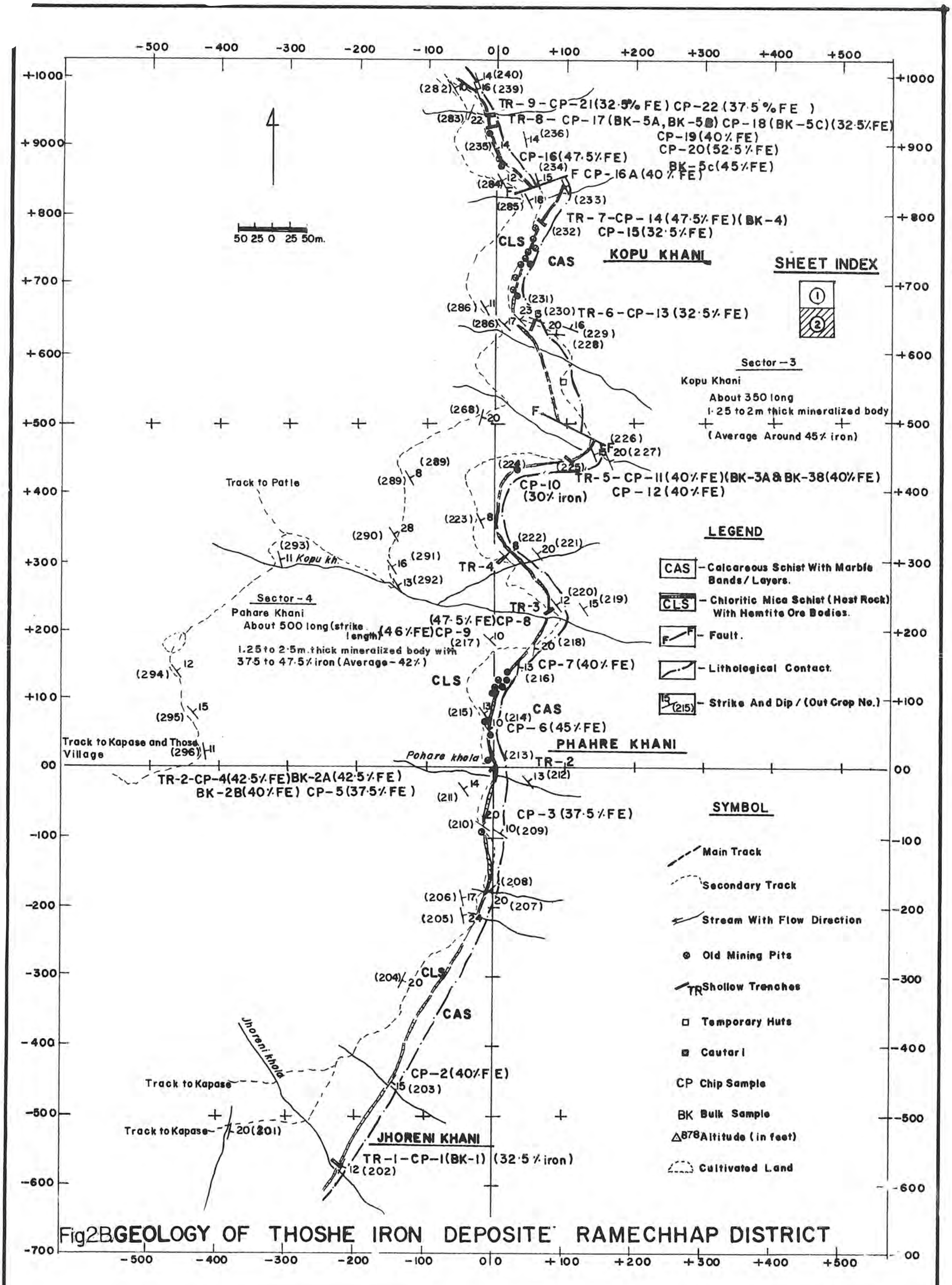

Fig2B GEOLOGY OF THOSHE IRON DEPOSITE RAMECHHAP DISTRICT sericitic white to grayish white quartzite. Towards uppermost part, specially in Sikri Khola and Jiri Khola section it is calcareous and gradually grades into silicious dolomite and magnesite with talc lenses. Quartzite is mainly consists of quartz (80-90%), sericite (5-10%) and calcareous materials and iron oxide etc (2 –5%).

Dorje Khola Formation

This formation overlies the Thoshe Magchan quartzite and separated by a local thrust. It is well exposed in Dorje Khola, Sotre Khola, part of Khimti Khola, Sikri khola and Jiri Khola sections. The thickness of this unit varies considerably in different section (Fig.1). On the basis of lithology this unit is subdivided into two members: (IIIA) Fine grained gray to dark gray (black) slaty phyllite, quartzite and green to greenish gray chloritic mica schist and (IIIB) Fine to medium grained chloritic biotite schist, calc mica schist and crystalline dolomite. Hematite bands are located at the base of crystalline dolomite (marble) and calc schist with chloritic biotite schist. At places mica schist is poorly garnetiferous. Minor amphibolite bodies are recorded only at few places. Hematite mineralization bands occur towards the lower part. Barren white quartz veins are common in this unit. Quartz + Ilmenite and Quartz + Pyrite + Pyrrhotite and Ilmenite veins are recorded close to or within the hematite mineralization bands in Arubote and Sotre mine area. Isolated dolomitic limestone blocks and bands are also recorded in Patale, Arubote, and Ghunsa (Fig.1).

Yalung Khola Formation

This formation overlies the Dorje Khola Formation conformably. It is well exposed in the Yalung Khola, Shamble Khola and a small part of Khimti Khola section and east of Jiri on the ridge top. It is represented by medium to coarse grained calcareous mica schist (at places chloritic) silicious marble (crystalline dolomitic limestone), garnet mica schist and quartzite bands. Few sill like basic rock bodies (amphibolite) are also recorded within this unit. Ferrugenous calc schist and quartz mica schist are recorded in the upper part of Sotre Khola. Except very few quartz and quart + chlorite veins no other mineralized veins are recorded in this unit.

MINERALIZATION

Preliminary field investigations followed by follow up exploration and assessment of the deposit revealed that Thoshe Iron deposit occur within the low dipping chloritic mica schist (host rock) of Dorje Khola Formation. It is overlain by calcareous mica schist and silicious marble and underlain by green chlorite sericite mica schist and carbonaceous chloritic schist (Fig.1). There exist at least two (possibly three) mineralization horizons (ore bodies) separated by less than 25 cm to almost 6 m thick poorly mineralized ferrugenous sericitic quartz mica schist and almost green chloritic mica schist bands. Both the mineralization bands extend from Singate in southeast to Arubote in the northwest (about 4km) in strike length. The mineralized bands lie on the upper most part of the chloritic sericitic quartz biotite schist close to the contact with calcareous schist and marble (crystalline dolomite). Minor mineralizations are also recorded in Barappu, Salyani, Dangadinger, Sotre and Ghunsa (Fig.1) but none of them were studied in detail.

In Thoshe three types of hematite mineralization are observed as (1) massive hematite with few crystalline magnetite (2) massive to foliated mixed hematite and very few magnetite with few thin sericitic quartz lamina and (3) Incipient mineralization along the foliation of the host rock. Khimti Khola fault and Singate fault might have provided some hydrothermal fluids, which could be one of the sources of Pyrite, Pyrrhotite and Chalcopyrite mineralization in some parts of Hematite bands in Arubote and Sotre area. Both the mineralized bands are well exposed in Jhoreni Khani, Pahare Khani, Kopu Khani, Patle Khani and partly in Arubote Khani. However, in other places they are covered with old mine dump and slided debris. Mineral concentration within the ore body is not uniform rather it is irregular. As a result iron content in the ore samples varies considerably (Table-2).

The upper mineralization band

It is 30cm to 1.5m thick and consists of medium to coarse grained, massive to poorly foliated shining silvery brownish gray hematite with cherry red streak and minor amount of shining steel gray to silver gray magnetite with gray streak. In Arubote and Sotre sections few pyrrhotite, pyrite and magnetite are also recorded along with quartz veins and lenses in it. Iron content in the mineralization bands is not uniform as the analytical results revealed 22.5 to 66% iron in them. The average iron content is below 45% i.e. around 42%. Study of hematite ore under the ore microscope revealed that it consists of mainly hematite (60 – 80%), magnetite (<5 – 8%), iron sulphide (1 – 3%) and gangue minerals (8 – 15%). Hematite is partly replaced by magnetite. Gangue minerals are mainly quartz and mica.

The lower mineralization band

It is separated from the upper mineralization ore body by less than 25 cm to 6m thick, foliated, incipiently mineralized ferrugenous sericitic mica schist and almost barren chlorite mica schist. It is 80cm to 1.6m thick and well foliated, medium grained, shining gray micaceous hematite with or without magnetite. At places quartz + magnetite with or without ilmenite veins or lenses are also recorded. The thickness and concentration of the ore minerals in this band (ore grade) varies considerably (from 22.5 to 45% iron) in different sections. However, the ore minerals remain the same. There exists few, very thin, thread like interlayers of quartz and quartz mica schist within the mineralization bands. Generally the

Table 2: Chemical Analysis Results of ore and rock Samples

Sample Number (Chip/Channel samples)	Fe (%)	Location/ Remarks
RM/2052/53		
KK/Th/Jh/Tr-1/Cp-1	32.5	Jhoreni Khani / LG ore
" " Cp-2	40	Jhoreni Khani/ LG ore
" " Ph/Cp-3	37.5	Pahare Khani/ LG ore
" " Ph/Tr-2/Cp-4	42.5	Pahare Khani/ MG ore
" " " " Cp-5	37.5	Pahare Khani/ LG ore
" " " Cp-6	45	Pahare Khani/ MG ore
" " " Cp-7	40	Pahare Khani/LG ore
" " Tr-3 Cp-8	47.5	Pahare Khani/ MG ore
" " " Cp-9	45	" " "
" " /Kp Tr-5 Cp-10	30	Kopu Khani/ LG ore
" " /Kp.Tr-5Cp.11	40	Kopu Khani/ LG ore
" " " Cp-12	32.5	Kopu Khani/ LG ore
" " " Tr-6/Cp-13	47.5	Kopu Khani / MG ore
" " " Tr-7/Cp-14	47.5	Kopu Khani/ MG ore
" " " Tr-7/Cp-15	32.5	Kopu Khani/ LG ore
" " " Kp/Cp-16	47.5	Kopu Khani/ MG ore
" " " Tr-8/Cp-17	32.5	Kopu-BhaluKhani/LG ore
" " " Tr-8/Cp-18	32.5	" " "
" " " Tr-8/Cp-19	40	" " "
" " " Tr-8/Cp-20	52.5	" "/ HG ore
" " Tr-9/Cp-21	32.5	" "/ LG ore
" " " Tr-9/Cp-22	37.5	" "/ LG ore
" " " Tr-10/Cp-23	30	" "/ LG ore
" " " Tr-10/Cp-24	45	" "/ MG ore
" " Dk/Cp-25	35	Danda Kharka/ LG ore
" " Dk/Cp-26	35	" "/ LG ore
" " Dk/Cp-27	45	" "/ MG ore
" " " Tr-12/Cp-28	40	Sano " " / LG ore
" " " Tr-10/Cp-29	37.5	" " "/ LG ore
" " " Tr-10/Cp-30	35	" " "/LG ore
" " " Tr-10/Cp-31	37.5	" " " / LG ore
" " " Tr-10/Cp-32	40	" " " / LG ore
" " " Pt-1/Cp-33	**50**	Silili Khani/ **HG ore**
" " " Pt-1/Cp-34	52.5	" " / **HG ore**
" " " Pt-2/Cp-35	27.5	" " / LG ore
" " " Tr-14/Cp-36	52.5	Arubote Khani/ **HG ore**
" " " Cp/36A	33.7	" " / LG ore
" " Tr-15/Cp-37	**55**	" " / **HG ore**
" " " /Cp-38	45	" " / MG ore
" " " /Cp-39	**55**	" **" / HG ore**
KK/Th/Cps-16A	40	" " / LG ore
KK/Bml/Cps-40	47.5	Ghunsa Khani/ MG ore
KK/Th/Sii/Cp-41	47.5	" " / MG ore
KK/Th/Sii/Cp-42	27.5	Barmasthali/ LG ore
KK/Bml/Cps-43	**55**	" **" / HG ore**
Cp-44	NA	" " / (?)
Cps-45	37.5	" " / LG ore

Sample Number (Chip/Channel samples)	Fe (%)	Location/ Remarks
Bulk Samples		
KK/Th/Jr/Tr-1/Blk-1	31.5	Jhoreni Khani/ LG ore
" " Ph/Tr-2/Blk-2A	42.5	Pahare Khani /MG ore
" " " /Tr-2/Blk-2B	40	Kopu Khani/ LG ore
" " Kp/Tr-5/Blk-3A	42.5	" " / MG ore
" " Kp/Tr-5/Blk-3B	40	" " / LG ore
" "/ Jr/Tr-1/Blk-4A	35	Kopu Bhalukuwa/LG ore
" " Jr/Tr-1/Blk-5A	32.5	" " /LG ore
" " /Jr/Tr-1/Blk-5B	22.5	" " / LG ore
" " /Jr/Tr-1/Blk-5C	45	Kopu Division/ MG ore
" " /Jr/Tr-1/Blk-6A	28.7	Kopu Division/ LG ore
" "/Jr/Tr-1/Blk-6B	25	Danda Kharka / LG ore
" " /Jr/Tr-1/Blk-7	37.5	Danda Kharka/ LG ore
" " /Jr/Tr-1/Blk-8	37.5	Arubote Khani/ LG ore
" " /Jr/Tr-1/Blk-9	22.5	Arubote Khani/ LG ore
" " /Jr/Tr-1/Blk-10	NA	Arubote Khani/ ?
Grab Samples		
RM/2051/052		
KK/S-6A	**66**	Arubote Khani/**Very High grade ore**
" KK/S-6B	45	Arubote Khani/ MG ore
" **KK/S-8A**	**57**	Pahare Khani/ **HG ore**
" KK/S-8A-1	48	Pahare Khani/ MG ore
" KK/S-8B	31	Pahare Khani/ LG ore
" KK/S- 23A	30.5	Bhosbhose Khani/ LG ore
" KK/S- 23B	49.5	Bhosbhose Khani/MG ore
" KK/S- 23C	50	Bhosbhose Khani/MG ore
" KK/S- 25	45	Singate Khani/ MG ore
" KK/S- 26	45	Singate Khani/ MG ore
" KK/S- 26A	34	Singate Khani/ LG ore
" KK/S- 28	38	Barrapu Khani/ LG ore
" KK/S - 30	31.5	Salleni Khani/ LG ore
" KK/S - 30A	26.5	Salleni Khani/ LG ore
" KK/S - 31	33.5	Pahare Khani/ LG ore
" KK/S - 32	29	Pahare Khani/ LG ore
" KK/S - 34	32	Jhoreni Khani/ LG ore
" KK/S - 35	40	Jhoreni Khani / LG ore
" KK/S - 36	43	Kuwa Khani/ MG ore
" KK/S - 38B	34.5	Pahare Khani/ LG ore
" KK/S - 39A	42	Darim Danda/ MG ore
" KK/S - 39B	40	Darim Danda/ LG ore
" KK/S - 41	29.5	Kopu Khani/ LG ore
" KK/S -42A	37	Kopu Bhalukuna/ LG ore
" KK/S -42B	***55.5***	*Kopu Bhalukuna/* ***HG ore***
" KK/S -43	38	Kopu khani/ LG ore
" KK/S -66	40	Silili Khani/ LG ore
" KK/S -67	49.5	Sano Dandakharka/MG ore
" KK/S- 67A	35	Sano Dandakharka/LG ore
" KK/S- 70	31.5	Danger Dinger/ LG ore
" KK/S- 78	NA	-
" KK/S- 001	-	-
" KK/S- 117	41	- MG ore
" KK/S -141B	22.5	- LG ore

(Cp = Chip sample, Blk =Bulk sampl , S = Grab sample, LG = Low grade, MG = Medium grade, HG = High grade)

concentration of ore minerals is comparatively rich towards the upper part. In addition to this in trench no 8 a 70 to 80cm thick mineralization band consisting reddish brown hematite is also recorded at the basal part of the lower mineralization band. In hematite, quartz and mica are the two main gangue minerals. The combined thickness of both the mineralization bands becomes 2 – 3 m. From the analytical results of the chip samples the average grade appears to be around 40% and from bulk samples it comes less than 40%.

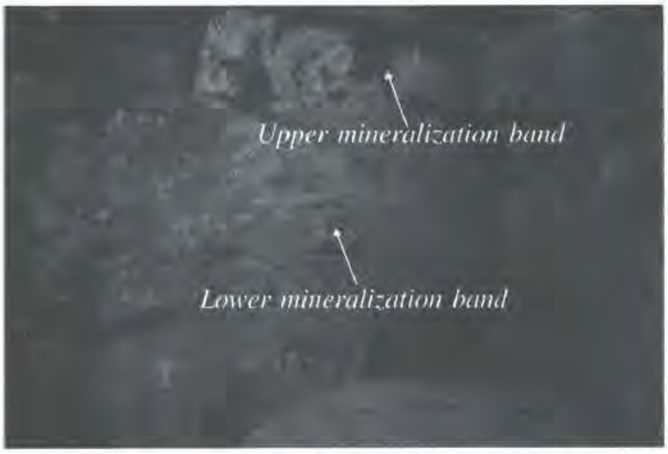

Fig.3 Two hematite mineralization bands exposed in Kopu Khani, Thoshe.

According to the old miners there exists a 1.5 to 2m thick third mineralized body. It is comparatively rich in grade at Gairi Khani and Bhosbhose Khani where they have mined the ore in later part of mining activity (during 1960 – 1966). Because of foliated and brittle nature of mica rich hematite ore, mining was fairly easy. However, thick overburden of the overlying loose materials, old mine dumps and the overlying rocks it is not possible to expose the mineralization band by shallow trenching. Only 35 to 100m deep drill holes could confirm the existence of the third mineralization bands (ore body). The combined geological ore reserve (tonnage) and average grade are calculated only on the basis of the upper and lower mineralization bands (Fig. 3).

Ore Genesis

Field study of the ore bodies and laboratory investigations of the ore samples and the nature of the mineralization revealed that it is a synsedimentary hematite deposit, which was later affected by medium grade regional metamorphism. As a result the sedimentary hematite ore has been recrystallized into a less foliated to well foliated micaceous silvery gray hematite with minor amount of magnetite and almost massive hematite with few magnetite and very rarely pyrrhotite and pyrite (only in Arubote and Sotre). Minor hydrothermal effects has been indicated by the presence of few small quartz + magnetite + ilmenite veins and lenses as well as quartz + pyrite + pyrrhotite lenses within the hematite bands or in the host rock very close to the contact with the mineralization bands. The grade of the ore varies considerably from 22.5 to 66% iron with few Titanium, (<800 to 1600pm), Chromium (<20 to 50ppm), Nickel (<20 200ppm) and rare amount of Silver (<1 - 2ppm).

Geochemical Survey

Reconnaissance geochemical survey was carried out by Adhikary in 1980. The authors carried out Follow up Geochemical stream sediment survey in 100sq.km area around Thoshe covering some parts of Dolakha and Ramechhap district. 102 stream sediment samples with a sample density of 1 sample/sq.km and 20 Heavy mineral concentrate samples with a sample density of 1 sample per 5sq.km area was collected in the field. All of them were analyzed in the chemical laboratory. Analytical results are plotted in the anomaly maps of Copper, Lead and Zinc. No significant anomalous body for Cu, Pb and Zn was detected in this area.

FINDINGS

- Regional geological map of about 100sq km area of Thoshe and surrounding area in 1: 63,360 scale and semi detail geological map of 10sq.km area around Thoshe iron deposit were prepared in 1: 16,000 scale and the host rock of the hematite mineralization was clearly defined (Fig.1)
- Compass – Tape survey (map in 1:2500 scale) was able to delineate a 2–3 m thick two mineralization bands/bodies in a 4km strike length from Singate to Arubote (Fig.2A and 2B).
- Two mineralization bands were traced by excavating 15 shallow trenches and cleaning 2 old working pits. 50 chip samples, 15 bulk samples and 30 grab samples were collected from different parts of the ore bodies (Fig. 2A and 2B). All the samples were analyzed and petrographic studies were made in DMG labs.
- Rough estimation of geological reserve based on the assessment data indicates that there exist about 10 million tons of iron ore with an average grade of about 40% iron. However, separate calculation of comparatively high grade ore is also made. According to this the ore mineralization bands were divided into four sectors. Each sector was recalculated for their average iron content (Fig. 2A and 2B).

Sector 1: Arubote Khani (Fig. 2A)

This part is about 450 m long in strike length. The thickness of the mineralized body (combined) is 1.5 to 2.00m but the comparatively better mineralized parts only 1 to 1.5m thick. The iron content in this sector varies from 50 to 55% in chip samples and the average grade is about 52% only.

Sector 2: Sano Danda Kharka (Fig. 2A)

This sector is about 600m in its strike length. The thickness of the mineralized body (combined) is 1.5 to 2.6m. But the better mineralized part is only 1 to 1.5m thick. The iron content in this part is 37.5 to 45% in chip samples. The average grade is around 41% only.

Sector 3: Kopu Khani (Fig. 2B)

This part is about 350m in strike length. The thickness of the mineralized body (combined) varies from 2 to 3m but the better mineralization part is only 1 to 1.5m thick. Iron content in this part varies from 37.5 to 47.5% in chip samples. The average grade is around 42%.

Sector 4: Pahare Khani (Fig. 2B)

This sector is about 500m in strike length. Its thickness varies from 1.5 to 2.6m. In this area upper horizon is rich in iron content than the lower one. Iron content varies from 37.5 to 47.5% with an average of 42%.

CONCLUSION AND RECOMMENDATION

Thoshe iron ore deposit is the oldest known iron old working (mine) in Nepal. It was mined (in small scale) for about 102 years by local miners. The nature of the mineralization, its extension length, combined thickness and overall tonnage of the deposit appears quite interesting. But because of the non uniformity in the concentration of the ore minerals and low to medium average grade of the ore, unsuitable condition for open cast mining (except in Singate and part of Arubote), unavailability of basic infrastructure like road networks, electricity and fairly low price metal, this deposit is categorized as a low grade, medium tonnage iron deposit, which does not appear to be an economic deposit at this stage. However, price increase of iron, development of all infrastructures and application of high metallurgical techniques may help to upgrade the quality of ore and then only it could be feasible for mining in future.

Geophysical/magnetic and gravity survey is recommended to confirm the shape, size and depth extension of the ore bodies. Such survey supported by selective test drill holes (6 – 10 holes) may help to confirm the grade, tonnage of the deposit and also trace the possible third mineralization horizon (body).

Selective mining of the comparatively rich ore may be possible but smelting of hematite ore into a sponge iron needs high amount of energy (coal or electricity).

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Follow-up Geochemical Exploration for Base Metals in Bauli Gad, Kucha, Dil Gad, Sain Gad/Tamatoli and Sheri Areas, Bajhang District, Far Western Nepal

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INTRODUCTION

Follow-up Geochemical Exploration for copper, lead and zinc was carried out in Bauli Gad, Kucha, Dil Gad, Sain Gad/Tamtoli and Sheri areas of Bajhang district in Far Western Napal. All the five investigated areas lie within the Longitude 81° 00' 00' to 81° 15' 00' E and Latitude 29° 30' 00' to 29° 45' 00' N. Chainpur, headquarter of Bajhang district is situated within 5 to 25km range of the study areas (Fig-1).

Dikshit (1984) prepared a regional geological map of the area. The author himself conducted a 'Reconnaissance Geochemical Survey' for base metals (Cu, Pb and Zn), gold and uranium in this area in 1995. Preliminary investigation was able to identify few geochemical anomalies of copper, lead and zinc in this area. Occurrences of few fine gold colours/flakes were also recorded in the river beds of Taru Gad and its tributaries. Besides that an uraniferous band is also recorded in this area. Because of encouraging results of Reconnaissance survey, a preliminary follow-up exploration work was carried out in all the above mentioned five areas in 1997 (F.Y. 2053/54). This paper is prepared on the basis of above exploration works and their results.

OBJECTIVE

The main objectives of the follow-up exploration were:

- To prepare semi-detail geological map (scale 1:16,000) of the selected areas
- To confirm the anomalous areas and trace the mineralized ore bodies (source of Cu, Pb, Zn and Au) and find out the metal content in them

METHODOLOGY

- Topographic base maps (enlarged to 1:16,000 scales) were used in Geological mapping. Lithological units/subunits and structural features are identified during field investigation.
- Geochemical survey such as stream sediment sampling, heavy mineral concentrate sampling and soil sampling were the main methods applied in the field to delineate the anomalous areas.
- Chip and selected channel samples of the ore and other rock types were collected for petrographic study and chemical analysis to confirm copper, lead, zinc and gold content in the ores.

FIELD ACTIVITIES

- Semi-detail geological maps of the above mentioned five areas covering more than 70 km^2 area were prepared in 1: 16,000 scale.
- Detail stream sediment sampling was conducted in the same 70 km^2 area. In total 688 stream sediment samples were collected with average sampling density 9.8 samples per sq. km.
- 26 heavy mineral concentrate samples were collected with a sampling density of about one sample/2.6 km^2 area.
- Ridge and spur soil sampling was carried out only in selected 10 km^2 area and 136 soil samples were collected with a sampling interval of 50 to 100 meters.
- 100 m^3 trenching/pitting was carried out to expose the mineralized bodies (ore bodies) and collect fairly good fresh ore samples.
- 81 Chip and channel samples of the ore and rocks were collected for petrographic study and chemical analysis for different elements mainly Cu, Pb, Zn and Au.

REGIONAL GEOLOGY

All the five investigated areas lie in the Inner Lesser Himalaya. They are represented by both crystalline as well as metasedimentary rocks consisting of phyllite, schist, gneiss, quartzite, dolomite, slate and basic rocks (Fig-1). A brief description of Lithotectonic Units of the area is presented in the table-1 below.

Table-1: Lithotectonic Units of the Area

Age	Complex	Group	Formation (Rock Unit)	Lithology
Neogene		Surkhet Group	Suntar Formation (st)	Greenish grey to bluish sandstone and purple shale, occasionally with few conglomerate bed.
			Unconformity	
Paleozoic	Nawakot Complex	Upper Nawakot	Benighat Slate (bg)	Dark grey to black carbonaceous slate and phyllite with carbonate beds.
			Unconformity?	
Late Precambrian	Nawakot Complex	Lower Nawakot	Dhading Dolomite (dh)	Fine to medium grained, hard, compact, cherty and stromatolitic massive dolomite with slate intercalation.
			Kuncha Formation (kn)	Grey to greenish grey gritty phyllite with quartzite, amphibolite and massive basic rock bodies.
			Thrust	
PrecambrianTo Paleozoic (?)		Tapovan Group	Sallabagar Formation (sl)	Grey to dark grey slate with intercalation of black carbonaceous slate and carbonate layers.
			Bhatgaon Formation (bt)	Greenish grey sandstone and purple shale. At places ferruginous.
			Mayana Formation (mn)	Thinly to thickly bedded, bluish grey dolomite with dark grey to black carbonaceous slate.
			Thrust	
Precambrian (?)	Khandeshwari Crystalline Complex	Khatti-Marma Metamorphics	Surmasarowar Quartzite (sq)	Fine to coarse grained, massive to poorly foliated, sericitic white quartzite with phyllite, amphibolite and massive basic rock bodies.
			Suni Gad Schist/ Gneiss (sg)	Medium to coarse grained, light coloured quartzo-feldspathic mica schist and augen gneiss.
			Lumthi Quartzite (lq)	Medium to coarse grained, generally massive, white to dirty white quartzite with basic rocks. Occasionally with bands of gritty quartzite.

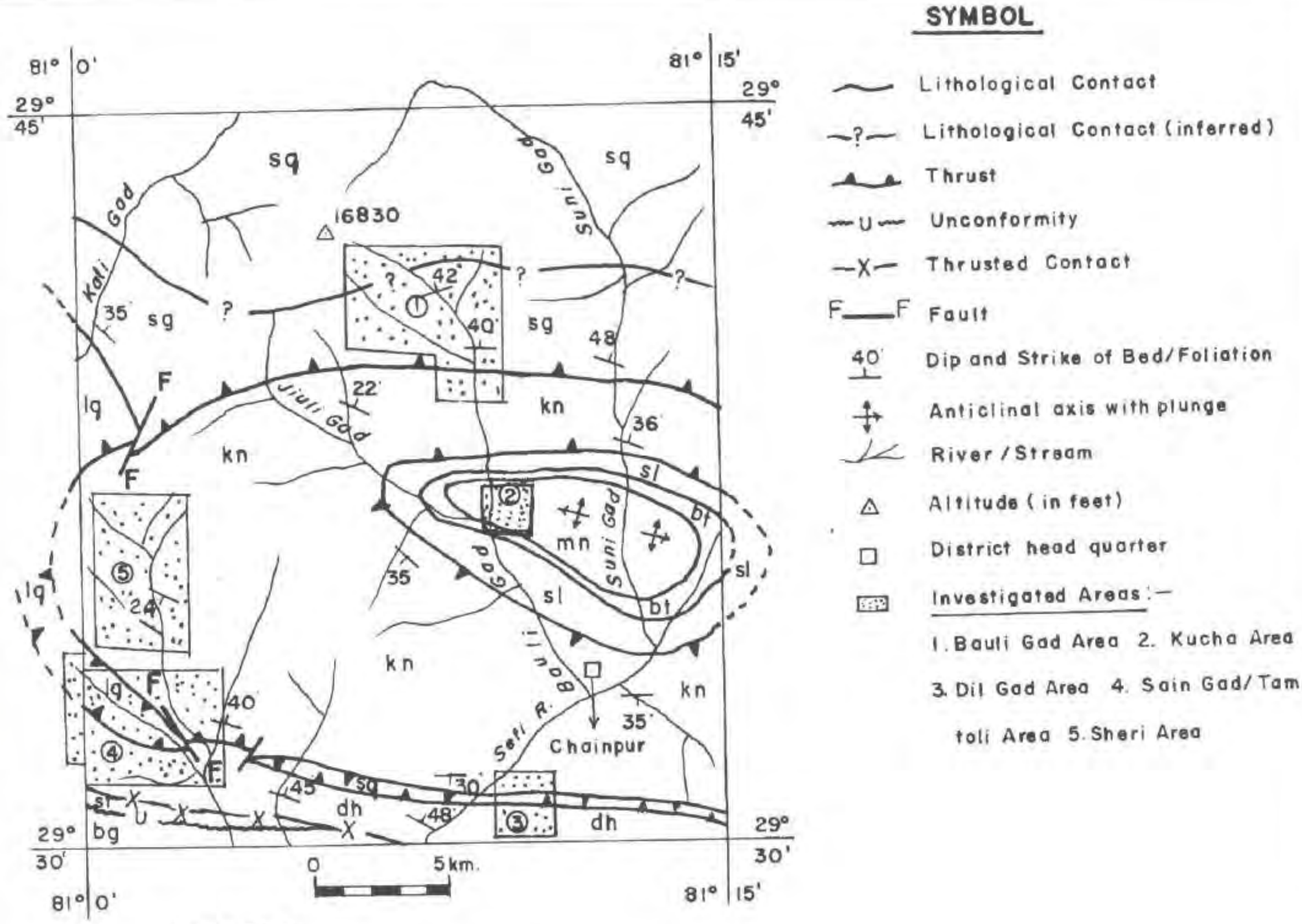
GEOCHEMICAL ANOMALIES AND MINERALIZATION (FINDINGS)

During follow-up exploration few copper, lead and zinc mineralized bodies are traced. A radioactive quartzite lens is also encountered in Sain Gad. Some ore floats are recorded in the tributaries of Bauli Gad and Taru Gad. Geochemical anomalies and mineralization in all the five areas are briefly described.

Bauli Gad Area

This area lies about 15 Km northwest of Chainpur. It has very irregular topography. Average relief is very high with minimum 7500 feet and maximum 15500 feet elevation above mean sea level. Accessibility in almost all parts of the area is difficult due to high angle slopes, waterfalls and narrow gorges. All the hill tops (ridges above 8000 feet) remain snow capped during the months of November to May.

Detail stream sediment sampling and semi-detail heavy mineral concentrate sampling were carried out in this area. All the stream sediment samples collected in this area were analyzed for copper, lead and zinc. Copper value is not interesting as it shows only up-to two times higher value than the threshold value. But the ore floats of this area shows up-to 13.99 % copper and 3.8 ppm gold (Table-3 and 3A). Lead value is up-to 18 times higher than the threshold value. Ore float sample shows up-to



LEGEND

st	**Suntar Formation:**	Greenish grey sandstone and purple shale.
bg	**Benighat Slate :**	Dark grey to black carbonaceous slate and phyllite with carbonate bed.
dh	**Dhadig Dolomite:**	Stromatolitic and cherty dolomite with slate intercalation.
kn	**Kuncha Formation:**	Greenish grey gritty phyllite with quartzite, amphibolite and massive basic rocks.
sl	**Sallabagar Formation:**	Grey to dark grey slate with carbonate layers.
bt	**Bhatgaon Formation:**	Greenish grey sandstone and purple shale, at places ferruginous.
mn	**Mayana Formation:**	Thinly to thickly bedded dolomite with slate intercalation.
sq	**Surma Sarowar Quartzite:**	Massive to slightly foliated, sericitic white quartzite with phyllite and amphibolite.
sg	**Suni Gad Schist & Gneiss:**	Quartzo-feldspathic mica schist and augen gneiss.
lq	**Lumthi Quartzite :**	Generally massive, white to dirty white quartzite, occasionally with bonds of gritty quartzite and basic rocks.

Fig. 1 Regional Geological Map of Investigated Areas.

0.18 % lead. Likewise zinc value is two times higher than the threshold value. But ore float samples shows up-to 0.27 % zinc (Table-3A). Heavy concentrate samples of this area consist of several grains of chalcopyrite with few grains of galena and sphalerite. No visible gold colours were observed.

The area is represented by Suni Gad Schist/ Gneiss and Surmasarowar Quartzite units of Khandeshwori Crystalline Complex and Kuncha Formation of Lower Nawakot Group of Nawakot Complex (Fig. 1). Few mineralized bodies and ore floats are recorded in this area.

- A 4.0 m thick and 40m long copper mineralization band is recorded. The host rocks are quartzite and gneiss. The lower 0.7 m thick part of this band is sericitic quartzite and consists of disseminated malachite which contains 0.2 % copper. Likewise the upper 3.3 m thick part of the mineralized band is augen gneiss with layers of mica-schist. It contains disseminated pyrite and chalcopyrite which reveals 0.5 % copper (Table-2).
- Two poorly mineralized lenses consisting of pyrite, pyrrhotite and chalcopyrite are traced in the area. The sizes of these lenses are 0.8 m x 5.0 m and 1.7 m x 10.0 m. The host rock is augen Gneiss. Copper content in these lenses varies from 0.2 to 0.3 % (Table-2).
- A very small lens of 10.0 cm x 15.0 cm size consisting of molybdenite is also recorded within augen gneiss of this area.
- Several ore floats consisting of chalcopyrite, pyrite, pyrrhotite, galena and sphalerite are also recorded in the river bed of Bauli Gad. Host rocks are quartzite/quartz vein, schist/gneiss and amphibolite. Among these floats, some floats of quartzites/quartz veins are very rich in concentration of chalcopyrite. **The copper content in the chalcopyrite rich ore floats are found up-to 13.99%.** But copper rich mineralized bodies could not be traced due to thick snow cover and steep slopes of the area. A brief description and chemical analysis of the ore floats are given in Table-3. Some ore floats samples are also analyzed in Federal Institute of Geosciences and Natural Resources (BGR) laboratory, Germany. Results of these samples are presented in Table-3A.

Kucha Area

This area lies about 6 Km northwest of Chainpur. It is mainly represented by metasedimentary rocks of Tapovan Group consisting of dolomite, carbonaceous slate, phyllite, sandstone and shale. Stream sediment sampling and ridge and spur sampling were conducted in this area. Copper value of stream sediment samples does not show any interesting result. Lead value is little bit higher than the threshold value in some samples. Zinc value is 6 times higher than the threshold value. Likewise ridge and spur samples (soil samples) also show the same trend as stream sediment samples. Although Kucha area appeared anomalous for zinc (geochemical anomaly), but no mineralized body or ore floats are found in this area. Relatively higher concentration of zinc in the stream sediment samples of the area could possibly be due to abundance of carbonaceous slates in the area.

Dil Gad Area

This area lies about 5 Km southwest of Chainpur. The entire area is represented by Kunchha Formation and Dhading dolomite of Lower Nawakot Group. Dil Gad is a tributary of Seti River.

Copper values in stream sediment samples collected from this area are not interesting. Lead and zinc values are up-to 58 and 6 times higher than the threshold value respectively. These higher values are due to presence of two small mineralization lenses of galena and sphalerite bearing dolomite. Ridge and spur samples (soil samples) follow the same trend as the stream sediment samples.

Two mineralized bodies containing lead and zinc are recorded in this area. The ore minerals are galena and sphalerite hosted by fine grained bluish grey dolomite. Thicknesses of the mineralized bodies are 90 cm and 75 cm. These bodies appeared in the form of lenses. Polished section study of the ores revealed that galena is the chief ore mineral associated with sphalerite. Quartz and dolomite are the gangue minerals. Galena shows flow structure in the carbonate and locally sphalerite is replaced by galena. Triangular pits can be clearly seen within galena.

Sain Gad/Tamtoli Area

This area lies about 20Km west of Chainpur. It is represented by Lumthi quartzite Unit of Khandeshwari Crystalline Complex and Kunchha Formation and Dhading Dolomite of Lower Nawakot Group. In the investigated area Lumthi Quartzite is thrusted over Lower Nawakot Group (Fig. 1).

Copper value of stream sediment samples of the area are up-to 9 times higher than the threshold value. The pattern of copper value indicates the existence of irregular copper ore body in this area. In this area lead values show no interesting result where as zinc value is up-to 9 times higher than the threshold value. But higher values are in scattered form. That is why the possibility of zinc mineralization of economic interest is low in this area. Soil samples also show higher value for copper due to existence of copper mineralized body in the area. Lead and zinc values of soil samples show no interesting result. The mineralized bodies which are recorded in this area are briefly described below.

- A 3.0 to 5.0 m thick copper mineralized band is recorded near Baikatya village. Its extension is traced up-to 40m. Malachite is the chief ore mineral in association with some pyrite and chalcopyrite. The host rock is quartzite that belongs to Lumthi

Quartzite unit. It is a medium to coarse grained, hard and compact, highly fractured and slightly sericitic quartzite. The mineralized band shows up-to 0.7% copper in it (Table-2).

- A radioactive quartzite lens is also recoded within Lumthi quartzite in Sain Gad section near Baikatya village. Thickness of this band is 3.6 m and extension is traced up-to 10.0 m. Radioactive Intensity (R.I.) value ranges from 600 to 3000 cps (count per second) in total count (U, Th and K combined). Host rock is medium to coarse grained, sericitic white quartzite. This lens shows up-to 575 ppm uranium (Table-2).
- A 3.0 m thick band of gritty phyllite consisting of pyrite and chalcopyrite bearing quartz veins is recorded in Khatiyaro Khola section. This gritty phyllite belongs to Kunchha Formation of Lower Nawakot Group. The mineralized quartz veins are slightly calcareous and parallel/sub-parallel to the foliation. Thickness of the quartz veins ranges from 20 cm to 60cm. Pyrite is fine grained, massive and associated with disseminated chalcopyrite. Chemical analysis of the samples reveals up-to 2.7 % copper (Table-2).
- One meter thick band of amphibolite containing mineralized quartz veins within Kuncha Formation

Table-2: A Comprehensive Description of Mineralized Bodies in the Area

S.N.	Mineralization	Location	Host Rock (Lithological Unit)	Thickness (m)	Strike Length(m)	Analytical Result	Remarks
1	Disseminated Cp and Py bearing Schist/gneiss band	Bauli Gad	Augen gneiss and schist(sg)	3.3	40.0	0.5 % Cu	Lower copper content
2	Disseminated Mc bearing schist/ gneiss band	Bauli Gad	Sericitic quartzite(sg)	0.6	40.0	0.2 % Cu	Lower copper content
3	Disseminated Py, Po and Cp bearing gneiss lens	Bauli Gad	Augen gneiss (sg)	0.8	5.0	0.2 % Cu	Lower copper content
4	Disseminated Mc, Cp and Py bearing gneiss lens	Bauli Gad	Augen gneiss (sg)	1.7	10.0	0.3 % Cu	Lower copper content
5	Gal and Spl bearing dolomite lens	Dil Gad	Fine grained dolomite (dh)	0.9	6.0		Low Zn and Pb content
6	Gal and Spl bearing dolomite lens	Dil Gad	Fine grained dolomite (dh)	0.75	6.0		Low Zn and Pb content
7	Disseminated Mc, Cp and Py bearing quartzite band	Sain Gad/ Tamtoli Area (near Baikatya village)	Slightly sericitic quartzite(lq)	3.0-5.0	40.0	0.2 – 0.7 % Cu	Low to medium Cu content
8	Radioactive quartzite lens	Sain Gad/Tamtoli Area (near Baikatya village)	Sericitic quartzite(lq)	3.6	10.0	575 ppm U	600-3000 cps **(fairly high count)**
9	Py and Cp bearing quartz veins	Sain Gad/Tamtoli Area (Khatiyaro Khola)	Quartz veins within gritty Phyllite(kn)	0.2 – 0.6	-	0.1 – 2.7 % Cu	Low to high Cu content
10	Cp and Py bearing quartz veins	Sain Gad/Tamtoli Area (Right slope of Khatiyaro Khola)	Quartz veins within amphibolite(kn)	0.1 – 0.3	-	5.9 % Cu	High copper content
11	Disseminated Mc, Cp and Py bearing basic rock	Near Sheri village	Coarse grained basic rock	1.0	-	0.7 -1.5 % Cu	A 10.5 m long old working adit present here
12	Phosphorite bearing stromatolitic dolomite band	Below the confluence of Khatera Khola and Khatiyaro Khola	Fine grained dolomite(dh)	5.0	-	-	Pradhanang (1983) reported up-to 5.0% P_2O_5

N.B. - Cp = Chalcopyrite, Py = Pyrite, Mc = Malachite, Po = Pyrrhotite, Gal = Galena, Spl = Sphalerite, cps = Count per Second is recorded on the right slope of Khatero Khola. Thickness of the mineralized veins ranges from 10 cm to 30 cm. These veins consist of fine grained chalcopyrite and pyrite minerals. Analytical results show up-to **5.9 % copper** (Table-2).

- A 5.0 m thick band of phosphorite bearing stromatolitic dolomite is present at about 500 m below the confluence of Khatero Khola and Khatiyaro Khola. Pradhanang (1983) has reported up-to 5.0 % P_2O_5 in this band.
- Some ore floats of pyrite, chalcopyrite bearing quartzite and basic rock are also recorded in the stream beds of Sain Gad/Tamtoli area. A brief description and chemical analysis of the ore floats are given in Table-3.

Sheri Area

This area lies about 25 Km west of Chainpur. It has generally rugged topography. Accessibility in the upper part of the area is very difficult. Altitude varies from 6100 to 13,500 feet above mean sea level. Geologically the entire area is represented by Kunchha Formation of Lower Nawakot Group.

Stream sediment samples collected in this area show up-to 2.5 times higher copper value than the threshold value. A 10.5 m long copper old working is recorded in this area. Lead value does not show any interesting result. Zinc value is up-to 5 times higher than the threshold value but in scattered form. Some very fine to fine gold colours were recorded in the heavy mineral concentrate samples from Dhauli Gad of the area.

Table-3: Brief Description and Analytical Result of the Ore Floats

S.N.	Sample No.	Location	Rock Type	Size of Float	Cu (%)	Remark
1	Rh/Bds-550	BauliGad	Cp rich Quartzite/quartz vein	30 cm x 30 cm	**12.4**	1520 ppm Pb and **3.8 ppm Au (high grade ore)**
2	Rh/Bds-554	BauliGad	Cp rich Quartzite/quartz vein	20 cm x 15 cm	**7.7**	**1740 ppm Pb (high grade ore)**
3	Rh/Bds-555	BauliGad	Cp and Py bearing schist	30 cm x 20 cm	0.6	
4	Rh/Bds-556	BauliGad	Cp and Py bearing schist	25 cm x 20 cm	**2.8**	**High copper content**
5	Rh/Bds-557	BauliGad	Cp and Py bearing schist	10 cm x 15 cm	1.2	
6	Rh/Bds-558	BauliGad	Cp and Py bearing schist	25 cm x 20 cm	1.2	
7	Rh/Bds-559	BauliGad	Cp and Py bearing gneiss	32 cm x 34 cm	0.7	
8	Rh/Bds-560	BauliGad	Cp and Py bearing schist	20 cm x 15 cm	0.9	
9	Rh/Bds-568	BauliGad	Cp, Py and Po bearing schist	10 cm x 12 cm	0.7	
10	Rh/Bds-569	BauliGad	Cp, Py and Po bearing schist	35 cm x 32 cm	2.0	
11	Rh/Bds-570	BauliGad	Cp, Py and Po bearing quartzite	15 cm x 10 cm	0.6	144 ppm Pb
12	Rh/Bds-574	BauliGad	Cp, Py and Po bearing quartzite	20 cmx 22 cm	0.8	
13	Rh/Bds-575	BauliGad	Cp, Gal, Spl and Py bearing quartzite	12 cm x 10 cm	**2.9**	1500 ppm Pb **(high copper content)**
14	Rh/Bds-578	BauliGad	Py, Cp bearing quartzite	20 cm x 15 cm	0.3	
15	Rh/Bds-581	BauliGad	Py, bearing quartzite	35 cm x 30 cm	0.03	
16	Rh/Bds-583	BauliGad	Cp, Py and Po bearing quartzite	30 cm x 15 cm	**2.7**	**High copper content**
17	Rh/Bds-585	BauliGad	Cp, Py and Po bearing quartzite	20 cm x 18 cm	1.4	
18	Rh/Bds-586	BauliGad	Py, and Cp bearing amphibolite	10 cm x 10 cm	0.05	
19	Rh/Bds-588	BauliGad	Cp, Py and Po bearing quartzite	12 cm x 14 cm	0.2	
20	Rh/Bds-592	BauliGad	Cp, Py and Po bearing quartzite	15 cm x 12 cm	0.6	
21	Rh/Bds-593	BauliGad	Cp and Py bearing quartzite	12 cm x 10 cm	**3.8**	**High copper content**
22	Rh/Bds-664	Sain Gad	Cp and Py bearing basic rock	12 cm x 10 cm	0.2	
23	Rh/Bds-680	Trib. of Sain Gad	Ferruginous basic rock	14 cm x 12 cm	0.3	
24	Rh/Bds-708	Trib. of Khatiyaro Khola	Cp and Py bearing quartz vein within phyllite	15 cm x 12 cm	0.2	
25	Rh/Bds-732	Khatera Khola	Py and Cp bearing quartz vein within phyllite	14 cm x 10 cm	0.03	
26	Rh/Bds-772	Sheri Area	Py and Po bearing quartz vein within phyllite	30 cm x 25 cm	0.07	
27	Rh/Bds-781	Sheri Area	Py and Cp bearing quartzite	10 cm x 8 cm	0.5	
28	Rh/Bds-782	Sheri Area	Py and Po bearing quartz vein within phyllite	15 cm x 12 cm	0.3	

N.B. - Cp= Chalcopyrite, Py=Pyrite, Po=Pyrrhotite, Gal=Galena, Spl= Sphalerite, Trib.= Tributary

Table-3A: Analytical Result of Ore Floats Collected from Bauli Gad (BGR Lab, Germany)

S. No.	Sample No.	Cu %	Au ppm	Pb %	Zn %	As ppm	Bi ppm	Co ppm	Mo ppm	Ni ppm	Cr ppm	Rb ppm	Sb ppm	Sn ppm	W ppm
1	Rh/Bds-550	**13.99**	**0.6**	0.18	0.27	73	1980	<3	<2	<3	<3	100	112	76	<3
2	Rh/Bds-554	**8.67**	-	0.17	0.12	60	1265	<3	7	8	24	75	77	32	<3
3	Rh/Bds-570	0.58	-	0.017	0.012	190	22	705	8	291	138	32	10	27	<3
4	Rh/Bds-575	**8.53**	-	0.17	0.13	59	1196	<3	9	<3	20	68	68	34	<3
5	Rh/Bds-583	**2.96**	**0.2**	0.026	0.1	28	45	142	<2	58	5	40	16	56	<3

A copper mineralized body and old working adit of 10.5 m long is recorded near Sheri village. Disseminated chalcopyrite, malachite and pyrite occur in medium to coarse grained basic rock. The mineralized band is 1.0 m thick. The upper part of this band is slightly foliated while the lower part is almost massive. This band consists of up-to 1.5 % copper (Table-2). Besides the mineralized band some ore floats of chalcopyrite, pyrite and pyrrhotite bearing quartzite and quartz veins (within phyllite) are traced in the stream beds of this area. A brief description and the result of chemical analysis of the ore floats are given in Table-3.

CONCLUSION AND RECOMMENDATION

- As mentioned above, the copper values of stream sediment samples in Bauli Gad area is not interesting. Some samples show higher value for lead and zinc. But the ore float samples of this area contain up-to **13.99% Cu**, 0.18 % Pb, 0.27 % Zn, 190 ppm As, 1980 ppm Bi, 705 ppm Co, 8 ppm Mo, 271 ppm Ni, 138 ppm Cr, 100 ppm Rb, 112 ppm Sb, 76 ppm Sn and **3.8 ppm Au** (Table-3 and 3A). These results clearly indicate the existence of copper rich polymetallic mineralized body/ bodies in the area which appears to be of economic interest. Few low grades copper mineralized bodies have already been traced in the area. But the field team could not trace the copper rich polymetallic ore body due to very difficult terrain with snow cover of the area. Therefore a semi-detail/detail follow-up work to trace the copper rich polymetallic ore body is recommended in the upper part of Bauli Gad catchment area. The follow-up work should be conducted in the month of Jeshtha (May/June) to avoid the snow cover of the area.
- Copper values in stream sediments and soil samples of Sain Gad/Tamtoli area indicate the existence of irregular ore bodies in this area. A copper bearing quartzite band containing up-to 0.7% Cu is traced in the area. Some quartz veins consisting of pyrite and chalcopyrite and also few radioactive quartzite lenses are recorded in this area. However, the whole area does not seem to be of economic interest for copper mineralization.
- Result of stream sediment samples of Sheri area is not interesting. But the presence of gold colours in heavy mineral concentrate samples collected from Dhauli Gad of the area clearly indicates the existence of source rock for alluvial gold in its catchment area. A copper old working is also present in this area. The catchment area of Dhauli Gad is less than 10 square kilometers. That is why a semi-detail/detail follow-up work to trace the gold bearing mineralized body/bodies in the area is highly recommended.
- As a whole the results of lead and zinc do not warrant any more work for only these elements in the above mentioned five investigated areas.

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The author would like to express his gratitude to Mr. N. R. Sthapit, Director General, Department of Mines and Geology for giving permission to make use all the reports and mps to prepare the paper. He is also grateful to Dr. R. B. Sharestha, 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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Investigation of Kajeri Limestone Deposit of Sallyan District, Midwestern Nepal

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INTRODUCTION

His Majesty's Government of Nepal has a policy to establish cement industry in all development regions so as to balance the economic activities in the country. With this view the Department of Mines and Geology has investigated and evaluated the limestone deposit of Kajeri, Sallyan, Mid-Western region in the eighth five-year plan. High grade limestone occurrence was identified in the fiscal year 2051/52. Preliminary exploration work on Kajeri limestone prospect was carried out with geological mapping of 150sq.km. area and few selected chip sampling. Follow up exploration work was carried out in the following year with detail geological mapping (in 1:2000 scale), extensive channel sampling (1146m), chip samplings and grab sampling. Detail exploration of the limestone deposit was carried out from FY 2053/54 to FY 2055/56, with topographical survey, geological mapping and core drilling. Altogether 10 Exploratory bore holes were drilled totaling 1310.50 m length to confirm the grade and depth continuity of the limestone deposit. The total limestone reserve (proved, probable and possible combined) in the study area is calculated as 74.11 MT. Because of its high quality due consideration has to be given for proper utilization not only for cement industry, but also for other lime based industries. Based on the above studies of this limestone deposit, a cement plant with a capacity of 1000 – 1500tpd can be established in this area. The basic infrastructure networks are there but they have to be extended.

The Kajeri limestone deposit is situated in Kajeri VDC about 5km north of Sallyan Bazar, the District Headquarter and 4Km Northwest of Barala village. It falls within the Toposheet 62 L/3, Survey of India (Scale 1" = 1 miles). It lies in between latitudes 28° 24' 30" – 28° 25' 15" and longitudes 82° 8' 45" – 82° 10' 45". The Kajeri limestone deposit site is accessible from the nearest road head at Barala which is 112 km northwest of Lamahai, the entry point from East - West Highway. Barala can be reached by road via Ghorahi and Tulsipur from Lamahi.

The study area lies in the Lesser Himalaya geomorphic division. It has rugged mountainous terrain. There are several east – west and north – south trending ridges and spurs having well developed drainage pattern. The relief of the area is high. The limestone lies generally on hill tops. Dhar Khola, Bhalu Khola and Ghatte Khola are the tributaries of Sharada River. Sarada River is the major drainage that flows from north to south through a valley of about 300 – 1000 m width with paddy fields on either side (Fig. 1).

Fig. 1 Kajeri Limestone Deposit, Sallyan

OBJECTIVE

- to identify the cement grade lime stone deposit in Kajeri area
- to perform detail surface exploration by topographical mapping, geological mapping, trenching/pitting, chip, channel and bulk sampling and exploration drilling
- to ensure the depth and grade continuity of surface of the limestone
- to evaluate the limestone deposit suitable for cement and other purposes

METHODOLOGY

- Preliminary and follow up investigation were carried out with topographical survey, Geological mapping, trenching, pitting chip sampling, channel sampling, and bulk sampling for petrographical studies and chemical analysis. Trenches were excavated to expose the fresh limestone wherever necessary.
- Plane table survey was carried out for topographical surveying to prepare the topo-geological map at 1:2000 scale.

- Detail geological map was prepared to determine actual thickness and trace the lateral extension of the limestone beds.
- Grade and nature of the limestone was tested by exploration drilling using double tube core barrel with wire-line technology. The cores samples were examined by chemical analysis and petrographic study. The grade and tonnage (reserve) of limestone was estimated with the help of surface (thickness, lateral extension) and drill hole (depth continuation) data.

REGIONAL GEOLOGY

The investigated area is represented by low to medium grade metamorphic rocks and sedimentary rocks that are comparable to the Midland Group of Western Nepal and Nawakot Group of Central Nepal. These rocks are divided into three tectonic units (Kansakar and Chitrakar 1980) as described bellow. Due to lack of the fossil evidences and complicated tectonics, it is very difficult to establish the stratigraphic position of this area. However, it is clear that each tectonic unit is separated by a thrust.

Chorpani Unit

This unit mainly consists of quartzites with basic intrusions. The quartzite is well exposed in Chakli Gad, north of Kajeri village and along the road section from Dhorchaur to Tharmaraya. It is a fine grained, massive white, grayish white to yellowish colored sericitic quartzite which consists of mainly quartz and sericite; feldspar and muscovite also occur as accessory minerals. At places quartzite is gritty in nature. Current beddings and cross beddings are common in this quartzite. A number of mapable size basic intrusive bodies, mainly amphibolites are recorded. They are metamorphosed in various degree. Near the thrust they are changed into chloritic schist.

Kumak Carbonate

This unit is well exposed along the road section in Sarada River, Dhar village, Halchaur, Madamgaur and Bhalukhola area. It is a major carbonate unit which consists of cement grade/ chemical grade limestone bands and dolomites. The basal part of this unit is composed of thin interlayers of dark gray, green and lead gray phyllites and white to bluish grey sericitic quartzite. Kajeri Limestone can be correlated with the Lakharpata Formation that is composed of mainly carbonate rocks (limestone and dolomite) with minor amount of black shale.

Sallyan Unit

Sallyan unit consists of low grade metamorphic rocks and sedimentary rocks like quartzite, shale and conglomerate. It is well exposed in the southern and eastern part of the investigated area.

GEOLOGY OF KAJERI AREA

The rock types present in this area are limestone, dolomites, phyllite and quartzite. A thrust, which can be observed at the southern part of the mapped area, separates phyllite from limestone (Fig.2). Few outcrops of quartzite and phyllite are recorded at Siddhi Gufa Danda. Colluvial deposits are present along the base of the hill in the southern part. Limestone is widely distributed in the central and north-eastern part along its NE-SW strike direction. The limestone is massive, fine grained, gray, light gray to bluish gray and grayish white. It is quite distinct from the surrounding dark gray colored dolomites. It is fine grained and in most parts homogenous and massive. The lower band of the limestone is thin bedded, fine grained, gray to dark gray in colour.

The limestone deposit in the eastern part and northeast of the Bhalu Khola is overlain and underlain by grey to bluish grey dolomite. The contact between the limestone and the dolomite is sharp and conformable. There are isolated lenses and patches of bluish grey dolomite and grayish white quartzite. The limestone is laminated near to the contact of dolomite where as it becomes thick bedded to massive in the central part. The exposed surface is light to dark grey tone with occasional reddish brown to yellow stain but it is white to grey white, when fresh. Total thickness of the limestone bed varies from 150 m to 250 m.

The general strike of the limestone beds are NE-SW and the dip 40^{0} - 80^{0} towards northwest and southeast. At places the limestone beds are highly jointed due to which the attitude of the beds is obscured and measurement of dip and strike becomes rather difficult. At places, the strike direction of limestone beds are NW-SE with dip 60° to nearly vertical towards south-west where as, at few other places the strike direction changes to NE-SW and dip $>60^{\circ}$ towards SE specially in the central part, thus showing tight folded structure. Series of small anticlinal and synclinal folds are present. In the folded section the strike direction is NW - SE with dip 30° - 40° towards NE. The prominent joint sets are more or less parallel to the strike direction of limestone, but the dip of joint is much steeper than the dip of the limestone bed. A small-scale strike slip fault is observed near the confluence of Bhalu Khola and Jhyau Khola. The fault trends WNW-ESE. However, it does not seem to affect the main limestone body.

Dolomite is grey to dark grey, massive, fine to medium grained. It is widely distributed in the north-west and

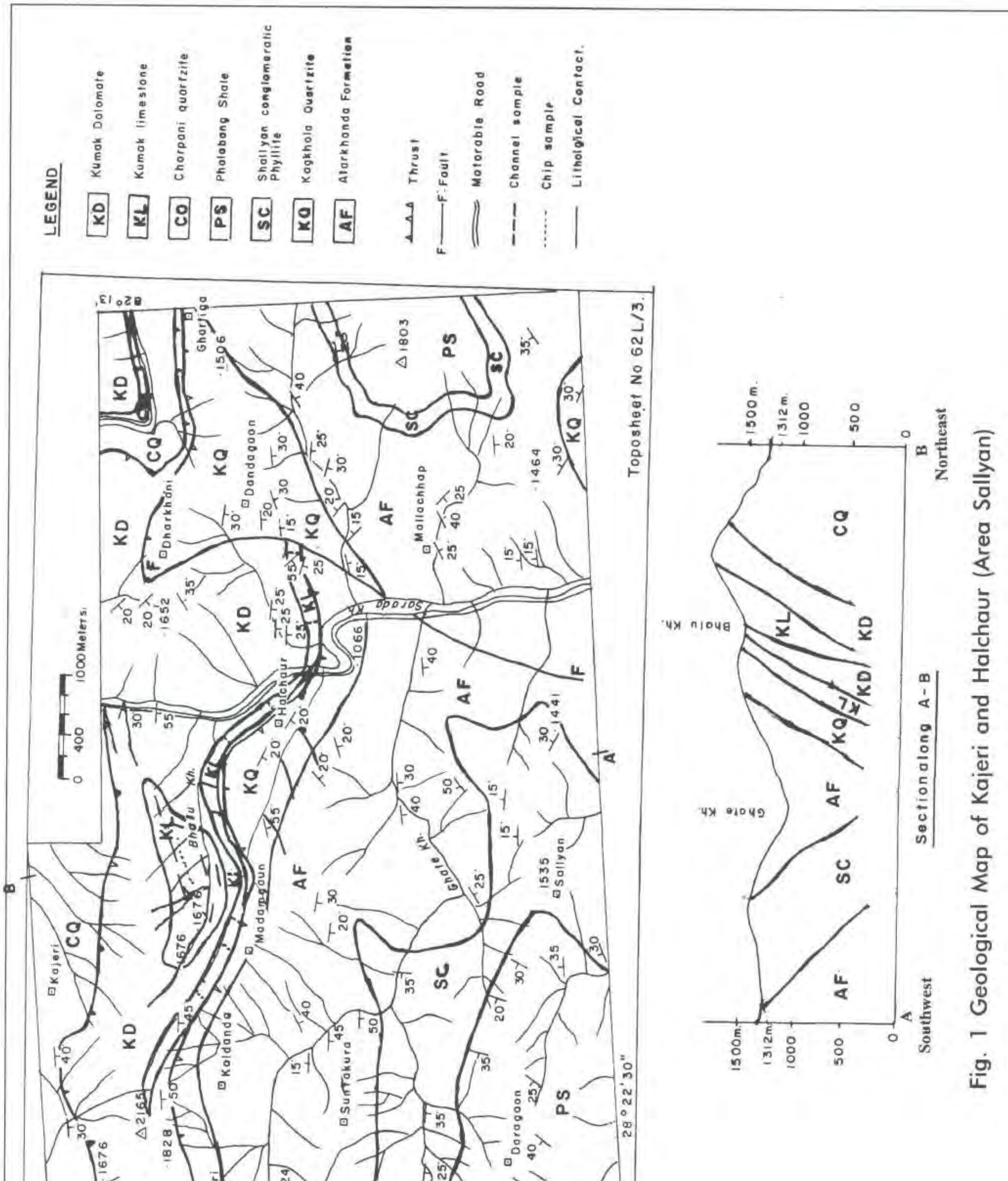

Fig. 1 Geological Map of Kajeri and Halchaur (Area Sallyan)

south-eastern part of the deposit (Fig 2). At places, Dolomite occur as small patches, lenses, pockets or nodules of few centimeters dimensions within the limestone, which is possibly a product of post depositional replacement. In the field dolomites are recognized by iron stain and generally elephant skin weathering. Phyllites are thinly bedded, grey to dark grey and sericitic. Quartz lenses concordant to foliation planes are abundant.

FIELD INVESTIGATIONS AND FINDINGS

Jha (1979) had shown thick limestone band (>100m thick) in the presently studied area during his reconnaissance geological mapping. Kansakar and Chitrakar (1980) prepared a regional geological map of Sallyan district and they included this limestone in Kumak Carbonate unit. Kaphle and Pradhanang (1985) reported cement grade limestone in Sarada Khola north of Barala village. Shakya and Ghimire (1994) did reconnaissance survey in and around the present target area to look for cement grade limestone.

The author did preliminary follow-up exploration works in FY 2051/52. He prepared a Geological map of 150sq. km area (in 1:20,000 scale) and identified two limestone occurrences. In the following year, he did the detail topo-geological mapping of Bhalu Khola - alchaur area covering 1 sq.km. (in 1:2000 scale) and did some trenching, pitting, channel, and chip sampling of the limestone bands.

In FY 2053/54, Karmacharya did detail geological mapping and 3 exploratory drilling (405 m). After this investigation he has reported about 10 million tones of proved plus probable reserve of very high grade limestone. In the following year (2054/55), he did additional 4 exploratory drill holes (501 m) in the central and western parts of the area and reported another 20 million tones of proved and probable reserve of high grade limestone. In FY 2055/56, Khandka did additional 3 exploration drill holes (404 m) north of Bhalu Khola, and indicated another 20 million tones of proved and probable reserve of high grade limestone.

D. M. Shrestha and J. N. Shrestha (2000) studied the background information needed for proposed Sallyan cement plant. They have identified suitable sites for cement plant and gave additional information including those related to infrastructure.

The average chemical composition of the channel samples and drill core samples of Kajeri limestone indicate that CaO and MgO content are 52.94 and 1.41 respectively. The total geological reserve of the limestone is reported as 74.11 million tones that includes proved (29.65mt.), Probable (22.46mt), and Possible (22.02mt) deposits. There is a high possibility to increase the reserves into proven category by additional drilling and extending the area further northeast.

At present, proved reserve category is considered as mineable reserve is 29.65mt. Assuming that 90 % of the proved reserve can be exploited the net mineable reserves is 26.7mt. Considering 300 working days in a year and daily production capacity of limestone 155 tpd the mine life could be around 42 years. Since the limestone deposit is situated at the hilltop, the topography, geology and mining parameters are suitable for opencast mining. The minimum mineable depth is considered as 1480 m level in most cases. However, detail study for mine plan is necessary during techno-economic study of the project.

CONCLUSION

The total proved reserve of this deposit is 29.65mt with average assay of 51.90% CaO and 1.86 % MgO. However, the total geological reserve (proved 29.63mt, probable 22.46mt and possible 22.02mt) in the study area is 74.1mt. There is a high possibility to find out more limestone reserve to the north east of the investigated area. It is thus necessary to carry out additional exploratory drilling work to prove more reserve.

This limestone deposit has fairly good networks of infrastructures such as road and electricity line although they have to be improved in quality and upgrade the capacity. Since the most part of the deposit lies on the hill top and there is less overburden which is quite favourable for opencast mining. It has less interbands of inferior quality limestone thus making mining much easier.

The proved limestone deposit can be used to manufacture Portland cement for a period of 53 years at the rate of 1200tpd (clinker base) production capacity.

RECOMMENDATION

The main aim of all these investigations of Kajeri limestone deposit is to make use of it as raw material for cement plant. For this purpose following additional works are recommended, which are prerequisite to establish a cement industry in this area.

- Study and find the red clay deposit in near by area
- Bulk sample test of the limestone to manufacture Portland cement/ white cement

- Additional bore hole, whenever necessary, to convert probable reserves to proven category and detail exploration in further east to prove additional deposit
- Detail techno-economic feasibility study for the establishment of a cement plant
- Grade of limestone is considerably higher than it is required to manufacture Portland cement. The assay results of both the surface and borehole data show that a high grade limestone with CaO over 50 % on average and MgO less than 3 % is present. It is imperative, therefore, that due consideration should be given for the proper utilization of this limestone resource.
- Calcite coatings, veinlets, lenses, thin layers and calcite crystals frequently occupying cracks and cavities of limestone. Surface grade of limestone at Bhalu Khola area is chemical grade, which is in consistent with the borehole assay data.
- It is highly recommended to establish a cement industry based on the Kajeri cement grade limestone deposit. High grade limestone can be utilized in white cement plant and chemical industries like lime, calcium carbide, calcium carbonate, bleaching powder etc.
- At places the quality of dolomite is also fairly good. The dolomite drilled at the ends of some of the drill holes shows that MgO content is above 18 %. Therefore due consideration of high grade dolomite should be given in future exploration activities in the area.

ACKNOWLEDGEMENT

The author is grateful to N. R. Sthapit, Director General of Department of Mines and Geology for giving me the opportunity to make use of all the reports and references to prepare this paper. The author is also greatly indebted to Mr. K.P. Kaphle, Superintendent Geologist, Department of Mines and Geology for valuable suggestion to prepare the paper and editing.

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Exploration of Polished and Dimension Stones in some Parts of Makawanpur District, Central Nepal

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INTRODUCTION

To fulfill the growing demand of polished and dimension stones in the country, exploration of these stones have been included in the annual field programs of Department of Mines and Geology (DMG) in the 10th five year plan. This program (F.Y. 2061/62) is a continuation to the previous ones. The exploration target covers an area of 100sq.km. including preliminary and follow up investigation of the potential areas in some parts of Makwanpur district. Previous workers like Joshi (1971); UNDP (1981); Shrestha and Napit (2001); and Ghimire and Napit (2003) had reported the existence of marble, quartzite and granite bodies in this area. Preliminary and follow up exploration polished and dimension stones were carried out by Shrestha and Napit in 2001; Ghimire and Napit in 2003 and Ghimire and Dhakal in 2004 support that there are possibilities to make use of these rocks as polished and dimension stones.

Present preliminary investigated area includes Kulekhani, Phakhel, Sisneri in some part of HMG/ Survey Department's Toposheet No. 2785 05 D (1:25000) within Latitude 27° 32'30" to 27° 37' 30"N and Longitude 85° 10' 00"to 85° 15' 00" E covering 70 sq. km area (Fig.1). The central part of the areas is accessible through seasonal gravel road that passes through Pharphing – Phakhel – Kulekhani. Eastern parts of the area are accessible through Dashhinkali - Sisneri-Kulekhani road. Kulekhani area is also accessible through Chitlang - Markhu road.

The follow-up investigation area covers 30sq. km. It includes Simbhanjyang (3 sq. km) for Palung Granite; Kitini Khola, Bhainse (3 sq. km.) for Bhainsedobhan Marble; Kisedi – Tarubas area (9 sq. km.) for quartzite; and Supin – Sikneghari area (15 sq. km.) for Markhu Marble. These three areas lie on HMG/ Survey Department's Toposheet no. 2785 05 'C', 2785 09 'A' & 2785 05 'D' (scale 1: 25,000) respectively (Fig.1). All these areas are accessible through Tribhuwan Rajpath. Simbhanjyang, the highest pass (2520m above msl) lies at a distance of 72 km from Kathmandu. Bhainse is situated 12 km north of Hetauda along Tribhuwan Rajpath. Kisedi khola area lies at 7 km north of Hetauda on

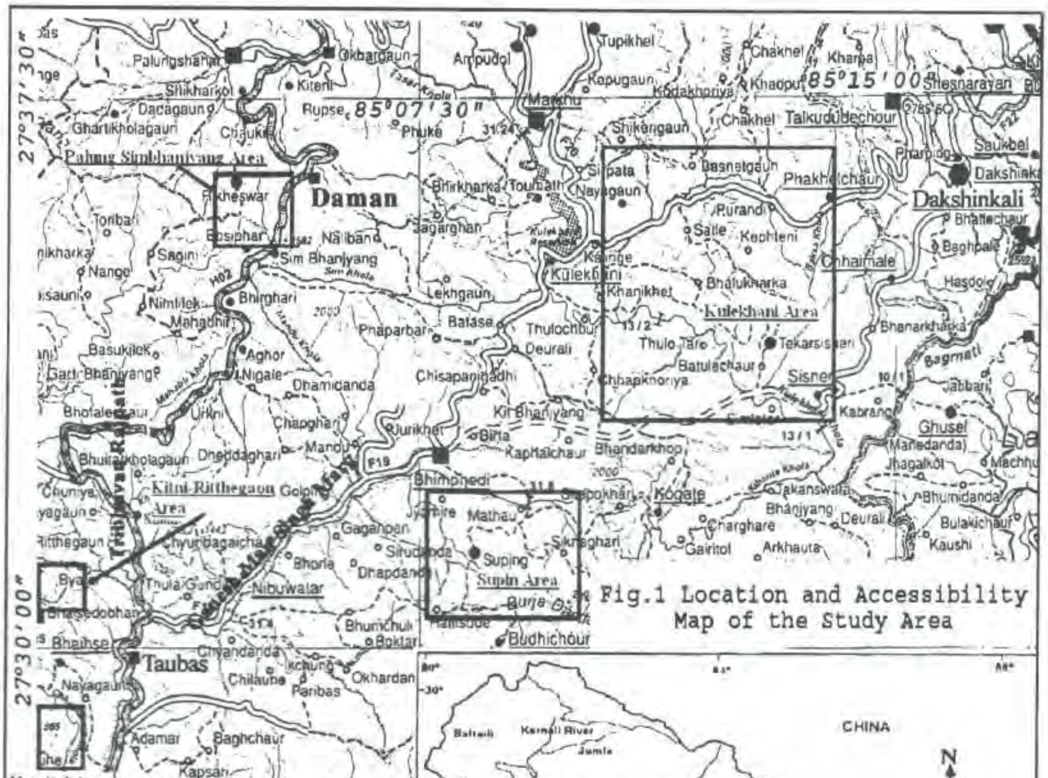

Fig.1 Location and Accessibility Map of the Study Area

Tribhuwan Rajpath. Bhimphedi lies on the way to Kulekhani from Bhainse. Kulekhani is 34 km north of Bhainse whereas Bhimphedi is only 12 km. (Fig.1).

OBJECTIVE

The objectives of the present study are:

- to find out the rocks suitable for polished and dimension stones
- to delineate the deposit by examining its durability and suitability
- to give recommendation for the next phase of exploration for further evaluation

METHODOLOGY

The field investigation included geological traverse along the roads, rivers, ridges and foot tracks. During field investigation topography of the area from the mining point of view, rock types and their physical properties e.g. appearance, color, texture, luster etc. were studied. Different rock types were identified. The attitude of beddings, joints, joint spacing, joint sets, weathering nature, rock strength, roughness, blocks size etc were measured. Some trenching / pitting (250 m^3) to expose the fresh rock and collect the samples were carried out. Geological map of preliminary investigated area were prepared in the scale of 1:25,000 whereas the follow –up areas were prepared in the scale of 1:5,000 and 1: 10,000.

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. Discontinuity analysis was also carried out to evaluate the possible block sizes.

GEOLOGY

The study areas comprise of the rocks of Bhimphedi Group of Kathmandu Complex and Upper Nawakot Group of Nawakot Complex and Palung Granite and Ipa Granite intrusion.

Southern parts of the study area at Bhainse, Tarubas and Supin are occupied by quartzite, phyllite and calcareous rocks belonging to the Nawakot Complex. Kulekhani and north-eastern area mostly comprises of the rocks belonging to Kathmandu Complex, which lies north of Mahabharat Lekh. In this area the Lesser Himalaya is represented by thick succession of prevalent metasandstone, phyllite, quartzite and calcareous rocks of Bhimphedi and Phulchowki Group. Simbhanjyang area and the southern ridge of Kulekhani Khola area consist of Palung Granite and Ipa Granite intrusion respectively.

Tarubas – Shikaribas area consists of garnetiferous mica schist and lenses of quartzite beds. Thin beds, high degree of weathering, numerous fractures and thick cover of top soil has deteriorated the economic importance of these quartzite beds.

FIELD INVESTIGATION

In the investigated area, granite and marble appear to be the main resources for Polished and Dimension stones. The details are briefly described below.

Granite

Palung Granite

The present study area lies at the periphery of Simbhanjyang along the East –West running Mahabharat Lekh. Palung granite is intruded into quartzite, schist and calcareous rocks and dipping towards north. In this area two types of granite are identified on the basis of grain size and the predominance of biotite or muscovite (1) medium grained Muscovite-Tourmaline Granite (MTG) and (2) coarse grained Biotite-Tourmaline Granite (BTG). In addition to these, fine grained equigrannular, dirty white colored Aplitic Tourmaline Granite (ATG) is also recorded as later intrusive in both of these granite bodies. The central parts of the Mahabharat Lekh along Simbhanjyang and Bosiphat consist of Biotite – Tourmaline Granite, whereas the southern slopes of the ridges along Daman consist of Muscovite-Tourmaline Granite (Fig.2). The kaolinization of feldspar and alteration of muscovite/biotite is fairly active in Muscovite – Tourmaline Granite. The area lying 2 km west of Simbhanjyang is represented by Biotite – Tourmaline Granite. Since it lies on the hill top, it can be easily mined.

Biotite - Tourmaline Granite is coarse grained, inequigrannular with porphyritic texture. Chief mineral constituents are quartz, feldspar, biotite and muscovite. Black tourmaline and dark gray to black unevenly distributed biotites are present. Tourmaline occurs as a minor mineral.

Steep slope areas, north of Bosiphat show thin vegetation and have less weathering effect, whereas moderate slope areas mostly covered with thick soil and vegetation show high and deep weathering effect up to 5m thick. High surface weathering is the reason behind discontinuity in this granite. In this area granite is characterized by 3 major joint sets generally represented along the drainage pattern i.e. north – south, along the strike and oblique to the strike. Structural analysis of the granite near

Simbhanjyang-Bosiphat area shows numerous discontinuities. Most of the wedges developed by major joints are unstable. Joint spacing is quite open and it is as high as 2 m. Good blocks of granite up to 3 m can be obtained.

Ipa Granite

Geological information of Kulekhani, Sisneri, Chhaimale area cover the units of Kulehani Quartzite, Markhu Marble Tistung Formation, Sopyang Formation, Chandragiri Limestone and granite intrusion (Fig. 3). Most of the area covers the Tistung Formation that is unsuitable for polished or dimension stone purposes. As shown in Fig. 3. in southern part, east –west ridge is occupied by granite known as Ipa Granite whereas the northern slope consists of marble, known as Markhu Marble. The Ipa Granite is intruded into north dipping Kulekhani Formation and Markhu Marble. The granite is porphyritic, medium to coarse grained, light grey in color. Feldspar is mostly weathered near the surface. In addition to the quartz and feldspar, both biotite and muscovite are present in these granites. Follow-up detail study is required to confirm whether this granite is suitable for polished stone or not.

Marble

Bhainsedobhan Marble

This marble belongs to Bhimphedi Group of Kathmandu Complex. It is medium to coarse grained crystalline, white, yellowish white to grey, light pink in color. The stratigraphic sequence shows Raduwa Formation as underlying rock and Kalitar Formation as overlying rock unit. At places, there are scattered grain of pyrite, galena, magnetite and mica as impurities. Marble forming ridges are steep. The general trend of the marble bed is $110^0 – 135^0$ with dip $70 – 80^0$ N. The exposures are limited along the Khola and foot track sections. The marble bodies to the west of Kitini Khola at Bhainse appear to be of economic interest (Fig.4). Based on the color, texture, uniformity in grain size etc. the marble of Kitini Khola section is divided into three types. From bottom to top, they are (a) Thinly bedded greyish white marble (b) Thin to thickly bedded greyish white marble and (c) thickly bedded white to grayish white marble.

The total thickness of marble bed is about 400 m. It looks massive but at close look there is distinct bedding of 50 cm to 1 m thickness. Often there are 15 to 20cm thick interlayers of mica schist. Frequently scattered grains of pyrite, galena and magnetite are observed. Four major types of Joint sets are common. Structural analysis of the discontinuities within the marble beds shows the wedge is dipping in the opposite direction to that of bedding.

Markhu Marble

The Supin - Sikneghari marble (crystalline limestone) is a part of Markhu Marble of Bhimphedi Group (Fig.5). In this area occasionally, the marble beds are interbedded with few bands of schist, quartzite and carbonate rock in varying proportions. More than 50% is marble. Bedding exhibits parallel arrangement of micas. The marble is white to grey in colors, few occasionally pinkish, medium to coarse grained and crystalline. The main constituents are calcite, quartz, biotite and few accessory minerals like pyrite. Markhu Marble beds range in thickness from few cm to few meters. At places the marble is jointed, locally folded and fractured.

General trend of the marble beds is NE – SW and dip towards south at 32^0 in Supin and in the area immediate south of Rapti River. In the southern part in the periphery of Burja Danda the orientation of the marble beds is mostly north and dip 22^0 NE. Core of synclinorium runs parallel to the Burja Danda. Marble is widely exposed in this area. Bedding thickness is 0.5 cm to 1 meter. As the deposit lies on hill top, good mineable marble is found in Supin, Mathan and Sikneghari area (fig.5). Marble observed at Hatisude-Damar area hosts lead/ zinc minerals. Structural analysis of the marble beds shows two major joint sets and the wedges are stable.

Markhu Marble identified at Kulekhani, Sisneri, Chhaimale area lies in the northern slope of the ridge and granite is exposed at ridge top (Fig.3). Markhu Marble bulges out to significant thickness in the middle of the extension at Sanotar area. Marble bed of light pink to white color extends east-west along the Kulekhani Khola. Some of the study area also consists of distinct grey colored marble. The test results resembles with the Markhu marble of

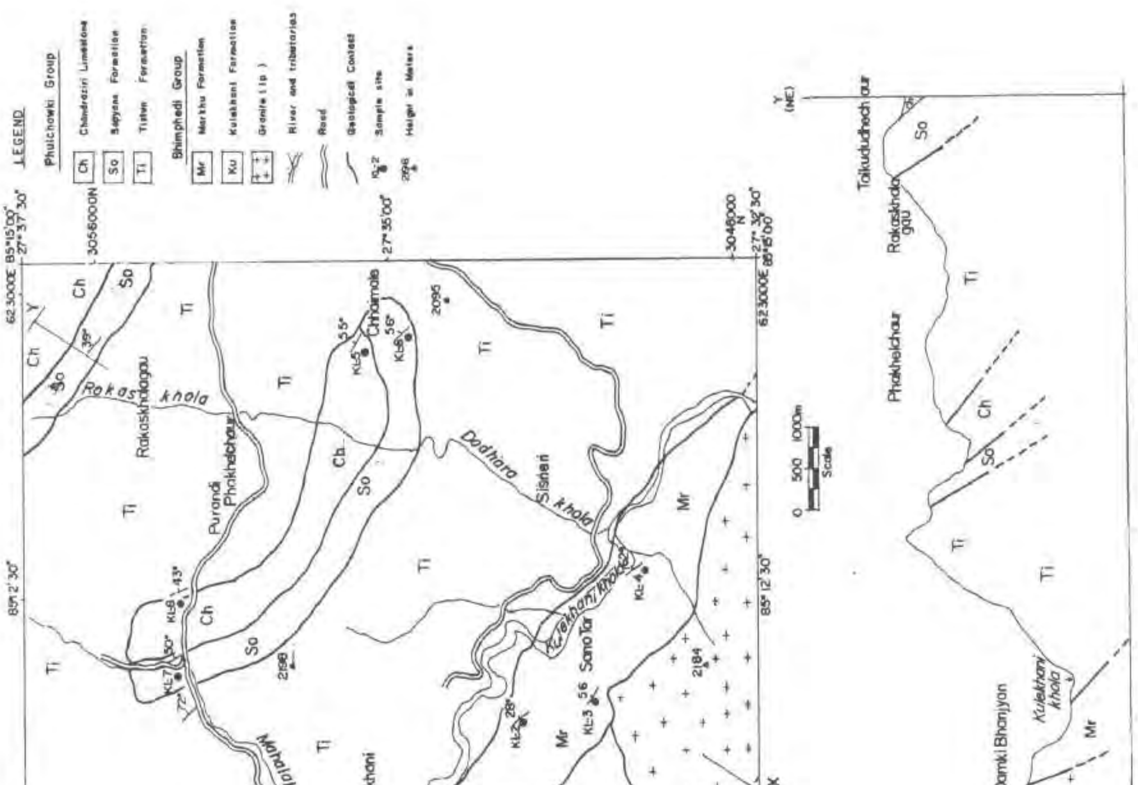

Fig. 3: Geological Map of Kulekhani-Sisneri-Chhaimale Area

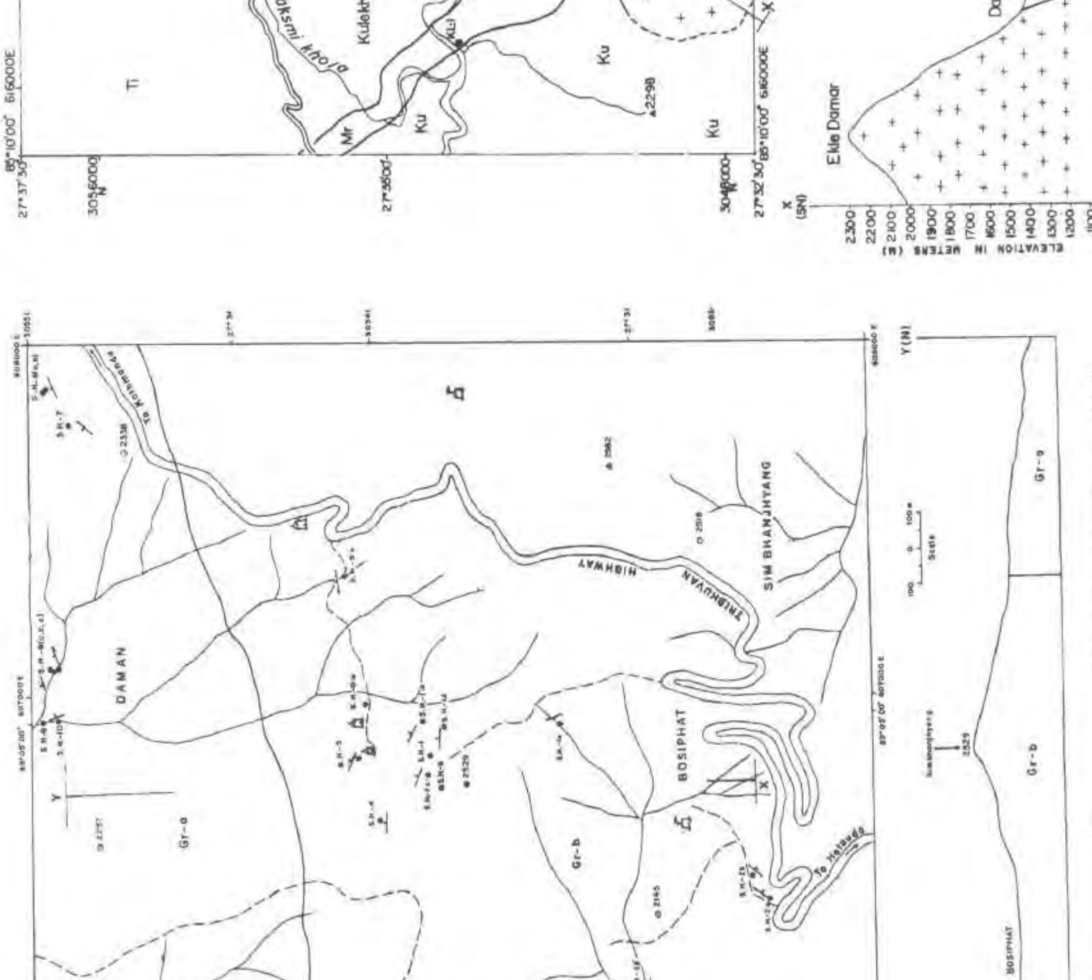

Fig. 2: Geological Map of Simbhajhyang Area

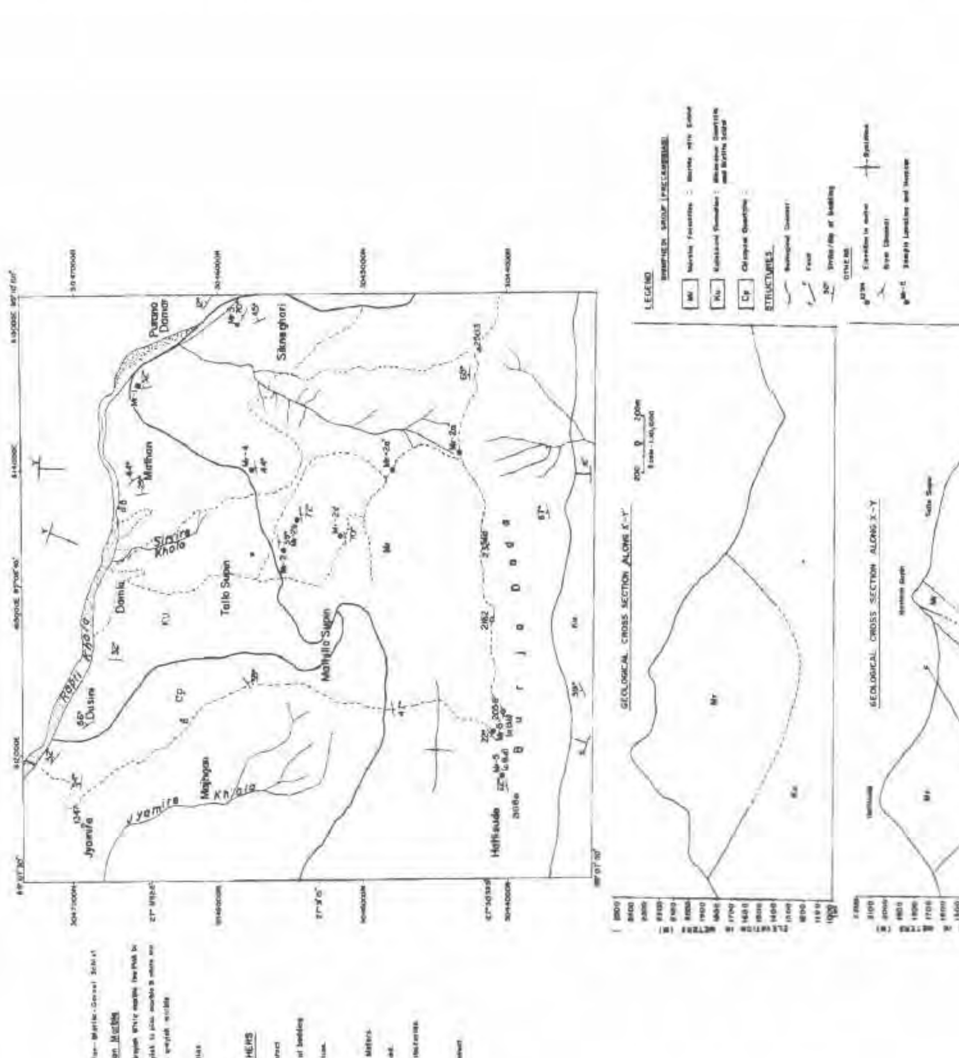

Fig 5: Geological Map of Hattisude, Supin, Sikneghari Area.

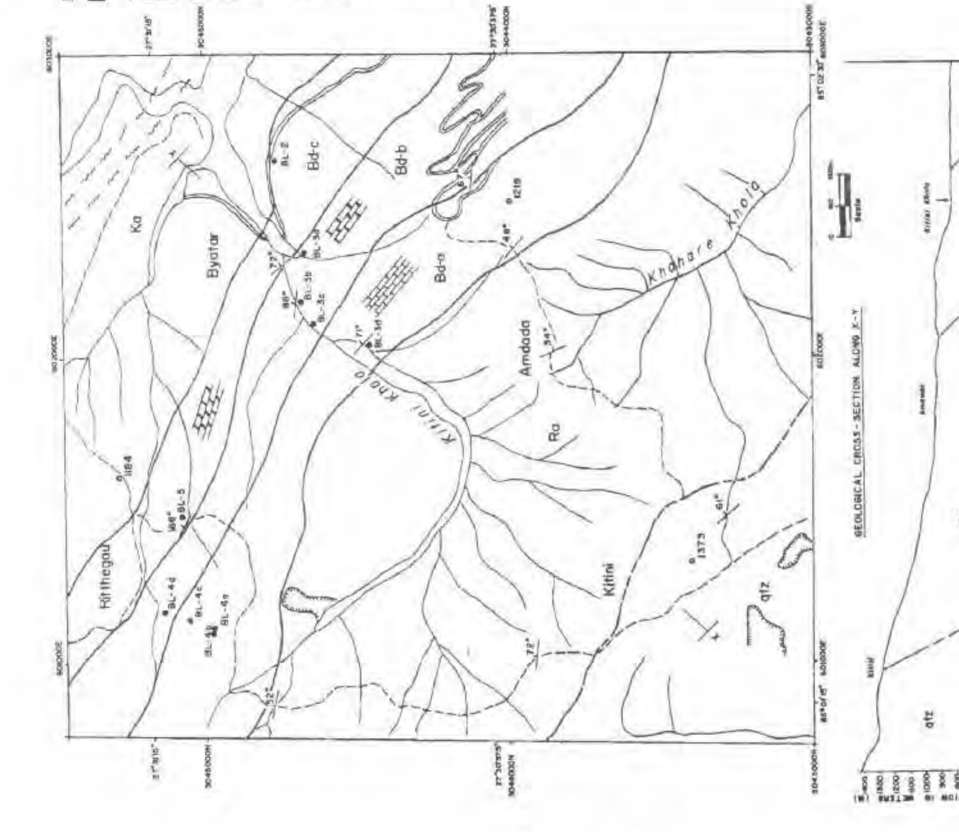

Fig 4: Gelogical Map of Rittegau-Kitini Area.

Supin-Sikneghari area. The newly developed road helps to access these marble prospect. Detail follow up study is warranted to explore the marble deposit.

RESULTS OF LABORATORY TESTS

Laboratory tests were done in DMG laboratory to supplement the filed study data to delineate the possible resource areas. Samples were polished to check for their suitability to obtain the information about color, appearance and luster. Petrographic study, chemical analysis and physico-mechanical tests were performed to check their durability.

(a) Suitability Tests

Cutting & Polishing: The polished surface of Bhainsedobhan Marble shows shiny luster (Fig 6a) but contains a bit more pyrite minerals. The polished surface of granite shows shining luster and attractive appearance. There is abundance of irregular crystal of feldspar and mica in granites (Fig.6b). Similarly, the Markhu Marble shows more mica minerals (Fig.6c) as compared to Bhainsedobhan Marble.

(b) Durability Tests

Petrographical Study: The petrographic study is based on the 5 thin sections of each rock type. The details are presented in Table-1

Chemical Analysis

The chemical analysis result of different rock types are presented in Table 2.

Physico-mechanical Study: The physico-mechanical tests were conducted (5 tests) for each rock specimens. Bulk Specific Gravity (D), Absorption by weight, % (Abs.) @ 24 hours soaking was performed according to ASTM test methods (ASTM, 1996 & ASTM Standards). Uni-axial Compressive Strength (Cu) tests was calculated based on the field investigation of cube Compressive Strength (Cc) of the insitu rocks measured with Schmidt Hammer Values (SHV) taken by Schmidt Hammer. The test results are compared with ASTM requirements. The results of physico-mechanical tests obtained from laboratory study for granite and marble are presented in Table 3.

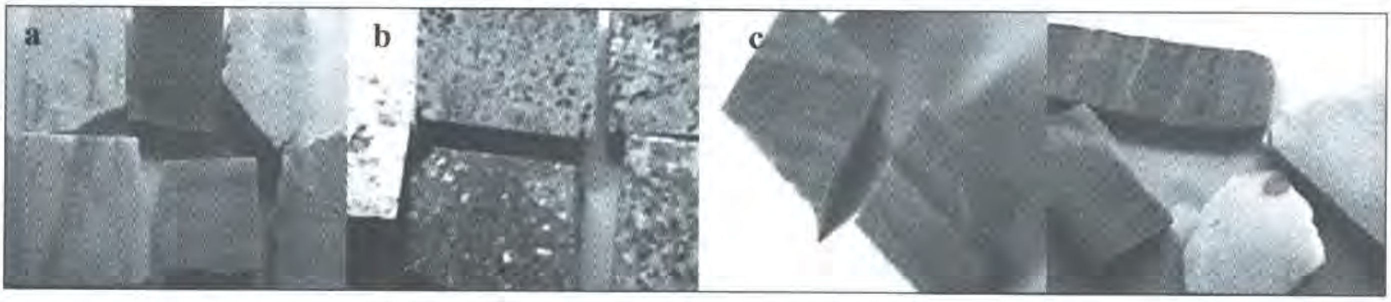

Fig. 6: Polished Samples of (a) Bhainsedobhan marble (b) Palung granite (c) Markhu marble

Table 1: Details of Petrographical Study

Rock Type	Color	Texture	Mineral Constituents (%)						
			Quartz	Feldspar	Biotite	Muscovite	Calcite	Tourmaline	Opaque
Palung Granite (BT Granite)	Smokey White and milky shades, Predominant black patches/spots of biotite and tourmaline	Smokey White and milky shades, Predominant black patches/spots of biotite and tourmaline	45-55	30-35	6-7	few	-	1	1-2
Ipa Granite	Light Greyish white, black spot/ patches of biotite and tourmaline	Light Greyish white, black spot/ patches of biotite and tourmaline	50-55	12-15	10-15	5-8	-	2	3-5
Bhiansedobhan Marble	Upper part light pink and lower part light grey to white	Upper part light pink and lower part light grey to white	10-15	-	-	1-3	75-80	-	1-2
Markhu Marble	light Grey, Light Pink, Grey	light Grey, Light Pink, Grey	1-3	few	1	-	85-90	-	1

Table 2: Results of Chemical Analysis

Rock Type	Sample No.	LOI	Insoluble	SiO_2	R_2O_3	CaO	MgO
Palung Granite	Sh -1	1.14	-	72.36	9.25	4.21	2.52
	Sh - 2a	0.75	-	72.78	10.15	2.80	3.02
	Sh - 3	0.36	-	73.56	14.10	4.21	2.52
	Sh - 6	0.30	-	75.26	8.60	4.21	2.52
Ipa Granite	Igr - 1	0.81	-	72.72	7.35	4.21	2.52
	Igr -2	1.14	-	71.36	8.00	3.51	2.02
Bhainsedobhan Marble	Bl – 3a	39.36	10.58	-	1.85	44.86	3.15
	Bl – 3c	23.83	43.86	-	2.15	28.22	1.39
	Bl – 4a	33.58	25.42	-	1.97	29.62	9.20
	Bl – 4b	41.38	7.26	-	1.57	44.86	4.79
Markhu Marble (in Supin)	Mr - 1	39.98	7.98	-	3.30	43.11	5.04
	Mr - 2	40.97	5.18	-	2.37	49.95	0.63
	Mr - 3	40.83	4.46	-	1.95	50.12	1.64
	Mr - 5	35.40	17.06	-	1.82	41.71	2.02
Markhu Marble (in Kulekhani)	Kl - 1	31.76	22.34	-	5.02	40.66	0.88
	Kl -2a	39.54	5.80	-	3.25	50.82	0.63
	Kl -3a	21.69	45.68	-	3.95	27.69	0.63

Table - 3: Results of Physico-Mechanical Tests

Rock Type	Bulk Density, D (Kg/ m^3)		Absorption by weight, Abs (%)		Compressive Strength, Cu (Mpa)	
	Required by ASTM	Value Obtained	Required by ASTM	Value Obtained	Required by ASTM	Field observation values
Palung Granite Biotite-Tourmaline- Granite Ipa Granite	2560 min.	2660 2640	0.4 max.	.0.74 0.40	131 min.	21.8 - 43.6 NA
Bhainsedobhan Marble	2595 min. Calcite 2800 min. Dolomite 2690 min. Serpentine 2305 min.	2660	0.7 max.	0.23	52 min.	48.4 - 52.3
Markhu Marble	Travertine	2650		0.27		38.3 - 48.4

CONCLUSION

- The field investigations supplemented by laboratory tests and analysis of the rock samples for durability and suitability revealed that Palung Granite, Ipa Granite, Bhainsedobhan Marble and Markhu Marble all are the suitable rocks for polished / dimension stone to be used as interior decoration or exterior use.
- Palung Granite at Simbhanjyang area and Ipa Granite at Sanotar and at Sisneri area show low to moderate weathering effects on the surface exposures. The Uni-axial compressive strength of these insitu rock show low values compared to ASTM specified values. Good mineable deposit is available in these areas. The exact mineable reserve of these granites can be estimated only after detail investigation and drilling.
- Markhu Marble at Supin, Sanotar and Sisneri area and Bhainsedobhan Marble at Kitini Khola and Bhainse are quite suitable for polished/ dimension stone. These rocks meet the specifications required by ASTM standards while performing durability tests. These deposits lie at hill top and are quite suitable for mining. The exact mineable reserve of suitable block size can only be estimated after detail drilling and surveying.
- Compressive strength tests, modulus of rupture tests need to be carried out in the laboratory, so that the test results can be compared and correlated with field data.

RECOMMENDATION

- Detail exploration with test drilling, surveying and geological mapping in the scale of 1: 2000 scale needs to be carried out at Supin for Markhu Marble, at Simbhanjyang for Palung Granite and at Kitini Khola for Bhainsedobhan Marble for estimation of mineable reserve with possible block sizes.
- Sanotar to Sisneri area (35sq.km.) needs to be explored in detail for Markhu Marble and Ipa Granite for its weathering profile, possible block size, estimation of mineable reserve etc.
- At least one of the areas (Simbhanjyang area or Supin area or Bhianse area) should be floated to the private entrepreneurs to invest for detail exploration.
- Additional laboratory tests on the samples as specified by ASTM need to be carried out on other laboratory as it could not be performed in the laboratory of Dept. of Mines and Geology.

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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 material such as sand, gravel and stone quarries. However, DDC acquires technical approval from DMG before issuing of such license. Issue of prospecting/ mining licenses and monitoring of mining activities is 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 these mines, monitoring of the mining activities of 'Ordinary Construction Materials' of which the licenses are issued by DDC, were also inspected since there is no technical manpower in DDC to monitor the mining activities. In the fiscal year 2061/62, the inspection and monitoring works were carried out by three different field inspection 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 of 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 paper is based on the inspection and monitoring of 27 different operating mines in Lalitpur, Dhading, Makwanpur, Sindhuli, Udayapur, Jhapa, Tanahu, Kaski, Dang, Dolakha, Kavrepalanchowk and Sindhupalchowk 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 applicants before award of mining licenses
- 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 Mining and Mineral Rules, 2056 of His Majesty's Government of Nepal
- to take further actions if the previous suggestions/ directives were not followed by the licence 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 (Mining 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 of all the mines/ quarries (mentioned above) submitted by the teams are categorized in three different groups based on the types of mineral commodities.

a. Ordinary Construction Minerals

Inspection and monitoring of mines of ordinary construction minerals (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 mine were in operation. They were operating in a very unsafe manner. DDC has been directed to stop all those illegal mining activities immediately. Local administration office has also been requested by DMG to stop all the illegal mining activities over there.

Similarly, most of the sand and raw stone quarries operating within the Kathmandu valley and at Dhading District were in operation without developing proper 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 license holders were directed through the concerned DDC to work by making small benches from top to bottom and 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 (P.) 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 boulders 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 2060/61 only. Deurali Int. Mines was allowed to export 2000cft. gravel to India via Rani Custom Office, Biratnagar in the FY 2060/61. It has exported only 161cft of stone boulders till 25 Ashwin 2061. 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 damage the fertile cultivated land. It was directed to initiate production immediately at optimum capacity by environment friendly manner.

c. 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 2061/62.

Out of the seven limestone quarries, Hetuada Cement Industry Limited (HCIL)'s two quarries at Bhainse and at Majuwa (Okhare) and 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 (P.) Ltd. was 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 (P) 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 was transported through the high natural chute to the lower level. Therefore, there is a high risk for the labours in the working area due to high slopes. On the other hand, 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 flows through the quarry area is not canalized. However, there were not much negative effects on water and air quality.

Bhianse 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, borehole diameter of 100 mm, and the hole spacing of 2.5 m were in process at the time of inspection. Limestone extracted from this quarry is blended with those having high CaO content to produce cement. It was found that the waste disposal site was improperly maintained around the quarry hill slope. However, so far there was little effect on water and air quality. The management was found least concern about the safety of the 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 below. There is high overburden in the western part. Rocks are dipping on opposite sides to the natural slope. Manual and mechanical excavation was 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 malpracticing the 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 was no mining activity not much of environmental problems were noticed.

The limestone quarry owned by Maruti Cement Udhyog (P.) Limited at Kakur Takur VDC 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 also 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 are presented in Table – 1.

During the mine inspection, the professionals of DMG gave suggestions and directive to the owner / the lease holder 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. Annapurna Quarry (P.) Ltd. was instructed to maintain the benches properly to have minimum environment impact and erosion problem, to canalized the Jawang Khola, to have proper waste management and do the excavation and production of limestone under the supervision and guidance of a mining engineer

Bhainse quarry should be well managed and strictly dispose all the mining waste only 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 local people to maintain the basic amenities like drinking water supply, road. It was also directed that previous directives and instructions should be followed to improve the mining activities and minimum impact in the natural environment.

The inspection team also instructed Ajay Raj Sumargi, the owner of limestone quarry at Pandrang to report DMG about the close and re-open of mine timely. It was also directed to maintain proper recording of limestone

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

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

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 indicators.

Sarada limestone deposit at Purandhara in Dang district which is 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 the 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 (P) 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 (P.) 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. And 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 raised by DMG and to some extent, has followed the DMG directives. It was directed to do the work 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 (P.) Ltd. at Manapang, Tanahu; Dig Bijaya Products (P.) Ltd. at Phulping Katti, Barhabise, Sindhupalchok; Nepal Orind Magnesite (P.) Ltd. at Kharidhunga, Dolkha were in production. The production of talc from these three operating mines are 150 MT (up to Falgun 2061); 292 MT (up to Chaitra 2061) and 724.44 (up to Ashwin 2061) respectively. Dust Nepal (P.) Ltd at Phirphire, Tanahu and Singh Khanij Udhyog (P.) 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 in the process of bench development activities and others had already developed production benches. Due to poor waste management there appear erosion and siltation problem in nearby quarry areas in almost 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 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 cement factory 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 3 m to 6 m and was directly loaded to the dumper. The production of this quarry was 6128 m^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 up to 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. Therefore, the same directives were issued once again and also directed to pay the government royalties regularly.

c. 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 only in two operating coal mines 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 (असहज परिस्थिति). However, the inspection team was able to visit the corporate offices of eight operating coal 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 under-ground 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 3,498 metric tons by the end of Magh in the FY 2061/62.

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 out side 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 has also visited one coal prospect that was in the process to obtain mining license. For this purpose, 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 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 previously given directives by DMG. 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 and mines and environment monitoring of operating mines 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.
- All these inspected mines may continue the mine operation taking proper care of the guidance given by DMG.

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Engineering and Environmental Geological Mapping of Hetauda and Surrounding Areas

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INTRODUCTION

An area of 100 Km^2 covering Hetauda Municipality and adjacent areas in Makawanpur district, Central Nepal (Fig.1) was investigated in the fiscal year 2061/62. The investigated area lies in between modified UTM coordinates 3029000 N to 3041000 N and 597000 E to 607000 E (latitudes 27° 22¢ 29.40" N to 27° 28¢ 56.58" N and longitudes 84° 58' 50.73" E to 85° 04¢ 58.48" E) in parts of Toposheets 2785 09A and 2784 12B at 1: 25, 000 scales. Hetauda city is situated in the Dun valley at a distance of 226 km from Kathmandu. The Tribhuvan Rajpath links Hetauda from Kathmandu via Daman (132 Km).. The maximum elevation in this area is 1022 m at Dhumari and the lowest altitude is 436 m at Thanabharen. Raxaul, is the nearest Indian border town (55 Km south from Hetauda).

Hetauda town is one of the fast growing urban areas in terms of settlement expansion in Nepal. The population in the town as per the 2001 census is 68,000. In this regard, building construction activities are rapidly increasing in Hetauda municipality and the surrounding area. Floods and landslides threaten the inhabitants by inundating the riverside area every year. The highway bridge at Rapti River was severely affected by flood during the last rainy season and a part of the highway close to the bridge towards Hetauda bazaar was damaged.

Due to the lack of engineering and environmental geological knowledge, the study was focused to provide information on sustainable infrastructure development planning and identification of potential areas of natural resources. Discussions were held with the personnel from Makawanpur District Development Committee (DDC), Hetauda Municipality and other stakeholders during field visit. Their appropriate suggestions and important information were incorporated in the report.

OBJECTIVE

The main objectives of the present study are:

- Identify the various rock and soil units and prepare Engineering Geological map
- (1:25,000 scale)
- Delineation of tectonically weak zones, lineaments, flood prone areas etc.
- Mapping of landslides and erosion features
- Soil section study by pitting.
- Delineation of the area susceptible to liquefaction and ground settlement and associated risks so as to provide suitable preventive measures to reduce its effect on existing environment and structures.
- Compile Engineering geological information, Urban and Environmental geological data, types of hazards and prepare an Engineering and Environmental Geological map at 1: 25,000 scales and the report.

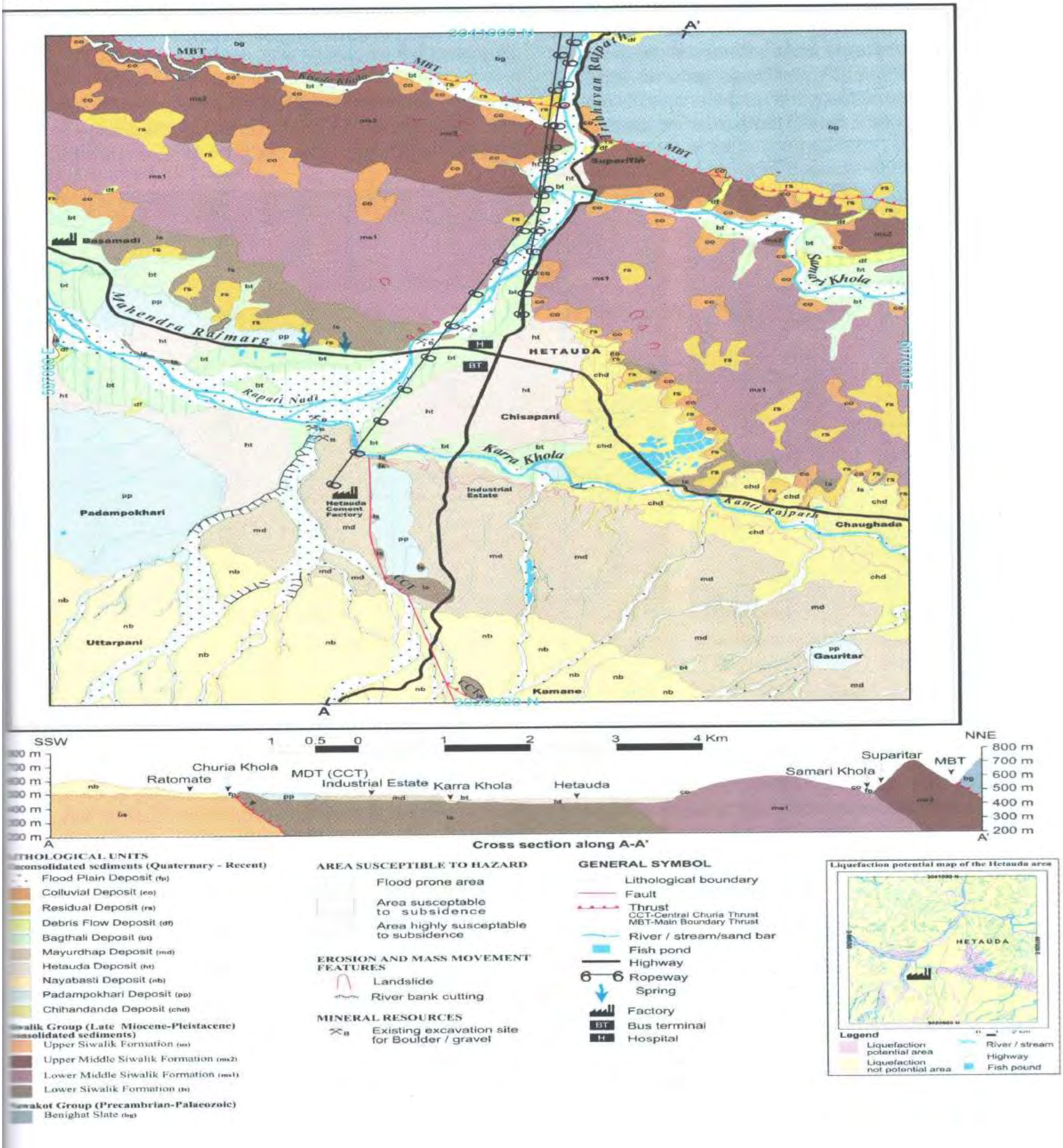
METHODOLOGY

Existing relevant literatures on geology, geohazards and regional geological as well as land use maps were reviewed. Available reports on groundwater provided by Hetauda Water Supply Corporation 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. Lineaments were marked in the TM – Scenes that are oriented in different directions. These lineaments could be the deep-seated faults or fracture zones or the boundary of the lithological variations. In most cases, they normally represent the tectonically weak zones. Topo maps of 1: 25,000 scale (1992) and the digital database of these maps was acquired from Topographical Survey Branch. They were used to prepare a base map. The final Engineering and Environmental Geological map was prepared by using software such as Arcinfo, Arcview and Freehand (Fig.1).

FIELD ACTIVITIES

The fieldwork was carried out in dry seasons of 2005. It was planned with an aim to verify the previously interpreted work in the field and look for possible neotectonic features as well as to compare the previously identified thrusts, faults, lithological formations, boundaries, land use and the infrastructures. Field survey enabled to delineate the potential areas of instabilities on the ground, landslides, flood prone areas, the area of low bearing capacity and

g. 1 Engineering and Environmental Geological map of the Hetauda area



neotectonic features. Preliminary survey was also made for Hetauda Municipality to find out the suitable sanitary landfill site for waste disposal. In total, 100 auger holes (Fig.2) were drilled for the investigation of the subsurface soil layer from which required soil samples were collected from different depth of the boreholes for laboratory analysis. 50 Standard Penetration Tests (SPT) were carried out to determine the stiffness of the ground at different locations (Fig.3). These tests were carried out to the maximum depth of 10 meter only because of the limitation of the type of the equipment used for the test.

Lower Pleistocene in age. Quaternary terraces are developed mainly to the south and western part of the Dun valley Hetauda area.

The Siwalik rocks are divided into **Lower Siwalik (ls)**, **Lower Middle Siwalik (ms_1)**, and **Upper Middle Siwalik (ms_2)** in ascending order. **Upper Siwalik (us)** sequence is not exposed in the present area (Fig.1).

Lower Siwalik Formation (ls): It is represented by fine to medium grained, light gray sandstone alternating with colorful mudstone (purple, orange, yellow, and brown),

Fig. 2: Performing Auger hole drill in the field

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

A number of geological traverses were taken along riverbanks, trails and roads to delineate geological units and to identify areas prone to flooding, riverbank erosion and riverbed scouring. Soil sections exposed along riverbanks were measured. A number of pits were dug in order to expose the soil section in areas other than river sections. The sediments up to the depth of 10m are broadly classified into different lithological units. Field data and information collected from aerial photographs were transferred in the topographical base map. Analyses of collected samples from the field were carried out in respective laboratories for their respective purposes. Geographical Information System (GIS) analysis was carried out using ARC/INFO software.

GEOLOGICAL SETTING OF HETAUDA AREA

The Siwalik (Churia Hills) surrounding the study area are the erosional detritus consisting of thick piles of fresh water molasses sediments deposited and lifted during the rising of the Himalayas. They are of Mid-Miocene to

siltstone (green, gray) and shale. Sandstone is calcareous and fine to medium grained. Predominance of mudstone over sandstone is generally observed. Cyclic sedimentation with fining upward sequence is often marked. Lower Siwalik has transitional contact with Middle Siwalik and is exposed near west bank of Rapati river, at the foot hills to the north of Karra valley and at Lamsure Dada. Approximate observed thickness of the Lower Siwalik is 1200 meters in the study area.

The Middle Siwalik Formation (ms): It is divided into two sub units: Lower Middle Siwalik (ms1) and Upper Middle Siwalik (ms2) Formations.

Lower Middle Siwalik Formation (ms1) is medium to coarse grained, thick bedded, calcareous, grey sandstone alternating with purple, blue, green, yellow and grey mudstone, siltstone (light blue, green, grey) and grey shale (with plant fossil). Dominance of sandstone over mudstone is observed. Lower Middle Siwalik is exposed along Tribhuvan Highway (north of Hetauda), middle and upper hill slopes (north of Karra valley) and in Bhairabdada. Observed thickness is 2000 meters.

Upper Middle Siwalik Formation (ms2) on the other hand is massive, gravely/pebbly, coarse grained, very thickly bedded, pepper and salt textured grey, arkosic sandstone and various colored mudstone (green grey, blue grey). Predominance of sandstone over mudstone is observed. Cross laminations are also found in the beds of pebbly sandstone. In upper part pebbly beds and lenses become common. Approximate observed thickness is 800 meters.

In general the Siwalik rocks show a gentle to steep dipping towards north, northeast and northwest. Repetition of the Siwalik rock sequence occurs once along Central Churia Thrust (CCT) within Siwalik Formation. CCT marks the tectonic boundary between the Upper Siwaliks to the south and the Lower Siwaliks to the north. The Dun gravels that occurred extensively to the south of Ratomate village often cover Upper Siwalik Formation. Northern margin of the Siwalik Group is marked by Main Boundary Thrust (MBT). The upper Middle Siwalik MS2) is thrusted over by the slates of Benighat Formation of Nawakot Group along MBT (Stocklin and Bhattarai, 1980). Although Tamrakar et al. 2003, mentioned about the existence of Pre-Siwalik rock in the south of MBT but in view of the present authors, further detail study is necessary before concluding the remarks.

Valley Floor Setting (Quaternary Geology) of Hetauda Area

The valley floor within the study area consists of the sediments derived from the rivers that originate within Siwalik hills except in the depositional sites of Rapati River and Samari Khola. Mainly the alluvial, residual and colluvial soils of Quaternary deposit are observed on the plain along the river valleys, hill slopes and on the elevated terraces as well as flat spaces on the hills. Based on the study of soils along river sections, pits and existing litho logs, they are differentiated into:

Flood Plain Deposit (fp)
Residual Soil Deposit (rs)
Colluvial Soil Deposit (co)
Debris Flow Deposit (df)
Baghthali Formation, (bt)
Mayurdhap Formation (md)
Hetauda Formation, (ht)
Nayabasti Formation (nb)
Padampokhari Formation (pp)
Chihandada Formation (chd)

Their brief descriptions are given below (Fig.1).

Flood Plain Deposit (fp)

The flood plane deposit (Fig.1) composed of mainly boulder to sand size material of quartzite, gneiss, limestone, and dolomite is derived from Lesser Himalaya and sandstones of Siwalik hill (Sub Himalaya). The sediments are derived both from north and south. The sediment derived from north is transported chiefly by Rapati River, whereas the sediments derived from south are by the streams originating in Siwalik Hills. The source of coarse sediment from the southern slope is mainly the conglomerates of upper Siwalik Formation. Auguring and SPT tests were not carried out in the flood plain deposit of the study area because of the looseness, coarseness and highly abrasive nature of the sediment.

However, the flood plain other than those occupied by lacustrine deposit is the accumulation of loose detrital sediments. This deposit has relatively low bearing capacity. Such area is prone to flood hazard. This unit changes its landforms almost every year due to change in the river course. The ground water level is shallow (1-2m in general) in the area occupied by the flood plain deposit.

Colluvial Soil (co)

The colluvial soil in the study area is derived mainly by landslide and slope wash deposited either on the mid-slopes of a hill or at the foot of the slopes (Fig.1). The colluvial deposit is mainly derived from gravity action. The material involved in this deposit is either Siwalik rock materials or the terrace materials of different ages. The colluvial soil contains heterogeneous mixture of unsorted gravel to silt size material with some boulders. Occasionally the clay and silt dominant soil mass is also involved in the formation of colluvial soil. Unlike flood plain deposit, the shape of the material in colluvial deposit is angular to sub angular. In most of the cases the area occupied by this soil is susceptible to landslide hazard. Being a heterogeneous soil mass, it is not possible to predict the engineering properties of the colluvial soil. It varies laterally as well as vertically within a short distance. The depth to ground water level depends upon the location of the soil mass. In general the colluvial soil is not suitable for civil construction purposes without proper site investigation. However, it can be considered that older the colluvial soil safer for the construction purposes provided that the input of geotechnical knowledge is properly applied. The thickness of the colluvial soil varies from tens of centimeter to few meters.

Residual Soil (rs)

The residual soil in the study area (Fig.1) is mainly located in the hill tops as in the Sahid Park, Manakamana temple etc. It contains mainly sand to silt size materials with some gravel and little amount of clay. The thickness of the residual soil deposit varies from few centimeters to few meters. This type of soil is dense and compact in its natural form. The area occupied by this soil is suitable for construction purposes as a sub-base. The SPT testing for the residual soil near Sahid Park area revealed that the soil is very stiff with at least 20 ton/m^2 of bearing capacity. Considering the low thickness and the nature of origin of the soil the value 40 ton/m^2 seems maximum achievable value in residual soil in the study area. Ground water depth is considerably deep in the area occupied by this soil.

Debris Flow Deposit (df)

The debris flow deposit is located mainly on the right side along Samari Khola valley (Fig.1). The nature of the soil in debris flow deposit is heterogeneous mixture of Boulder to Sand size materials originating from Lesser Himalayan and Siwalik hills and consist of quartzite, sandstones, phyllite, limestone etc. This type of deposit is appearing in isolated patches at the confluence of Samari Khola with its tributaries. The area occupied by the soil of debris flow deposit is not considered suitable for construction purposes because it is susceptible to future debris flow event making the land use more vulnerable. Since the material is rapidly accumulated, water borne deposit of low bearing capacity zone is possible. Considerable seasonal variation in depth to ground water is expected in this type of soil.

Bagthali Formation (bt)

Baghthali Formation (Fig.1) is basically a river terrace deposit, which is just one level higher than the flood plain deposit. It is named after the prominent terrace deposit situated in Baghthali area on the right bank of Rapati River. The materials of the Baghthali Formation consist of about 30cm humus mixed soil on top followed by 1 to 1.50 m fairly dense pebble to sand size particles in clasts. According to the Unified Soil Classification System (USCS) it can be named as silty sand and gravel with isolated boulders. At places big boulders of granite up to two meters diameter were found in this unit. This is considered to be the result of a high flooding event along Rapati River in the past.

The area occupied by this formation cannot be considered as suitable sites for civil structures and settlements since the proximity of the river is hazardous due to flooding and present of swampy lands at places.

The bearing capacity obtained from SPT testing is 40 ton per square meter or more in gravel predominant area. SPT tests in the swampy area could not be performed where the bearing capacity of the soil is negligible. The material of the Baghthali Formation is highly porous and not suitable for fishponds purposes in general. However, the topsoil up to 1.5 m at places being finer in nature containing sandy silt or silty sand, the area is widely used for agricultural purposes.

Mayurdhap Formation (md)

Mayurdhap Formation is mainly developed on the southern slope of the study area (Fig.1). It contains mainly silty sand, and sandy silt on top followed by coarse sandy gravel deposit. At the northern boundary, predominantly gravel of Mayurdhap Formation is inter-fingering with mainly silt and clay deposits of Chihandanda Formation (Fig.4).

Although the gravel deposit of the Mayurdhap Formation is comparatively loose, the SPT value obtained for this formation varies from 15 to 30 tons/m^2 and more with some exceptions. In terms of loads this formation provides fairly good bearing capacity.

Hetauda Formation (ht)

Hetauda Formation is developed as a fan like feature deposited mainly by Rapati River and presently occupied by Hetauda city (Fig.1). The Hetauda Formation dominantly consists of the gravel deposit with interlayering of sandy to silty beds as shown in the marginal part. The grain size diminishes rapidly from 50 cm to 20 cm at the central part to less than 5 cm at the marginal part of the deposit. The SPT tests were carried out in the central part of the Hetauda and it was found that the material content of the deposit is about meter thick soft sandy silt, and silty sand on top followed by compact and hard sandy gravel deposit. The low SPT values obtained for top layer is attributed to the presence of fill material, where as the high SPT values of 30 or above obtained for the lower horizon. The top layer rarely exceeds 2 m in general and reaches up to 3.75 m in campus road whereas the lower layer exceeds 10 m in the central part. In general the bearing capacity of this formation can be considered high; however, the site-specific tests should be carried out for the construction of any individual structures.

Nayabasti Formation (nb)

The name Nayabasti Formation also known as Dun gravel (Fig.1) has been given to predominantly gravel deposit of the Hetauda dun valley (Kimura et. al, 1995). In this report this name is applied to the material mainly developed in the southern elevated terraces of the study area. Though in the study area the Nayabasti Formation is represented by thick red soil deposit exceeding 5m on top, it continues to the south where the thickness of red soil diminishes and underlying loose gravel deposit become thick. This gravel deposit more or less looks like Dun gravel. Morphologically the area occupied by Nayabasti Formation is slopy terrace. It consists of dominantly fine-grained reddish to brown silty sandy clay to sandy clayey silt with some gravel at the base.

Inter layering of fine and coarse-grained material is frequently observed. Dominance of fine grained or coarse-grained materials at particular locations was commonly observed. At the lower part of the deposit coarse gravel material is dominant whereas on the upper part fine-grained material is dominant. The exposed thickness of this formation in Nayabasti area was up to 10 m. The terrace is sloping towards North at an angle of approximately 10^0 - 15^0.

From engineering point of view this formation is composed of relatively stiff soil mixed with some gravel, which is considered fairly suitable for construction of buildings etc. However site-specific tests will be required for the individual structure. Water-table in the area is deep exceeding 10 m in general. Shallow strip foundation will be suitable for normal residential buildings up to 3-4 floors.

Padampokhari Formation (pp)

Padampokhari Formation is widespread in the southern part mainly in Lamsure, Padampokhari, Gauritar etc. and in the northern part near the Sahid Park (Fig.1). It is considered to be the oldest terrace deposit. Rolling topography containing deep red to brown silty sandy clay or silty clay with some gravel marks the morphology of Padampokhari Formation. Occasionally lenses and pockets of gravel or sand deposits were also observed. The maximum observed thickness of this formation in Lamsure and Padampokhari area was above 10 m. Several auguring and SPT tests were carried out in the area occupied by this unit. In Lamsure Danda it is resting over the bedrock of Lower Siwalik Formation (ls) representing sandstones and mudstones. Well-rounded big boulders of dominantly quartzite mark the bottom part of the Padamapokhari Formation. The biggest boulder of 3m diameter was observed in Lamsure. The boulders of 1–1.5m size were frequently observed at several places in Lamsure and Padampokhari.

The area occupied by this formation is suitable for various purposes such as engineering construction and waste disposal sites. However site-specific tests should be carried out for individual constructions. The bearing capacity as obtained by SPT tests increased gradually from top to bottom. At the top it was about 10 tons/m^2 and at a depth of 7m it was 30 tons/m^2. Hence, for normal residential buildings, strip foundation or pad footing will be suitable as has been the normal practice for house construction in Hetauda area.

Further detail site investigation will be required to select the suitable site for waste disposal. Moreover, the red soil of Lamsure is found to be suitable for the industrial use for Hetauda Cement Industry. Presently the hematite ore is imported from India instead of using the red soil resource which is readily available from the proximity of the cement factory. It is recommended to use this red soil for the cement production in future, after performing necessary tests.

Chihandanda Formation (chd)

Chihandanda Formation is a lacustrine deposit. It is named after the Chihandanda situated on the left bank of Karra Khola in ward no.8 of Hetauda Municipality (Fig.1). This formation is represented by alternate layering of gravelly and silty material deposited by slow and rapid flow of water respectively. The extent of this deposit is mainly in the Karra Khola valley. However, in other places tributaries are dammed by terraces of Rapati River, few lacustrine deposits were also observed. One of such examples is near Sahid Park, where lacustrine deposit was encountered while augering. Keen observation of the Chihandanda Formation in several places reveals that Karra Khola valley could be a big lake in the past. The lake probably formed due to the rapid uplifting of the southern Siwalik Hills of Hetauda together with rapid flow of the coarse gravelly sediments both from north and south. Close observation at the confluence of Rapati Khola and Karra Khola, it can be seen that the accumulation of the sediments from Rapati River from north and Kukhreni Khola from the south is periodically damming the Karra Khola resulting lakes in Karra Khola valley. According to the local people of Chaughara, temporary damming of Karra Khola takes almost every year causing temporary lake. Hence, age variation of the lake deposit from Chihandanda Formation is probably from Holocene to Recent. This can be attributed to the two different observations, one in Sanopokhara, which seems to be recently dried out lake and other in tilting beds in Chihandanda Formation, which has witnessed at least one tectonic event. The soil is very soft in Sanopokhara whereas the black carbonaceous clay beds in Chihandanda area is dipping at an angle of up to 30^0 towards southeast (Fig. 4). In the marginal parts of the lacustrine deposit, the sediment is represented by yellowish colored silty sand, sandy silt and clay.

SPT tests in several places to investigate the soil properties of the formation revealed that the lacustrine deposit which is appearing on the ground surface in the area of Sano Pokhara, was found to be the softest

Fig. 4 Chinhandanda Formation

(bearing capacity is less than 5 ton/m^2). At places the SPT tubes were found sinking without being loaded by hammer. This type of ground is not suitable for any type of construction without any prior foundation treatment.

In general the area occupied by Chihandanda Formation is not suitable for construction purposes. However it is suitable for agricultural purposes and for the development of the sanitary landfill (waste disposal) sites. Site-specific investigation is strongly recommended for individual uses. Water table in Karra Khola area and in the area occupied by Chihandanda Formation is shallow (within a meter).

Geological Structure

Near Lamsure Danda (hill) the Siwalik bedrocks are dipping towards east at 30^0- 80^0. In other areas they dip towards northeast, northwest and north and the dip amounts varies from 14^0-73^0. The easterly dipping beds near Lamsure Danda seems to be the result of a north-south running transverse fault, which also offsets the Central Churia Thrust (CCT) or the Main Dun Thrust (MDT) exposed near Ratmate. The effect of the transverse fault can be seen on the Lower Siwalik sandstones exposed along the left bank of the Karra Khola near the confluence of the Karra Khola and Rapati River. The CCT marks the tectonic boundary between the Upper Siwaliks to the south and the Lower Siwaliks to the north.

The Siwalik sequence is thrusted over by the Lesser Himalayan meta-sedimentary rocks along the Main Boundary Thrust (MBT). The thrust can be observed in the north of Suparitar following the Kisede Khola to the west and also along the break of slope to the east. The MBT is marked by black, mylonitic, sheared slates resting over the pebbly sandstone beds of the Siwaliks in the field. The sheared slates are observed near Khoplan north of Suparitar where the Siwalik beds dip towards north at an angle of 50^0 near MBT.

Laboratory Tests

In the fieldwork 200-auger drill holes were drilled and 50 SPT tests were conducted in order to investigate subsurface geology and the bearing capacity of different soil unit in the area. About 200 soil and rock samples were collected in the field and they were brought to the geotechnical laboratory of the department for laboratory tests. Engineering tests such as grain size analysis (Fig. 5), Atterberg's limit tests were conducted. The results of the laboratory tests of some of the samples are shown in the table below (Table-1).

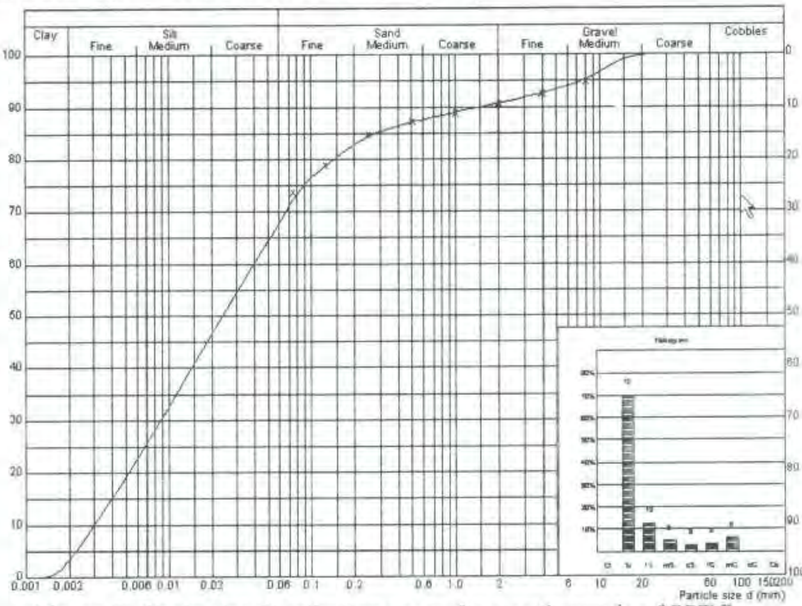


Figure 5: Grain size distribution curve for a soil sample of SPT 7, depth 2.3 – 2.75m

Table -1. Laboratory results for engineering properties of the soil samples

Sample No.	Depth (m)	Fines (%)	Coarse (%)	Liquid Limit(%)	Plastic Limit (%)	PI	Soil type	Perm(k) m/s	Remarks on Permeability
SPT-3	1.3-1.75	82	18	50	25	25	Sandy silt	$1.2*10^{-6}$	Very low
SPT-4	1.3-1.75	63	37	48	33.23	14.77	Gravelly sandy silt	$2.1*10^{-6}$	Very low
SPT-7	1.3-1.75			54	38.09	15.91			
	2.3-2.75			61.8	47.72	14.08			
	3.3-3.75			58	32.32	25.68			
	5.3-5.75	75	25	66	50	16	Sandy Silt	$1.4*10^{-6}$	Very low
	6.3-6.75	67	33	60.25	29.44	30.81	Sandy silt	$1.6*10^{-6}$	Very low
SPT-16	1.3-1.75	66	34	28.85	25.73	3.12	Sandy Silt	$1.8*10^{-6}$	Very low
	2.30-2.75	61	39	27.75	23.66	4.09	Sandy Silt	$2.0*10^{-6}$	Very low
	1.6-2.65	57	43	39	19.09	19.91	Sandy Silt	$2.4*10^{-6}$	Very low
	5.2-5.5	55	45	26.25	26	0.25	Sandy Silt	$2.6*10^{-6}$	Very low

NATURAL HAZARDS / GEO-HAZARDS

Debris flow, floods, landslides and soil erosion are the major types of natural hazards frequently occur in the Hetauda area. Evidences of recent debris flows and floods are observed in the tributaries of the Samari, Kisede and Rapti Rivers in the form of huge amount of debris deposit. Debris flow from the tributaries accumulated on the bank of Rapati River created devastating flood and bank cut along the sides of the River. Frequent flooding occurs around Chinaquarter, Chauki Tole (Ward No. 1) and Guraubirta area. Every year, people living in these areas are frightened during the rainy season due to possible floods. Preventive measures such as gabion walls constructed along the riverbanks are already damaged by toe scouring of the banks and by heavy floods (Fig. 6 and 7). People have reported that three major debris flood already occurred in the last 15 years period (in 2050, 2057 and in 2061 B.S.). The last flood of 2061 B.S. flood has broken the main highway of east abutment of the Rapati Bridge.

Fig. 6: A typical example of riverbank failure problems along the Kukhreni Khola near Mayurdhap

Landslides are common in Kisede and Samari Khola catchments areas. Evidences of recent slope failures are observed along the south facing slopes in the north of Sanopokhara in Kusumdada area. These slope failures did not affect the property and life but indicate that the slope is vulnerable to further sliding. It is based on the concept that "past is key to the future", that is, landslides are most likely to happen in areas where the ground conditions that caused them in the past and still persist today (Marsh, 2000). In this regard, fast growing urban settlement areas close to the foot of the slope near Sanopokhara area may suffer from mass wasting processes resulting to debris flow disaster in future. Recent slope failures are also observed to the north of Basamadi and Laljhadi indicating possibility of further land sliding in the area. The colluvial deposits developed on the slopes are prone to debris slides. Newly expanding settlement areas in the vicinity of these deposits may be affected by the debris slides in future.

High velocity flood in the Rapati River blocks the flow of the Karra River time and again near the confluence. As a result of this, the water level in the Karra River rises up and submerges the low-lying areas along the Karra River banks especially along Choughara areas. These areas are delineated as flood prone areas in the map. Flooding may also affect the cultivated land along the banks of the Rapati River west of the Bhutan Devi Mai temple, south of Thanabharen, north of Chinaquarter etc.

Most of the rivers originating from the southern part of the Hetauda valley have high gradients and remain dry during winter season. These rivers suddenly swell up by rainwater during high precipitation creating flash floods in the down stream. Such flash flood destroys farmlands, houses and sweep away cattle, people and damage infrastructures. Areas vulnerable to flooding by such

Fig. 7: Bank scouring by Kukhreni Khola, boundary wall of Hetauda Cement Factory.

events are Nagswoti village, Mayurdhap and Gauritar areas.

Bearing capacity

The bearing capacity of the soil in the investigated area was determined by using Standard Penetration Tests (SPT). A total number of 50 SPT tests were carried out in different locations. It was found that most of the study area occupied by Hetauda Formation, Bagthali Formation, Mayurdhap Formation, Padampokhari Formation and Nayabasti Formation, have moderate to high bearing capacities. On the other hand the Chihandada Formation has low bearing capacity. Some of the areas in Chihandanda Formation such as in Sanopokhara area and to the north of it has very low N-values ranging between 0 to 5, thus making the area susceptible to subsidence hazard. Because of the nature of the soil sediment of the area and presence of high water table, this area is also highly susceptible for liquefaction, where as the rest of the places are less or not susceptible to liquefaction (Fig. 8).

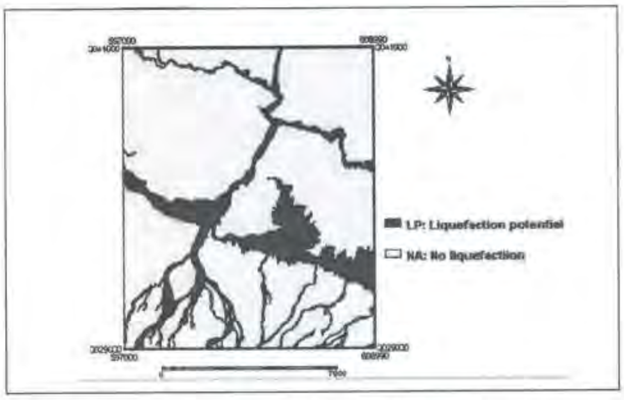


Fig. 8: Liquefaction potential map of Hetauda area

Natural Resources

Surface and groundwater, river boulders, gravels and sand as well as natural forests are the main natural resources in the area. Proper management of these resources for optimum utilization of the livelihood for the people is necessary.

Boulder, gravel and sand are extracted (mined) from the river beds of Rapati Khola, Karra Khola, Samari Khola. All these materials are used as construction materials mostly in Hetauda and nearby areas.

Rapati River, Karra Khola and Samari Khola are the only perennial river in the area. They contain enough water throughout the year. Kukhreni Khola also has very less amount of water during the dry season. As far as the ground water is concerned, it occurs in the pebbly, coarse (or gravelly) sand layers and the level of water is found to be in between 0.30 m to 3.10 m depths from the ground surface. Ground water is used in drinking as well as for irrigation purposes.

Land use

Various types of landuses such as agriculture, forests, settlements, industrial, and recreation centers (like public parks) and landfill / waste disposal sites exist in the study area. The valley consists mainly of cultivated land where rice and wheat are grown. Forestlands with sal trees are found in the surrounding Churia hills.

RIVER BED MINING AND EXPORT OF BOULDER AND GRAVEL

Sand gravels and boulders in Rapati River banks are extensively mined and used as construction material for various purposes. They are also exported to nearby border town in India. The amount of gravel extracted each year is replenished by the deposition of fresh sediments during flood in monsoon season. According to the local people, the gravel supplied by the river has decreased considerably in the last 10 years. But in reality the riverbed mining has caused the positive effect to minimize the flooding risk along the riversides.

RESULTS AND FINDINGS

Engineering and Environmental geological map (scale 1: 25,000) covering 100 Km^2 area in Hetauda and surrounding area is prepared. The map includes almost all the information regarding geology, engineering properties of rock, soil, hazard risk areas, mineral resources, sites, landuse pattern, existing and proposed landfill sites, forest cover areas etc. Therefore, this type of map is very much useful for planning at local level (municipality and adjoining village development committees) as it contains various geoscientific information that are necessary to the planners, decision makers, engineers, civil technicians and other users. It can be used for land use planning, mining and excavation of construction materials, identify hazardous areas, selection for waste disposal sites, urban and regional development planning, environmental protection and disaster management. However, the detailed site investigation is always required for specific engineering design and construction projects.

CONCLUSION AND RECOMMENDATION

Conclusion

- The study area is a dun valley bounded by Siwalik hills to the north as well as to the south.
- Sedimentary deposits of up to 10m depths were investigated. They are divided into 10 soil units based on their lithological characteristics and SPT values.
- Flood plain deposit often provides an excellent source of building and construction materials like boulders, gravels and sand. They could be properly mined/quarried for various construction works.
- River gravels (a renewable natural resource) of Rapati Rivers are extensively mined for construction material. They are mainly used locally and to some extent they are also exported to India.
- Lineaments observed on the satellite image were not identified in the field as tectonic faults but areas closer to these features should be regarded as weak zones.
- Areas with fine – grained sand and silt along with shallow groundwater level are prone to liquefaction.

RECOMMENDATION

- Mining of construction materials needs to be carried out with proper planning from safe sites such as away from bridge sites, river banks and other structures of public concerns.
- Sustainable mining and use of natural resources such as clay, sand, gravel boulders etc. is recommended under proper technical guidance. Over extraction should be prohibited.
- Existing waste disposal sites should be closed and look for a new site away from the settlement areas, forests, river valleys, drinking water sources, roadside etc. The waste disposal site should be properly managed as sanitary landfill site.
- Flood and landslide prone areas and other areas prone to natural hazards must be avoided while planning new settlement areas and infrastructure development activities.
- Maintain a buffer zone of 15–20 m. on either side of the riverbanks to protect riverbank erosion, infrastructures, settlement, agricultural land etc.
- The data provided in the report are not site specific and therefore should not be generalized for planning and design of large structures. Detailed site specific investigations are required for designing large and important structures.
- It is recommended to follow proper land use pattern in Hetauda Municipality and surrounding area to agree with the engineering geological properties of the soil obtained from present study as far as practicable.
- Part of Sanapokhara (ward 6) area lies in very soft ground condition (as shown in the map as highly susceptible to subsidence) where construction activity should not be allowed.
- Location of a suitable solid waste disposal site is possible in the area occupied either by lacustrine soil (Chihandanda Formation) or in the area of red soil (Padampokhari Formation).
- Carbon dating of some of the samples obtained from lacustrine deposit is recommended to know the time of the sediment deposit and to correlate it with other lacustrine deposits of the country.
- It is recommended to carry out specific site investigation for specific structure before construction of any heavy structures just to make the structures safe.

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Geology of Dharan - Bhedetar Section of Dharan – Dhankuta Road, Eastern Nepal

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INTRODUCTION

This field investigation was carried out in accordance with the annual field programme of Petroleum Exploration Promotion Project, Department of Mines and Geology for the fiscal year 2061/62. The field programme was scheduled to carry out Geological investigation in this area and prepare a measured geological section of Dharan – Bhedetar, a part of Dharan – Dhankuta road and adjacent areas in Eastern Nepal. During field investigation 20 line kilometer section measurement work along the Dharan - Bhedetar road section was completed.

The study area is a part of Sunsari district and lies in between 26° 48' 00" to 26° 51' 50" N latitudes and 87° 16' 15" to 87° 20' 00" E longitudes. It lies in the toposheet no. 2687 - 02C, published by the Survey Department, HMG Nepal. All the field investigation data were plotted on a 1:25,000 scale topomap.

Different Nepalese geologists have studied the area in connection with the regional geological mapping as well as mineral exploration. Tater (1968) visited the area in connection with geological mapping and preliminary investigation of phosphorite. He believed that Sanguri Formation is the oldest formation of Midland Group in this area. Singh (1970) mapped some of the area during the investigation of phosphorite in Barahakshetra – Dharan area. Kayastha, (1971) mapped the area in connection with the tracing of Phosphorite bearing horizon. Tshering (1971) prepared a geological map of phosphorite horizon of Barahakshetra – Dharan area. Similarly, Bashyal (1973) visited the Barahakshetra – Takure area to prepare a report on the geology of phosphorite and rocks exposed in Barahakshetra area had been named as Barakshetra Formation of the Gondwana Group. Kaphle (1976) studied the area to prepare a geological report on drilling of phosphorite horizons in Barahakshetra area. Subedi and KC, (1995) studied the area in connection with geological section measurement and Petrogeochemical sampling.

OBJECTIVE

The main objectives of the present investigation were:

- to prepare a Geological map and section of Dharan – Bhedetar road section
- to collect the Petrogeochemical samples from the shale horizons of Charchare Formation as well as Lower and Middle Siwalik Formations
- to identify the potential source rocks for hydrocarbon generation

FIELD INVESTIGATION

Methodology

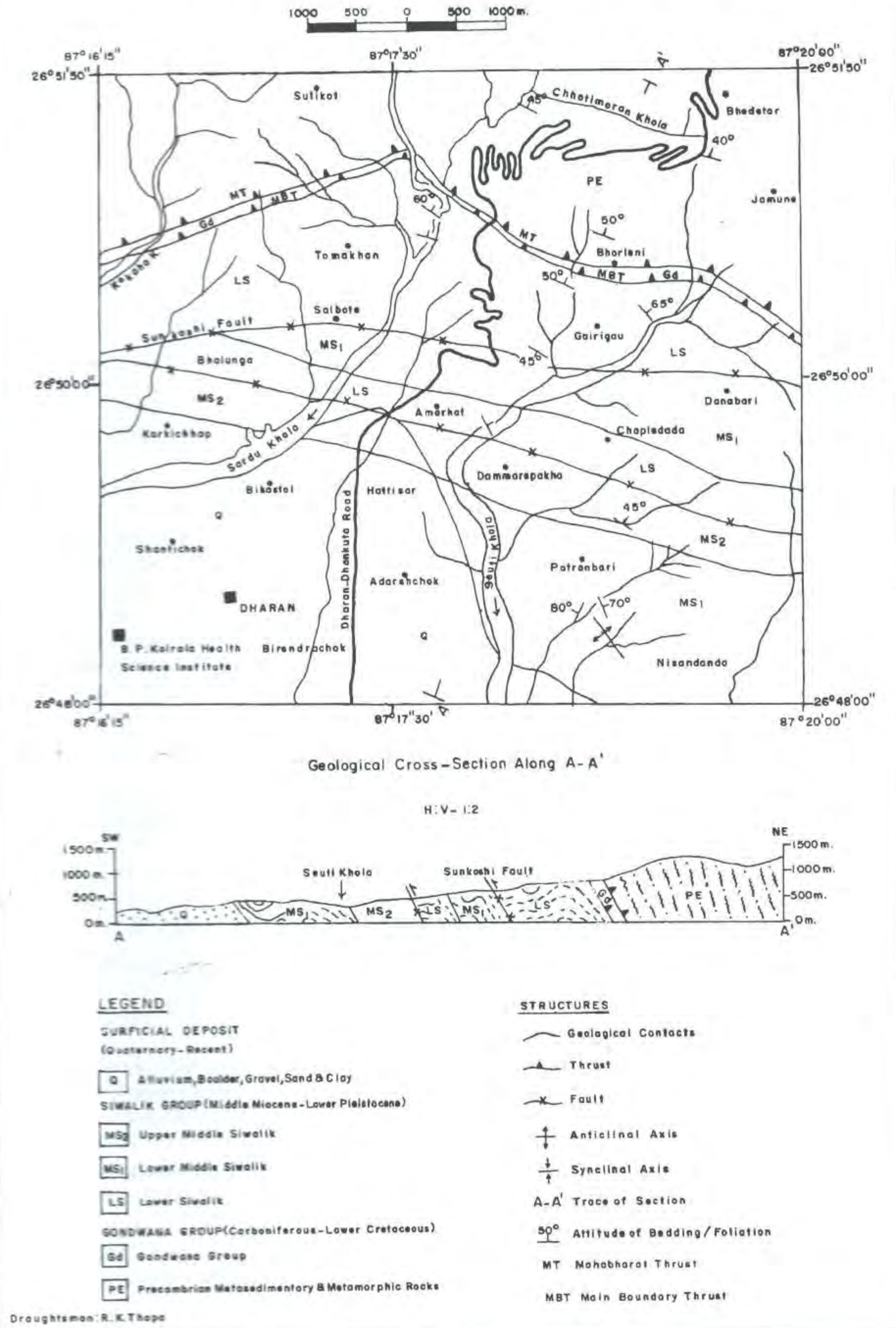
Geological mapping and section measurement was carried out using a topographic base map of 1: 25,000 scale. Traverses were made along the Dharan - Bhedetar section of Dharan – Dhankuta road and adjacent accessible areas. Lithological units and structural features were identified on the basis of field observations. 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 types in the formation to understand the source, seal and reservoir character of all the rock types. 10 rock samples were collected from the shale horizon of Gondwana Group for the hydrocarbon analysis. Out of ten samples collected from different outcrops for source, seal and reservoir analysis, only two selected samples were sent to Cairn Energy PLC head office in Edinburgh, UK for hydrocarbon analysis. Analytical results of these samples are awaited.

GEOLOGY

Presently investigated area is represented by sedimentary, metasedimentary and metamorphic rocks belonging to Siwalik Group, Gondwana Group and Midland Group. The rocks of Siwalik Group constitute the foot hills of Churia Range (the Sub Himalaya). Mahabharat Range or the Lesser Himalaya constitutes the Pre–Siwalik rocks (Fig.1) like dolomite, quartzite, phyllite, basic rock intrusions etc.

The rocks of Midland Group are observed in the northern part of the mapped area. The rocks of the Midland Group are thrusted over the rocks of Gondwana Group along the Mahabharat Thrust (MT). The oldest rock of Midland Group, exposed in the study area is Sanguri Formation that consists of white, massive quartzite talcosic phyllite, gritty phyllite interbedded with gritty quartzite, siliceous dolomite and argillaceous limestone. The dark grey slaty

Fig.1 Geological Map of Dharan–Bhedetar Area



phyllites are profusely impregnated with quartz lenses and veins along the foliation plane. The siliceous dolomite and argillaceous limestone are also interlayered within the phyllites and quartzites.

The rock unit of Gondwana Group exposed in the study area is Barahakshetra Formation. It is represented by shale, diamictite, conglomerate, quartzitic sandstone, siltstone and coal. The rocks exposed in the study area do not show uniform thickness throughout the area, rather it shows swelling and pinching character.

The youngest rocks exposed in the study area are the rocks of Siwalik Group. This Group has been classified into Lower Siwalik (LS), Middle Siwalik (MS) and Upper Siwalik (US). Further the rocks of Middle Siwalik have been subdivided into two units as Lower Middle Siwalik (MS1) and Upper Middle Siwalik (MS2). The rocks of Siwalik Group are mainly sandstones, mudstones, shale, claystones, pebbly sandstones, siltstones and conglomerates.

In the investigated area general strike of the formation is NW-SE, which is parallel to the general trend of the mountain chain and dip towards north- west. At places the dip of the bed shows south westerly due to folding. There are few major and minor folds and faults. Based on these structures, the area can be divided into the following Tectonic unit.

- The Upper Tertiary sediment in the southern foot hills is overriding the rocks of Siwalik Group.
- The Para–autochthon comprising of sedimentary and metasedimentary rocks of the Gondwana Group are overthrusted along the Main Boundary Thrust (MBT);
- The allochthon comprising of metamorphic rocks of Sanguri Formation of Metamorphic Group are thrusted over the Para-autochthon Gondwana Group along the Mahabharat Thrust (MT);

The Sunkoshi fault causes the repetition of Siwalik Group throughout the study area. Besides these major structures, there are a number of fault and fold structures, which causes the repetition and shifting of the formation (Fig 1).

FINDINGS/CONCLUSION

Detailed geological section (20 line km) measurement work was completed. The thickness of the sedimentary & meta sedimentary rock formations exposed along the Dharan – Bhedetar section of Dharan – Dhankuta road was established. 10 Petrogeochemical samples were collected from the shale horizon of Gondwana Group to evaluate source potential for hydrocarbon generation. The shale samples from the Lower Siwalik Formation (LS) were also collected for maturity test and possible source and seal rocks analysis. The rock samples from Middle Siwalik were collected to evaluate the possible reservoir rocks analysis.

Out of ten, however, only two shale samples were sent to Cairn Energy PLC Head Office (Edinburgh, UK) for geochemical analysis. Analytical results of all the samples are awaited.

RECOMMENDATION

- Detailed geological mapping and geochemical sampling covering large area should be carried out to evaluate the thickness, position and location of the Godwana Group.
- Detail geochemical analysis should be carried out to identify the source, seal and reservoir potential for the rock samples collected from Gondwana Group as well as Siwalik Group.

ACKNOWLEDGEMENT

The authors are grateful to Mr. B. M . Jnawali, Former Petroleum Exploration Promotion Project Chief for providing necessary facilities to conduct the field work. We would also like to thanks Dr. R.B. Shrestha (Project Chief PEPP) and Mr. K.P. Kaphle, Superintendent Geologist DMG for going through the manuscripts and valuable suggestions.

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Geological Section Along Saptakoshi from Chatara to Barahakshetra Area, Eastern Nepal

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INTRODUCTION

The investigated area falls in the Toposheet No. 2687 01B and 2687 01D published by the Survey Department, HMG Nepal. According to the annual field program of Petroleum Exploration Promotion Project (PEPP)/ Department of Mines and Geology (DMG) for the fiscal year 2061/62 twenty line km geological section measurement work was carried out along the Saptakoshi River from Chatara to Barahakshetra in some parts of Sunsari and Dhankuta Districts, Eastern Nepal. In this connection ten rock samples were collected for petrogeochemical analysis from the shale horizon of Charchare Formation of Gondawana Group which is the potential source rock. Out of 10 samples only 4 samples weresenttoEdinburgh, UK for petrogeochemical analysis. Results of the analysis of all the samples are awaited.

OBJECTIVE

The main objective of the present study is:

- to prepare geological map and carryout geological section measurement of the investigated area
- to collect the petrogeochemical samples from the shale horizon, (Gondwana Group) for source rock potential.

FIELD INVESTIGATION

Methodology

- Topography base map of 1:25,000 scales (Toposheet No.268701B and 268701D) was used in the mapping. Traverses were made along the accessible stream and Chatara road – Barahakshetra road section. Different lithological units and structural features are identified on the basis of field observations.
- Ten petrogeochemical samples were collected from Charchare Formation of Gondwana Group and Siwalik Group.
- Compass and tape survey method (compass, measuring tape, hammer, chisel and altimeter) were used to measure the geological section and collect the rock samples.

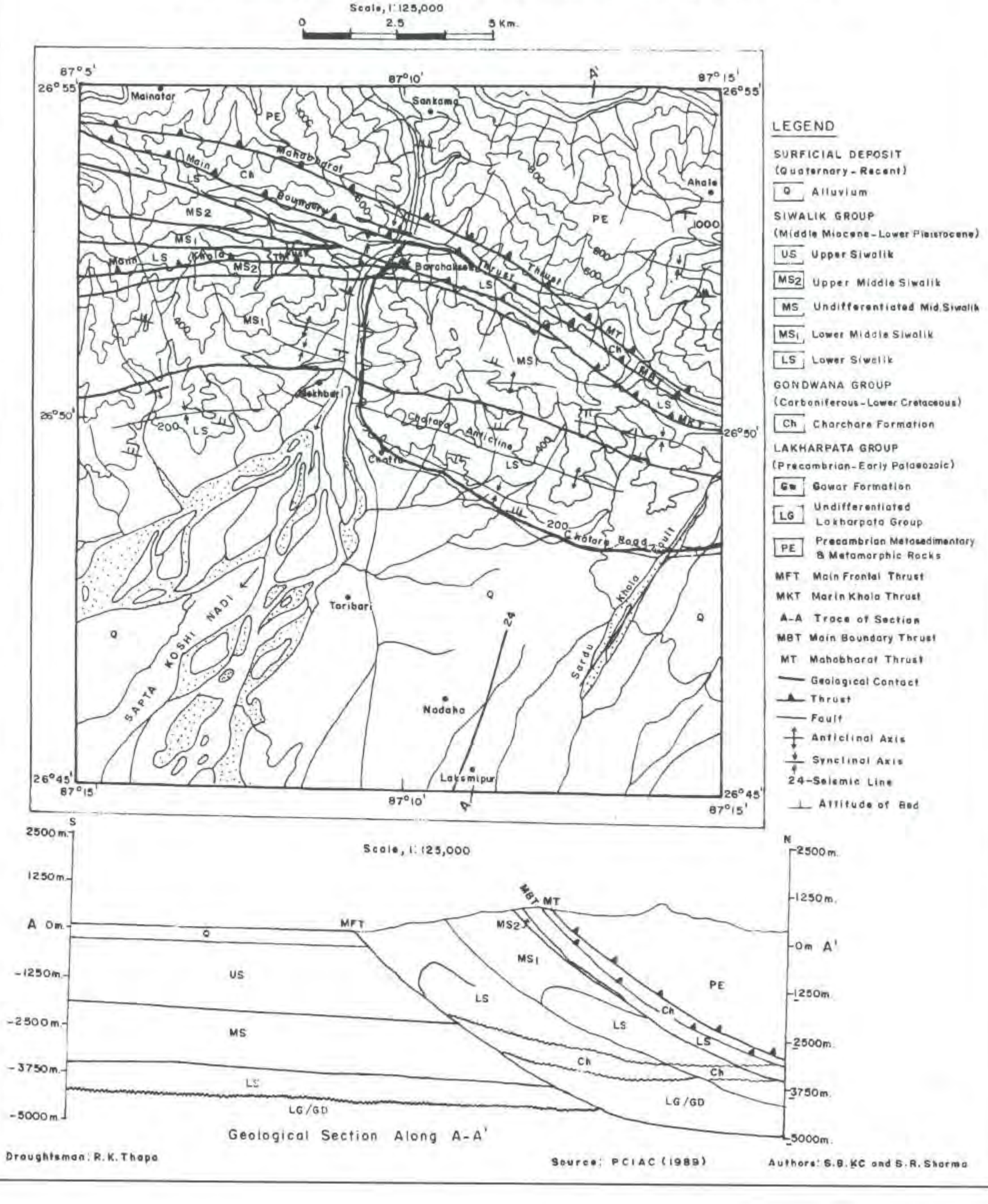
GEOLOGY OF THE AREA

The study area comprised of sedimentary, metasedimentary and metamorphic rocks which can be divided into five different tectonic units as the Terai Quaternary Sediments, Siwalik Group (Middle Miocene-Lower Pleistocene), Gondwana Group (Lower Carboniferous - Lower Cretaceous, Pradhan et al 1998), Lakharpata Group (Precambrian to early Paleozoic, Kayastha, 1971) and Metamorphic rock (Precambrian, Tater, 1968). The study area belongs to the northern part of Petroleum Exploration Block- 9, Rajbiraj.

Terai Alluvial plain is the northern fringe of Indo-Gangatic Plain. It is underlain by flat lying sequence of molasse sediments. It consists of boulders, gravels and pebbles. These sediments have been deposited by the river.

The Siwalik Group has been classified into Lower Siwalik (LS), Middle Siwalik (MS) and Upper Siwalik (US). The Middle Siwalik Formation is further subdivided into Lower Middle Siwalik (MS1) and Upper Middle Siwalik (MS2). The Siwalik Group (Middle Miocene-Lower Pleistocene) is composed of sandstone, mudstone, siltstone, shale, clay and conglomerate. The Lower Siwalik Formation consists of fine to medium grained light grey to grey sandstone, grey quartzitic sandstone, maroon nodular clay and reddish brown marl. Lower Middle Siwalik (MS1) consists of sandstone, mudstone, claystone, siltstone and shale. Sandstone of Lower Middle Siwalik (MS1) is light grey to grey, fine to medium grained, less friable and well bedded. The upper Middle Siwalik (MS2) is mainly composed of grey to brownish grey arkosic sandstone, pebbly sandstone and claystone. The autochthon Siwalik Group is bounded to the north by Main Boundary Thrust (MBT) and to the south by Main Frontal Thrust (MFT) followed by Quaternary sediment. The sandstone of Siwalik Group is medium grained, porous, permeable and could be reservoir potential for hydrocarbon accumulation. An anticline observed in the southern part of the study area, named as Chatara anticline (Fig.1) is also observed in the subsurface and it could be the structural trap for hydrocarbon accumulation.

Fig. 1 Geological Map of A Part of Chatra–Barahakshetra Area



The Charchare Formation of Gondwana Group consists of shale, siltstone, quartzite and diamictite. The Kokaha diamictite (Bashyal, 1973) from Barahakshetra area (presently studied area) is underlain by coal bearing quartzite and conglomerate. The Charchare Formation overlies grey dolomite with a disconformity.

The Gawar Formation of Lakharpata Group is well exposed in the north of Main Boundary Thrust (MBT). It is mainly composed of dolomite, limestone and shale. Dolomites are gray well bedded and fractured. The para-autochthon comprising of metasedimentary rocks of the Lakharpata Group is overthrusted along the Main Boundary Thrust (Kaphle, 1976).

The low grade Pre-Cambrian metamorphic rocks are exposed to the north of Gondwana Group. They are represented by grey and green phyllite, quartzite and amphibolite. Mahabharat Thrust (MT) demarcates the boundary between Gondwana Group and the overlying low grade metamorphic rocks. This longitudinal thrust sheet is oriented from NW to SE direction.

FINDINGS/CONCLUSION

Geological section measurement and petrogeochemical sampling in Chatra – Barahakshetra area were carried out in the sedimentary and metasedimentary rocks belonging to Siwalik Group and Gondwana Group. The sedimentary rocks of Siwalik Group are concealed under the thick alluvium deposits in the south and separated from the rocks of Lesser Himalaya to the north by Main Boundary Thrust (MBT). The metasedimentary rock is bounded by the MBT to the south and the Mahabharat Thrust (MT) to the north.

Ten rock samples were collected from the Charchare Formation of Gondwana Group for the source rock analysis. The lower coal bearing horizon of Charchare Formation of Gondwana Group could be the both source rock as well as reservoir rock for natural gas, where as the marine Upper Gondwana Group could be potential for a source rock for oil. The equivalent similar formations are producing hydrocarbon since long time in Assam field (India) in the east and Potwar field (Pakistan) in the west.

The petrogeochemical samples collected during field investigation were sent to Edinburgh, UK for the source rock for analysis. The results are awaited.

RECOMMENDATIONS

- Detail sampling work in the area should be carried out if the geochemical analysis result of the previous samples appear interesting with respect to hydrocarbon content.
- Further follow up investigation is recommended in order to evaluate the potential of source, reservoir and seal rocks of Gondwana, Lakharpata and Siwalik Group.
- 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 Groups.

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The authors are grateful to Dr. R.B. Shrestha, Project Chief, PEPP for his valuable suggestion in preparing the paper. The authors also would like to thank Mr. B. M. Jnawali (Former Project Chief, PEPP) for providing logistic supports to complete the field work. The authors also wish their sincere thanks to Mr. K. P. Kaphle, Superintendent Geologist, DMG, for his valuble suggestion and editing the paper.

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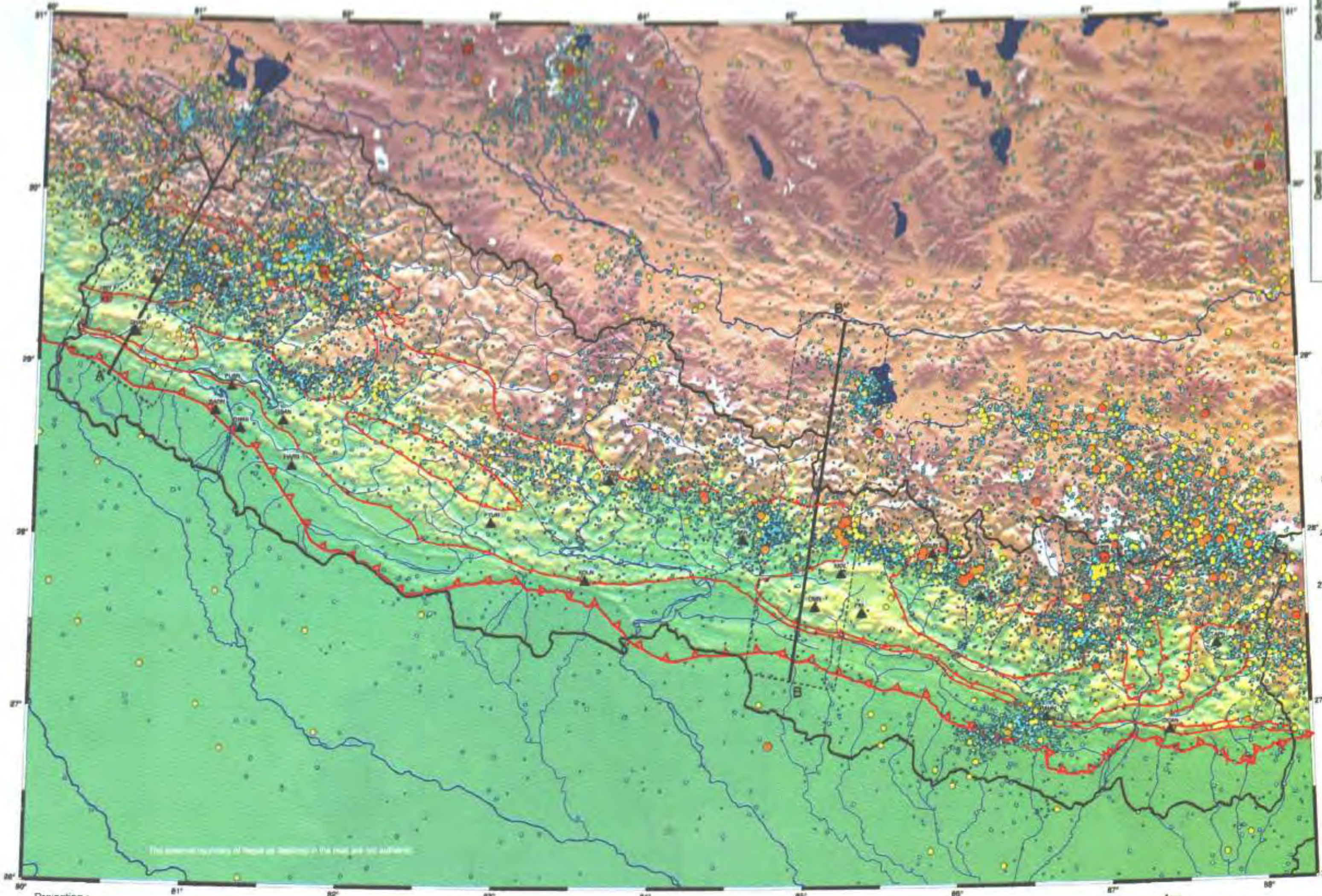
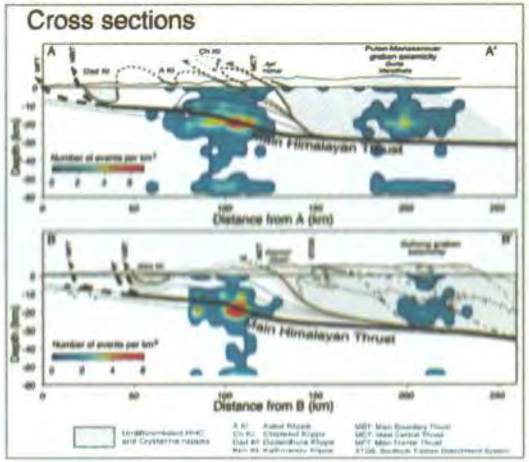
EPICENTRE MAP OF NEPAL HIMALAYA
1994-2005



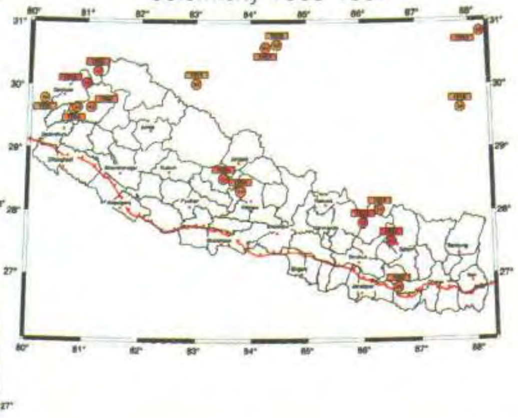
Projection :
Lambert conformal conic; Central longitude: 84°E; Standard parallels: 28°20'N and 38°40'N

km 0 50 100

Cross sections



Historical and early instrumental seismicity 1833-1994



Earthquake magnitude

size and color are proportional to local magnitude (M_L)

- Earthquake magnitude greater than 6 (M_L)
- Earthquake magnitude 5 to 6 (M_L)
- Earthquake magnitude 4 to 5 (M_L)

Seismic alert

NSC/DMG alert threshold

- Earthquake magnitude 3 to 4 (M_L)
- Earthquake magnitude 2 to 3 (M_L)

Altitude

(m) 8000 7000 6000 5000 4000 3000 2000 1000 0

Epicentres were computed by LDG-ISIS program and LDG-ONYX program with three layers local velocity model:

Vp Km/s	Vs Km/s	Thickness Km
5.6	3.2	23
6.5	3.7	32
8.1	4.6	–

Microseismic data were acquired under Nepal-France Cooperation.
Personnels participating in data acquisition processing and interpretation:

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GIS Data processed by
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References:

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Historical and instrumental earthquakes: ISC, SSB China, DMG
Geological Structures: Digitalised or interpreted and generalised from Geological Map of Nepal (1994) Compiled by K.M. Amatya and B.M. Jnawali
Digital elevation model: SRTM-Gtopo30

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