A GUIDE BOOK ON GEOLOGICAL SECTION OF MECHI HIGHWAY (CHARALI- ILAM- PHIDIM ROAD), EASTERN NEPAL

Government of Nepal
Ministry of Industry
Department of Mines and Geology
Lainchaur, Kathmandu, Nepal
July, 2010

Faulting across the fold axis

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PREFACE

This guide book is intended for the use of geo-scientists, engineers and students. At the same time, it is hoped that this guide book will be beneficial to tourists, trekkers and people of different walk of life, who would like to enjoy exploring nature including geology. One can enjoy the science, natural beauty and at the same time keep himself aware of his location along the road by the locality name and distance peg in every 5 km of the road in the map. This guide book is expected to guide the road to any body with some knowledge on geology or geography. It is the proposed programme of the Department of Mines and Geology (DMG) to provide information on geological, geomorphological, natural hazard aspects and development infrastructures around major highways of Nepal. As a part of the annual program for the fiscal year 2009-10AD, DMG is publishing this guide book on Mechi Highway (Charali-Ilam-Phidim road). The department had already published four such guide books, viz. I. Geological Section along Arniko Highway (Kathmandu-Kodari road), Central Nepal in June 2006, II.Geological Section of Siddhartha Highway (Butwal-Pokhara road), Western Nepal in June 2007, III. Geological Section of Bhupi Sherchan Highway (Pokhara-Beni road), Western Nepal in June 2008 and IV. Geological Section of Bhanubhakta Acharya Marg (Dumre-Besi Shahar road), Western Nepal in July 2009.

The guide book, along with the geological section has been prepared on the basis of field study, existing topographic maps, geological reports and maps of the area. This guide book contains general geological information about Nepal Himalaya and information on geology, geomorphology and natural hazards along the road section. Typical outcrops of geological formations, geological structures and natural hazards like landslides as well as other spots of general interest are described with photographs. Other information of socio-cultural aspects like location of hotel facilities, hospitals, petrol pumps etc are also shown in the map.

The area lies in Indian topo-sheet no 72M/16, 72N/13, 78B/1 and 78B/2 (1" = 1mile) and sheet numbers: 2787 16A, 2787 16C, 2687 04A, 2687 04B, 2687 04D, 2688 01C, 2688 01A, and 2688 05A-1:25000 scale topographic maps published by Survey Department, Nepal Government. The area extends from 26° 39' 06"N and 88° 03' 50"E at Charali in Jhapa district to 27° 08' 53"N and 87° 46' 10" E at Phidim in Panchthar district. The study area covers Jhapa, Ilam and Panchthar districts. The road from Charali to Phidim is black topped road. Except northern part, rest of the road is relatively stable but in northern part, there are number of landslides and creeps. In this road section, hotel facilities are available at Charali, Budhabare, Phikkal Bazar, Ilam Bazar, Kutidanda, Harkate and Phidim Bazar.

During March-April in 2009, field work of 5 week duration was carried out to prepare this geological section along Charali-Ilam- Phidim Road (Mechi Rajmarga) section. The field team carried out geological section study of Mechi Rajmarga, from Charali in south to Phidim in north. The field study was concentrated mainly along the road and its surrounding areas. Detailed studies of selected spots were carried out along with photographs. These spots included geological formations, geological structures, geomorphological structures and major development structures etc.

Charali-Ilam-Phidim Road starts from Charali, 575km east of Kathmandu. Charali lies in the East-West Highway and it is the junction between the north-south oriented Mechi Rajmarga with east-west oriented Mahendra Rajmarga. The road passes through the flat alluvial deposit of Terai from Charali in south to Hadiya Khola in the north. From Charali in south to Chihandanda in north, as the road passes through almost flat land, it has an almost straight north-south orientation. From Chihandanda towards north, the road passes through mountainous region and the road has meandering shape, climbing up or down slope of the hill. In general, the road has north-south orientation in northern and southern part and east-west orientation in the middle part. The minimum height of the road is at Charali, where the altitude is 133m above mean sea level and maximum height is 2500m at Pauwabhanjyang at northern part of the road section. Bus service is available from Charali to Phidim and further north to Taplejung.

Tea is produced at many places of Jhapa, Ilam and Panchthar districts. In this road section, two major tea estates, i.e. Berne tea estate in Jhapa and Kanyam tea estate in Ilam are present. In Jhapa district, coconut and betel nuts have been widely planted as cash crops. In Ilam, beside tea, black cardamom, amriso and ginger are also widely grown as cash crops. Economically Mechi Highway is one of the very important north-south road of Nepal. Agricultural products of Ilam and Panchthar like tea, cardamom, amriso, and ginger are transported to Charali at East-West Highway. From there, they are carried to different parts of Nepal as well as they are exported to India and third countries. These agricultural products of the area are contributing in the country's economy by earning foreign currency.

The author believes that the book will be very much useful and beneficial in further engineering development activities along the road corridor and adjacent areas. It will also help in the tourism development of the area

1. GENERAL GEOLOGY OF NEPAL

Nepal lies in the central part of the greater Himalayan Range. Geologically, Nepal Himalaya has been divided into five distinct morpho-geotectonic zones, which also correspond roughly to the geographical division of the country. These morpho-geotectonic zones are separated by different tectonic structures. The South Tibetan Detachment Fault System (STDFS), the Main Central Thrust (MCT), the Main Boundary Thrust (MBT) and the Main Frontal Thrust (MFT) from north to south are the major tectonic structures that divide the Himalayas. All these structures dip toward north. The Main Central Thrust (MCT), the Main Boundary Thrust (MBT) and the Main Frontal Thrust (MFT) are thrust faults but the South Tibetan Detachment Fault System (STDFS) is a normal fault. At present MFT is the most active structure of the Himalaya. MCT was initiated around 25 million years ago and was active until 15 million years ago. (Harrison et al., 1998). These structures divide the Himalaya into five major geological zones. From south to north they are: 1. Terai or Indo-Gangetic plain, 2. Siwalik (Sub Himalaya), 3. Lesser Himalaya, 4. Higher Himalaya and 5. Tibetan Tethys Zone (Figure 1).

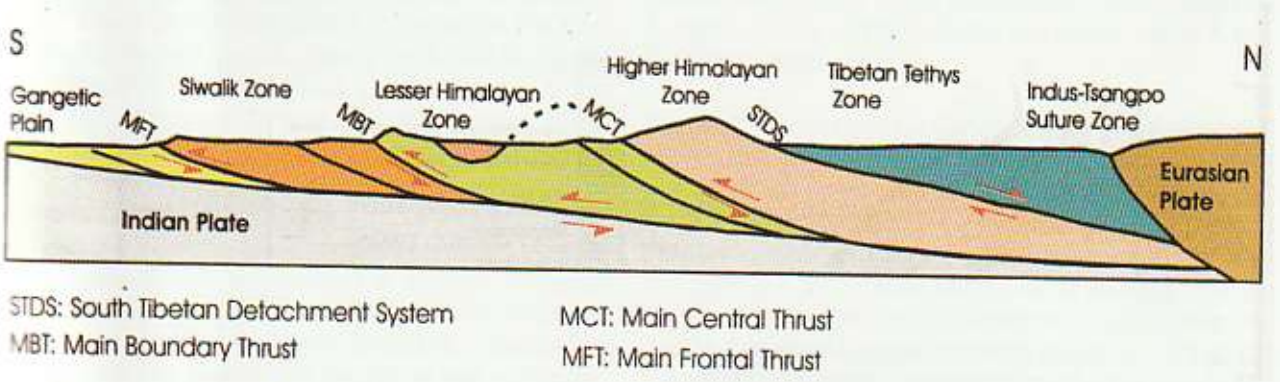

Figure1: A schematic geological cross section of the Himalaya (Upreti and others 2005).

The Terai (Indo - Gangetic Plain)

It is the northern fringe of Indo-Gangetic plain, which lies to the south of the Siwalik foot hills. It is composed of Quaternary alluvial deposits, which are consisted of gravel, sand, silt and clay. It is believed that the Terai is slightly tilted (2^0-5^0) towards south and south west. Total thickness of the sediments varies from 500 to 2500m.

Siwalik (Sub-Himalaya)

Siwalik range forms the southern most mountain range of the Himalaya. It is bounded to the south by the Main Frontal Thrust and to the north by the Main Boundary Thrust. It is consisted of Neogene to Quaternary fluvial sedimentary rocks such as shale, claystone, mudstone, sandstone and conglomerate. In general, coarsening upward sequence is the characteristic of the rocks of the Siwalik Group. It is divided into three units: Lower, Middle and Upper Siwalik Formation.

Lesser Himalaya

The Lesser Himalaya is bounded to the south by the Main Boundary Thrust (MBT) and to the north by the Main Central Thrust. In contrast to unmetamorphosed Siwalik rocks in south and high grade metamorphic rocks in the north, the Lesser Himalaya is composed mainly of low grade metamorphic rocks such as limestones, dolomites, slates, phyllites and quartzites. Stromatolites are the only known fossil evidences in the rocks of the Lesser Himalaya and age of these rocks is assumed to be Pre-Cambrian to Early Paleozoic. But at some places, such as Tansen area and Phulchauki area, these Lesser Himalayan rocks are unconformably overlain by fossiliferous younger rocks of Permo-Carboniferous to Miocene age.

The Higher Himalaya

The Higher Himalaya lies between the Main Central Thrust to the south and South Tibetan Detachment Fault System to the north. The Higher Himalaya is composed of high grade metamorphic rocks, which include various kinds of gneisses, schists, migmatites, quartzites and marbles. Rocks of the Higher Himalaya form the basement of the Tibetan –Tethys Sedimentary Sequence.

The Tethys Zone (The Inner Himalaya)

This zone is bounded by the South Tibetan Detachment Fault System (STDFS) to the south and the Indus-Tsangpo Suture Zone (ITSZ) to the north which is exposed beyond the Nepal border in Tibetan Plateau. The ITSZ marks the boundary between the Indian and Eurasian Plates. This zone is consisted of weakly metamorphosed to non metamorphosed sedimentary rocks such as limestone, sandstone and shales. Fossil evidences show that their age ranges from Cambrian to middle Cretaceous (Colchen and others, 1986). The rocks are considered to have been deposited in the Tethys Sea on a part of the north Indian Continental Margin (Liu and Einsele, 1994).

2. GEOLOGY, GEOMORPHOLOGY AND NATURAL HAZARDS OF THE AREA

2.1 Geology

This stretch of the road section has been worked by different geologists. R.N Yadav (1978) prepared geological map of southern part of the road section from Terai in south to Phikal in north. Kayastha (1983) prepared geological map of the area from southern part of Ilam to Rakse in north. Shrestha and others (1984) compiled geological map of Eastern Nepal. Similarly Duvadi and Rimal (2000) prepared geological map of the area from Ilam in south to Phidim in north. Also Pradhan and others (2006) compiled geological map of petroleum exploration block – 10, Biratnagar, Eastern Nepal.

The rocks occurring in Charali-Ilam-Phidim Highway, that is Mechi Rajmarg section can be grouped into Sedimentary Group, Meta-sedimentary Group and High grade Metamorphic Complex.

The Sedimentary Group is consisted of Siwalik Group. Rocks of the Siwalik Group occur in the southern part of the road section. Along this road section, Lower Middle Siwalik, Upper Middle Siwalik and upper Siwalik Formations are present, whereas Lower Siwalik Formation is not present in this road section. But the outcrops of Lower Middle Siwalik, Upper Middle Siwalik and Upper Siwalik are not exposed in the road section as they are covered by alluvial deposits, which can be extrapolated by the presence of those rocks exposed in the adjoining areas. Lower Middle Siwalik is consisted of fine to medium grained sandstone with interbeds of siltstone and mudstone. Coaly materials and plant fossils are present. Upper Middle Siwalik is consisted of medium to coarse grained sandstone, pebbly sandstone with siltstone, mudstone and relicts of sandstone. Upper Siwalik is consisted of conglomerate with subordinate sandstone and mudstone.

Metasedimentary Group in this area is consisted of rocks of Seti Formation, which is equivalent to Kunchha Formation of Lower Nawakot Group in Central Nepal. It is consisted of fine to medium grained, medium to thick bedded, light grey, dark greenish grey to dark grey, chloritic phyllite, gritty phyllite, siliceous phyllite and quartzites. In this area, due to the presence of two fault zones, that is, MBT in south and MCT in north, feldspars and biotites are also developed in the green chlorite schist resulting into feldspathic biotite schist and chlorite-biotite schist.

Rocks of the Metamorphic Complex can be grouped into Himal Group and Kathmandu Group. Kathmandu Group is equivalent to the Bhimphedi Group of Kathmandu Complex in Central Nepal (Stocklin,J. and Bhattarai, K.D., 1977). Himal Group is consisted of Himal Formation, which is consisted of two mica gneisses, muscovite-biotite schists, garnetiferous schists, crystalline quartzites, marbles, kyanite bearing gneisses and schists, granitic gneisses, migmatites and granites. Kathmandu Group is consisted of Shiprin Khola Formation and Sarung Khola Formation. Shiprin Khola Formation is consisted of coarse textured garnetiferous muscovite-biotite schists, calc-silicates, chlorite-muscovite schists, kyanite gneisses and schists and meta- basic rocks. Sarung Khola Formation is consisted of fine textured dark grey to greenish grey biotite schists, quartz-feldspar biotite schists, garnetiferous schists, kyanite gneisses and schists, augen gneisses, quartzites, calc silicates, marbles and intrusion of pegmatite and granite.

The augen gneisses, occurring in Sarung Khola Formation, are dark grey to milky white in color and contain bands of dark grey to black biotite feldspathic schists. Within the same formation, the mineral grains of feldspar, biotite, and quartz are fine grained in schist but they are medium to coarse grained in gneiss outcrop. The augens of white feldspar are about 1cm to 7cm wide and up to 20cm long. Black biotite micas occurring near augen structures are up to 2cm wide. At places, coarse crystalline biotite rich bands of 30 to 40cm thick are present.

The granite occurring in this Sarung Khola Formation is milky white to dark grey, salt and pepper textured, medium grained with 0.1mm brown garnets (few) and plenty of 0.1 to 0.6cm long black tourmalines. The granite, at places, contains bands of xenoliths of dark grey to black gneisses and schists. The granite is found to be composed of feldspar, quartz, black tourmaline and garnet. Only some mica is seen in the granite. One granite outcrop occurring at spot no. 12 is about 15m wide and is locally exploited for construction aggregate.

2.2 Geomorphology

Charali-Ilam-Phidim Road starts from Charali about 575km east of Kathmandu. Charali lies in the East-West Highway and it is the junction between the north-south oriented Mechi Rajmarga with east-west oriented Mahendra Rajmarga. The road passes through the flat alluvial deposit of Terai from Charali in south to Hadiya Khola in the north. In this sector, the road ascends only 64m at a distance of 9km toward north from Charali. The road has a short visible ascend at Hattistude for few hundred meter distance. Then again the road follows gently sloping flat alluvial terrace up to south of Chihandanda. From Charali in south to Chihandanda in north, as the road passes through almost flat land, it has an almost straight north-south orientation. From Chihandanda towards north, the road passes through mountainous region

and the road has meandering shape, climbing up or down slope of the hill. In general, the road has north-south orientation in northern section and southern section and east-west orientation in the middle section of the road. The minimum height of the road is at Charali, where the altitude is 133m above mean sea level (msl) and maximum height is 2500m at Pauwabhanjyang, which lies at northern part of the road section. From Kutidanda, the road follows the ridge climbing up to 1700m around Aitabare, then the road climbs down to Mai Khola, just south of Ilam. Mai Khola is at an altitude of 460m above msl. From Mai Khola, the road again climbs up the hill slope of Ilam, it climbs up to 1400m at Madreni and again climbs down to Puwa Khola, which is situated at an altitude of 1200m above msl. From Puwa Khola, the road again climbs up following the ridge up to Pauwabhanjyang at 2500m. Just south of Pauwabhanjyang, the road crosses small stream Nibhu Khola. From Pauwabhanjyang, the road starts climbing down towards Phidim. Phidim is at an altitude of 1170m above mean sea level.

2.3 Natural Hazards

The section of the road, passing through flat alluvial terraces from Charali in south to Chihandanda in north, lies in less hazardous zone. Portion of the road passing through tea estates are also generally stable, though they pass through sloping terrain; the roots of the tea are contributing in protecting the slopes. In Ilam district and parts of Panchthar district, actually, most of the hill slopes are stabilized by natural and cash crop plants. Many parts of the slopes are found to be covered by green tea plants and those not covered by tea plants are either covered by cardamom plants or amriso plants, which are also major cash crops of the region.

Some landslides are noted in northern part of the road section. Some of them are caused by natural phenomena like deep weathering of rocks like gneisses and granites, folding and faulting of rocks. Some of these landslides are triggered by men's intervention in nature like road cutting in steep slopes, road cutting in old dormant landslide and road cutting in scree deposit etc. In the northern part of the road section, hill slope protection by tea, cardamom and amriso plantation is not significant.

3. GEOLOGY ALONG THE HIGHWAY

For the geological description purpose, Charali-Ilam-Phidim road section has been divided into five sectors: 1. Charali-Kamitar sector, 2. Kamitar-Chihandanda Sector, 3. Chihandanda-Bhalujhoda Sector, 4. Bhalujhoda-Basbote Sector and 5. Basbote-Phidim Sector. (Map1 and Map2).

1. Charali-Kamitar Sector

This sector extends from Charali in south to Kamitar in north for a distance of 10.7 km. In this sector, the road passes through alluvial deposit of Indo-Gangetic Plain. The alluvial deposit is consisted of Quaternary to Recent sand, silt, clay, gravel and boulders. In this area, the sand, silt, gravel and boulders are generally covered by thick soil (Map1).

2. Kamitar-Chihandanda Sector

As the name implies,the Kamitar-Chihandanda Sector spreads from Kamitar in south to Chihandanda in north for a distance of about 5.25 km. In this sector, solely sedimentary rocks of the Siwalik Group occur. This sector starts with the rocks of the Upper Siwalik Formation, which is underlain by Upper Middle Siwalik Formation, consisting of medium to coarse grained sandstone, pebbly sandstone with siltstone, mudstone and relicts of sandstone. The Upper Middle Siwalik is folded into anticline and it is again overlain by thick band (3.5 km) of Upper Siwalik Formation, consisting of conglomerate with subordinate sandstone and mudstone. The Upper Siwalik Formation in the north is thrusted over by rocks of Lower Middle Siwalik Formation, consisting of fine to medium grained sandstone with interbeds of siltstone and mudstone with coaly materials and plant fossils. The east-west trend thrust is truncated in east by NNE-SSW oriented Timal Khola Fault (Map1).

Both Upper Middle Siwalik in south and Lower Middle Siwalik Formation in north occur as thin slices compared to thick Upper Siwalik Formation in the middle part. The contact between Siwalik in north and alluvium of Indogangetic plain in the south is supposed to be the Main Frontal Thrust, which is not exposed clearly along the road section in this area.

3. Chihandanda-Bhalujhoda Sector

The Main Boundary Thrust separates Chihandanda-Bhalujhoda sector from Kamitar-Chihandanda Sector (Map1). This sector extends from Chihandanda in south to Bhalujhoda in north for a distance of 4.0 km. In this sector, meta-sedimentary rocks of Seti Formation occur. Seti Formation is equivalent to Kunchha Formation of Lower Nawakot Group in Central Nepal. Seti Formation is consisted of fine to medium grained, medium to thick bedded, light grey, dark greenish grey to dark grey chloritic phyllite, gritty phyllites, silicious phyllites and quartzites. It is bounded by thrust faults both in north and south. In the south, it is thrusted over the Siwalik rocks along a thrust fault while in the north, the high grade crystalline rocks of Metamorphic Complex overlie it along the Main Central Thrust. In the east, both the Main Boundary Thrust and the Main Central Thrust are displaced towards south by the Timal Khola fault (Map1).

4. Bhalujhoda-Basbote Sector

This sector extends from Bhalujhoda in south-east to Basbote in north-west. This sector extends for about 119.05 km (Map1 and Map2). This sector consists of rocks of Metamorphic Complex. Metamorphic Complex is consisted of Himal Group and Kathmandu Group. Kathmandu Group is equivalent to Bhimphedi Group of Kathmandu Complex in Central Nepal. Himal Group is consisted of Himal Formation, which is consisted of two mica gneisses, muscovite-biotite schists, garnetiferous schists, crystalline quartzites, marbles, kyanite bearing gneisses and schists, granitic gneisses, migmatites and granites. Kathmandu Group is consisted of Shiprin Khola Formation and Sarung Khola Formation. Shiprin Khola Formation is consisted of coarse textured garnetiferous muscovite-biotite schists, calc-silicates, chlorite-muscovite schists, kyanite schists and gneisses and meta- basic rocks. Sarung Khola Formation is consisted of fine textured dark grey to greenish grey biotite schists, quartz-feldspar biotite schists, occasionally garnetiferous schists, quartzites, calc silicates, marbles, kyanite schist and gneisses and intrusion of pegmatite and granite.

The rocks of this sector are locally folded into anticlines and synclines at number of places. A major syncline occurs north of Kanyam. The axis of the syncline passes from Phikkal bajar in the east to Tinghare in the west. Also a major anticline occurs north of Biplayate (Map2).

5. Basbote - Phidim Sector

This sector extends for about 5.05 km from Basbote in south to Phidim in north. High grade rocks of the Metamorphic Complex are underlain in the north again by Seti Formation rocks along Main Central Thrust. Phyllites of Seti Formation in this area are found to bear garnets in some bands which might have been caused by the effect of Main Central Thrust in the south (Map2).

4. OUTCROP (SPOT) DESCRIPTION

Here for the purpose of outcrop description, right side of the road means the right side while driving from Charali to Phidim towards north. Many interesting geological formations, geological structures like folds, faults, geomorphological features like landslides, creeps and different development structures can be seen while driving from Charali to Phidim. Some of them are described below along with photographs.

Spot No. 1, (07. 10km): Betel nut and Coconut plantation, Budhabare, Jhapa, (Left side of the road).

Beside rice, timber and tea, Jhapa district is famous for the production of betel nut and coconut (Photo-1A). Along this road section, there are number of coconut and betel nut gardens. Generally, they are planted in the same garden in mixed pattern. Though both the plants look similar, coconut trees and their leaves are bigger compared to nut trees (Photo-1B). The betel nuts produced in the area are locally processed (boiling, cutting, peeling of skin and drying etc). The nut trees are found to grow from 130m above the msl at Charali in the south to 572m around Chihandanda in the north. The nut trees are 10 to 30 cm in diameter and 20 to 25m tall with bush of leaves on top and bunch of nuts are borne by the trees just below the leaves. Similarly, the coconut trees are 20 to 40 cm in diameter and 20 to 25m tall with bush of leaves on top and the trees bear coconut just below the leaves.

Photo 1-B coconut tree at Budhabare, Jhapa

Photo 1A: Betel nut tree

Photo 1-C: Betel nut and coconut trees along Charali-Chihandanda section of the Mechi Rajmarg

Spot No. 2, (10. 10km): Barne Tea Estate, Barne, Jhapa, (Both sides of the road).

This is the first tea estate along Charali-Ilam-Phidim road section, while traveling from Charali towards Ilam. The tea estate is 2.25km in NS and 2 km in EW direction and approximately 4.5 km^2 in area (Photo-2) Mechi Highway passes through the tea garden almost from the middle part along north-south direction. The tea garden has scattered trees for the protection of tea plants from excessive heat from sun light during summer. The tea gardens located in the cooler higher altitude in the north do not have such trees. The tea produced in Barne tea estate is carried to Tokla for processing. Tokla is 10.0km in east from Barne and it lies near Kakarbhitta, eastern border of the country. The tea estate extends from Hatisude (altitude 235m) to Pipalchok (altitude 325m) in the north.

Photo 2: Tea plants with scattered trees in Barne tea estate.

Spot No. 3, (18. 55km): Ptygmatic fold, Kiten, Ilam, (Right side of the road).

Tightly folded assymetrical fold is exposed on right side of the road (Photo-3) at 18.55km from Charali. Folded rocks are white grey, pinkish grey fine to medium grained quartzite with few sericites. Quartzites contain green chlorite partings. Quartzite layers are bulging and pinching with 2-3cm thick limbs and 3 to 6 cm thick hinge parts (flow structure). These quartzites also contain some green leaching of copper. The quartzite bed of about 1.5m is overlain by greenish muscovite, chlorite schist of about 60cm thick. The quartzite beds are locally faulted toward north.

Photo 3: Folded quartzite bands.

Spot No. 4, (18.95km): Calc Silicate, Kiten, Ilam, (Left side of the road).

At Kiten of Ilam, about 18.95km from Charali, the rocks, exposed consist of dark grey to greenish grey biotite calc-silicates (Photo-4). These rocks are composed of greenish grey, light bluish grey calcareous layers with fine black biotite partings and thin biotite rich layers. The rocks show sugary texture with twinkling of sericites. Rocks are hard, compact and fresh. The calc. silicate is overlain by thinly banded quartzites. Quartzites are fine grained and contain green chlorite, sericite partings. The calc-silicate contains 1-3cm thick white quartz veins. Further north, interbeddings of white quartzite and green chlorite schist continues. The quartzite bands are up to 2m to 3m thick while the schist bands are up to 1m to 2m thick. The beds are striking $N25^0E$ and dipping 70^0 toward west. Two sets of joints are present; they are $N35^0W/70^0W$ and $N10^0E/65^0E$.

Photo 4: Dipping calc-silicate bands

Spot No. 5, (24. 00km): Folded Quartzites and Schists, East of Paharigau, Ilam, (Left side of the road).

Very hard, medium to thick bedded but laminated, light bluish grey to milky white, fine to medium grained crystalline quartzites and fine to medium grained muscovite-biotite schists are exposed in the left side of the road. The quartzites contain bands of dark grey fine to medium grained muscovite, biotite schist, feldspathic schist. The exposure is about 20m thick and it is overlain by 4-6m thick bands of medium to coarse grained biotite schist, gneiss and augen gneiss. The rocks are folded into anticline. The axial plane of the anticline has strike of $N15^0W$ and dipping 25^0 toward east. A local fault plane has caused the shifting of axial plane of the fold (Photo-5).

Photo 5: Local fault plane across the bedding plane.

Spot No. 6, (26. 50km): Plantation of black cardamom, Kolbung, Ilam, (Left side of the road).

Ilam district is famous for its black cardamom production. Along the hill slopes and valleys of small streamlets, one can see the green plants of cardamom (Photo-6). They are generally grown in area with moist soil and low sun light. Cardamom produced in the district is used both within the country and also exported abroad. In the hill slopes, the cardamom plants are protected from bright sunlight by planting trees and bamboos.

Photo 6: Black cardamom grown in north-facing hill slopes of the hill south of Kutidanda

Spot No. 7A, (29. 85km): Has Pokhari Temple, Has Pokhari, Ilam, (Right side of the road).

A small temple and a pond represent Has Pokhari (Photo-7A-1 &7A-2). People used to worship the duck god. It is consisted of a duck shaped structure.Geologically, the area is consisted of high grade gneiss, augen gneiss, quartzites and schists. A big elliptical augen of white feldspar of about 25cm wide and smaller feldspar veins on one side of the elliptical augen structure have created the shape of the duck. The big augen looks like body and smaller veins as neck and head. A white temple is built over it, with the duck god inside it (Photo 7A-2). Just few meters north of the temple, a pond of about 900 m^2 size is present. The pond is dry during April-May and may hold water during rainy season. The area itself is known as Has Pokhari.

Photo 7A-1: Duck god inside the temple

Photo 7A-2: Has Pokhari temple on right side of the road.

Spot No. 7B, (29. 85km): Sano Pathivara Temple, Haspokhari, Ilam, (Right side of the road).

Similar to Pathivara temple of Taplejung, Sano Pathivara Temple of Ilam is established in a hillock at 450m south-east of Kutidanda, which lies at about 29.85km from Charali. The temple is located on top of a hillock at an altitude of 1763m above msl, which is above143m from the road at Kutidanda (photo 7B-1). The track for the Pathivara Temple starts from the side of the Has Pokhari pond (photo 7B-2).

Photo 7B1: Sano Pathivara temple south of Kutidanda

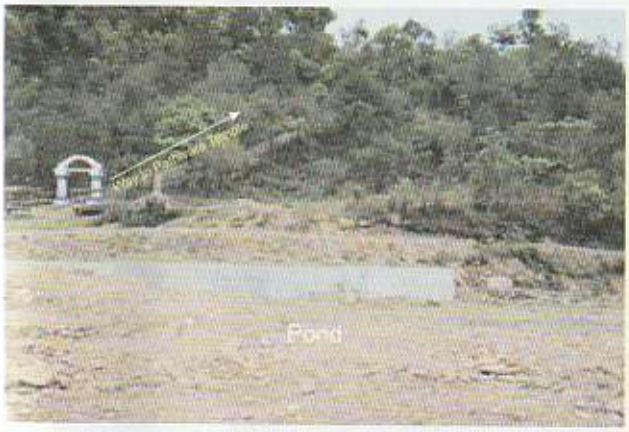

Photo 7B2: Has pokhari pond and entrance gate for Pathivara temple.

Spot No. 8, (30. 65km): Flow Folding in Laminated Crystalline Quartzite, North of Haspokhari, Ilam, (Right side of the road).

It is a big exposure of highly metamorphosed quartzite, gneiss and schist. The quartzites are thick to very thick bedded, milky white, white grey to dark grey in color, coarse crystalline in nature. The quartzites contain lot of feldspar grains, which are coarser than the quartz grains in the quartzite. The quartzites are laminated with alternate laminations of white grey quartz-feldspar layer and dark grey to black biotite rich layers. Two oblique sets of flow foldings within the quartzite show the metamorphic pressure and local disturbance during the metamorphic process (Photo-8). This outcrop lies in the axial part of the inclined anticlinal fold. Attitude of the bed in the upper part of the fold has $N70^0E$ trend and dips 50^0 toward north.

Photo 8: Two oblique sets of flow folding developed in quartzite

Spot No. 9, (33. 45km): Kanyam Tea Estate, Kanyam, Ilam, (Both sides of the road).

Ilam is synonym for tea. Kanyam Tea Estate is one of the most important tea estate in Ilam district (Photo 9-A). The tea estate spreads from 1480m to 1700m height providing with a nice view of green sloping terrain. The estate spreads for about $13km^2$ in area. It is 750m to 2.5km wide in east-west direction and 8km long in north-south direction. The tea estate spreads in east facing and west facing slopes of a north-south ridge. The ridge spreads from Harkate in south to Paltage in north. Mechi Highway crosses the tea estate through the eastern part from south to north. A tea processing plant and an office is located in the western part of the estate (Photo 9-B).

Photo 9-A: Eastern part of Kanyam tea estate

Photo 9-B: A tea processing plant of Kanyam tea estate.

Spot No. 10, (44. 45km): Amriso Plants, Aitabare, Ilam (Left side of the road).

Ilam district exports lot of amriso to outside the district as well as to India. Amriso is green shrub about a meter high (Photo-10). They are cut, dried and tied into a small bunch, which are widely used as broom. Amriso plants are grown in the hill slope. Amriso grow naturally and they do not need special caring as applying of fertilizer or watering. The leaves of the amriso plants are used as feed for cattle, hard branches as fuel wood and flowering top part is used for making broom.

Photo 10: Amriso plants on the hill slope with tea plant in the front

Spot No. 11, (45. 90km): Milk collection centre, Tinghare, Ilam, (Right side of the road).

Beside tea, amriso, Ilam district also produces and exports significant amount of milk and milk products. There are six milk chilling centres in Ilam (Photo-11), each of them collects 6000 to 7000 liters of milk every day. The milk is carried to the centre by vehicle, tractor, horses and men. Even during the general strike, milk vehicles are allowed to ply. The collected and chilled milk is carried to the town of Birat Nagar by milk tanker. In this particular centre, beside milk, timber for ply wood is also collected. Generally low grade timber trees such as utis, malaho, katus, gakul are used for ply wood. Beside milk from Ilam district, milk from Panchthar district is also carried to Biratnagar.

Photo 11: A milk tanker loading milk to carry to Biratnagar.

Spot No. 12, (49. 25km): Granite and migmatite, Godak, Ilam, (Left side of the road).

The exposure on left side of the road in this area is consisted of milky white to dark grey salt and pepper textured medium grained garnet-tourmaline granite (Photo-12). The granite contains few 0.1 mm brown garnets and abundant black tourmalines (0.1 to 0.6 cm long). The granite, at places, contains xenoliths of dark grey to black gneisses and schists. The granite is constituted of feldspar 55%, quartz-30%, and black tourmaline 5% and rest others including garnet and some mica. The granite is highly jointed and weathered. At places, segregation of fine grained black tourmalines up to 7cm wide is present. Similarly, dark grey banded gneiss occurring along with the granite also contains small 5 to 10 cm bands of granite and migmatite. The granite band, occurring within the gneiss, contains medium to very coarse grained garnets and tourmalines.

Photo 12: Dark grey gneiss xenolith in salt and pepper textured granite

Spot No. 13, (65. 50km): Hydro-electricity generation in Mai khola Valley, Mai Khola, Ilam, (Left side of the road).

At present, two hydro-electric projects are present at this part of Mai Khola valley: Puwa Khola hydro-electric project (Photo-13A), which is already producing and Mai Khola hydro-electric project (Photo-13B), which is under construction.

Puwa Khola power house is located on the right bank of Mai Khola, 650m downstream from Mai Khola bridge at 65.5km. The water from Puwa Khola is brought to this area through tunnel and pipe network. It has a capacity of 6.2 MW, but at present during dry season (during field period) it is producing only 3.0MW electricity and supplies electricity to Ilam Bajar and surrounding areas.

About 300m south of Puwa Khola power house, power house for Mai Khola is under construction. This project has a capacity of 4.5MW electricity. The tunnel of Mai Khola project is also under construction.

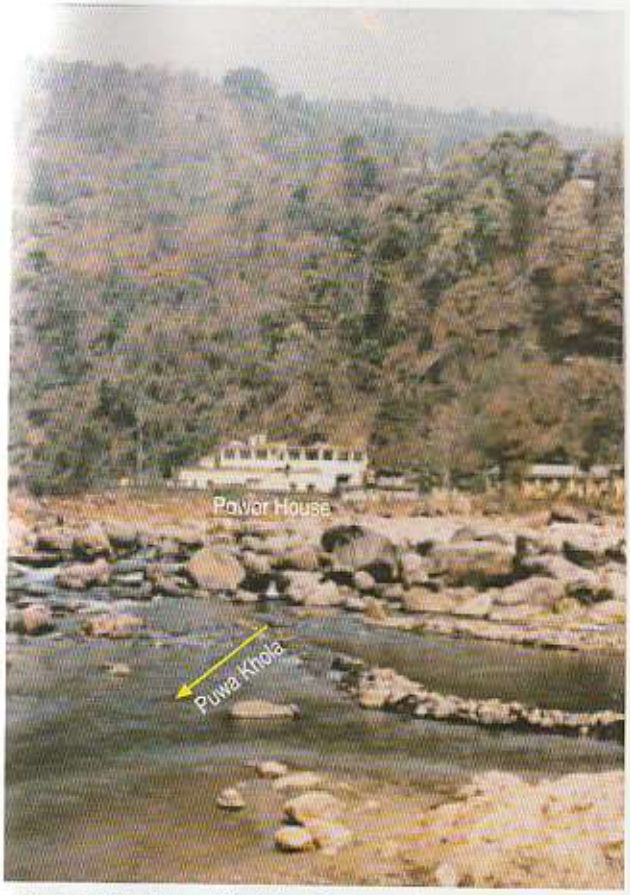

Photo 13-A: Puwa Khola hydro power house on the right bank of Mai Khola, Ilam.

Photo 13-B: Tunnel leading to Mai Khola power house under construction.

Spot No. 14, (86. 55km): Quartzite, schist and gneiss exposure, Malate, Ilam, (Right side of the road).

The rocks exposed in this area are consisted of medium to thick bedded bluish grey, fine to coarse grained biotite quartzite interbedded with white grey to dark grey coarse grained garnetiferous biotite schist and medium to coarse grained white grey gneiss. The gneiss contains 2 to 3cm thick bands of white feldspars. The rocks are moderately weathered and look dark grey to black on exposed surface (Photo-14). Migmatitic gneiss bands up to 50cm thick are also present. The rocks are jointed and are exposed on right side of the road. Exposed thickness is over 20m. White salt encrustation and yellow sulphur encrustations are present at places on the surface of the rock. The attitude of bed is $N10^0W$ and dips 40^0 toward east. Two sets of Joints are present: jt1-$N65^0E/60^0N$ and jt2- $N20^0W/65^0$ W

Photo 14: Steep slope made up of quartzite, schist and gneiss.

Spot No. 15, (90. 25km): Forest Resources, Magargau, Ilam, (Right side of the road).

Beside other agricultural products, Ilam and Panchthar districts supply lot of timber, which are used as raw materials for the ply wood industries. Along the Mechi Highway, one can see collection of piles of wood logs at number of places (Photo-15A). These wood logs are carried to ply wood industries in Ilam and Jhapa districts (Photo-15B). Generally low quality timber trees such as utis, malaho, katus, gakul are used for ply wood. The scale of collected wood logs indicates large scale deforestation in the mountains of Ilam and Panchthar districts. If adequate and quick reforestation is not carried out, large scale erosion in the hill slopes around Mechi Highway is imminent.

Photo 15A: Piles of wood logs lying on the side of the Mechi Highway at 90.25km.

Photo 15B: Ply wood industry at Charali, Jhapa.

Spot No. 16, (101. 75km): Light grey to white gneiss outcrop, Bhadaure, Ilam, (Right side of the road).

Rocks are exposed on right side of the road about 15m upslope from the road. Rocks are light grey to white, fine to medium grained, very thick bedded (80cm) to massive gneiss (Photo-16). The gneiss is banded with 0.2 to 0.4 cm thin bands. The rock looks like granite due to fairly white color, compactness and hardness like granite. Rocks on the exposure are slightly weathered. It contains bands of coarse crystalline garnet-biotite gneiss with coarse grained feldspar, quartz bands alternated with black biotite rich bands. The gneiss bands have attitude of N30^{0}W and dip 25^0 toward east. Three prominent sets of joints are present in the gneiss, they are joint1: N15^{0}E/65^{0}W, joint2: N80^{0}E/80^{0}S and joint3: N30^{0}W/90^0.

Photo 16: Highly jointed white gneiss at 101.75km.

Spot No. 17, (102. 55km): Jal Kanya Temple, Bhadaure, Ilam, (Right side of the road).

It is situated on right side of the road in a sharp turn of the road. The area is consisted of bluish grey to dark grey schist and white grey gneiss. They are folded into ptygmatic foldings (Photo-17). White pegmatite veins are present at hinge parts of the fold and some of them are up to 20cm thick. The area is regarded and worshipped as Jal Kanya Devi temple that is goddess of water. Folded gneiss and schist bands are thought to be snakes guarding the goddess. A temple like structure is built around the fold structure. May be due to presence of this structure, the road took sharp turn to protect it. Toward west of the structure, coarse grained biotite gneiss with 60cm thick white pegmatite band is present.

Photo 17: Ptygmatically folded gneiss and schist bands resembling twisted snakes.

Spot No. 18, (103. 90km): Sand Quarry in deeply weathered gneiss, Arubote, Ilam, (Right side of the road).

Highly weathered white gneiss, banded psammitic gneiss (with 80% quartz, feldspar) and dark grey gneiss with fine black biotite layers (0.1 to 1cm thick) are present in the area (Photo 18-A). White quartz, feldspar rich bands are 1 to 8cm thick in white gneiss. The white gneiss is overlain by the banded gneiss. The gneissic bands have an attitude of N10^{0}E and are dipping 30^0 toward east.

The white gneiss is so deeply weathered that grains of quartz and feldspar fall as loose sands even when scratched by fingers. Highly weathered gneisses are easily exploited for sand aggregate (Photo 18-B). The weathered gneiss is covered by a thin brown clayey layer. There are number of sand quarries, one of the quarry by the side of the road was 5m wide and 7m deep in March-April in 2009 and the sand quarry has been widened to 15m in May 2010. The sand, produced in this area, contains remarkable amount of fine grained silt and clayey silt, which are product of weathered white feldspar and fine grained biotite flakes. In the sand occurring in river valleys, these silt and clayey silts are generally washed away by running water.

Photo 18-A: Weathered psammitic gneiss and banded gneiss

Photo 18-B: Sand quarried from weathered gneiss

Spot No. 19, (107. 10km): Banded gneiss, North of Dhappar, Ilam, (Right side of the road).

Thick bedded dark grey to white grey banded gneiss is present in this area (Photo-19). It is consisted of 0.2 to 1cm thick alternate bands of white grey quartz feldspar rich layer and black biotite rich layer. Coarse to very coarse grained garnets are found to be present mainly in biotite rich layer. The rocks are relatively less weathered, hard and compact. Banded gneiss is overlain by white psammitic gneiss. The white gneiss is more weathered and soft, which may be due to high feldspar content of the band, as feldspar is more susceptible to rapid weathering in normal surface condition. The banded gneiss has joints almost at right angle to foliation plane causing block fall of gneiss. As the gneiss has joints and the outcrop is lying just on the side of the road, it is exploited for stone aggregate by local people.

Photo 19: Block fall has caused hanging of upper part of the gneiss.

Spot No. 20, (111. 15km): White Gneiss, East of Rakebhanjyang, Ilam (Right side of the road).

White grey to dark grey, hard and compact gneiss and augen gneiss are exposed in this area (Photo-20). The gneiss contains medium grained pink garnets. The gneiss is thinly layered with 0.2 to 2cm thick white grey and dark grey layers. Augens of 3-4cm wide are developed at some places. The gneiss is interbanded with white laminated quartzite and thick bedded to massive calc-silicates. The rocks are exposed on right side of the road. The calc-silicates and gneiss are overlain by medium to thick banded gneiss and quartzite & thinly banded gneiss. The thinly banded gneisses are highly fractured and are exploited for construction aggregates. It seems that the contact between the main gneiss and overlying fractured gneiss is a tectonic contact. The gneiss band has a trend of N25^{0}E and dips 15^0 toward east.

Photo 20: Heap of debris from overlying fractured thinly banded gneiss lying by the side of white gneiss

Spot No. 21, (119. 45km): Landslide, south of Pauwabhanjyang, Panchthar, (Right side of the road).

A landslide has taken place on right side of the road (Photo 21). It is a reactivation of part of old dormant landslide. The landslide is 40m wide at road level and 50m high and it is tapering upslope. The landslide debris is consisted of white grey and dark grey banded gneiss and white granitic gneiss. The slide debris consists of gravel, pebble to up to 3m sized boulders. The bigger boulders are representing the front parts of the slide covering more than 80% of the road. Boulders of banded gneiss contain coarse to very coarse grained brown garnets and black tourmalines. Materials from the slide debris have been used as construction aggregates by the local people.

Photo 21: Boulders of gneiss leading the slide debris towards the road.

Spot No. 22, (128. 50km): Pegmatite, Dahitar, Panchthar, (Left side of the road).

The country rock in the area is consisted of medium bedded fine grained biotite schist and feldspathic schist. The schist band contains a white medium to coarse grained about 1.0 m thick pegmatite band (Photo-22). The pegmatite band contains mostly white feldspar and quartz (total >95%) with some black fine to medium grained tourmalines and biotites. Muscovites are not seen in schist as well as in pegmatites. Beside the main pegmatite band, there are some smaller pegmatite bands. The country rock schist is moderately weathered. Some thin pegmatite bands are noted to contain pink feldspar grains. The biotite schist bands are striking $N70^0W$ and dipping 25^0 toward south.

Photo 22: White pegmatite band at 128.5km

Spot No. 23, (133. 50km): Landslide, North of Lalikharka, Panchthar, (Left side of the road).

A landslide of 20m wide and 25m high is present on left side of the road (Photo-23). The landslide seems to be reactivated by the construction of road, cutting old landslide deposit at steep slope. The debris of the slide is consisted of very few boulders but mainly soil with some gravels and pebbles. Towards west of the landslide, highly weathered gneissic rocks are present.

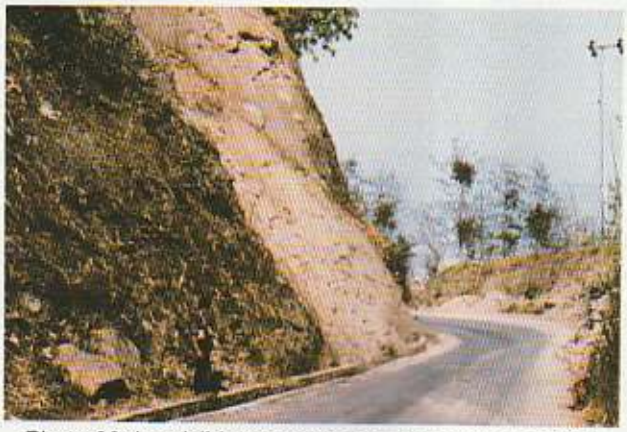

Photo 23: Landslide reactivated by steep slope cutting.

Spot No. 24, (139. 60km): Thrust Zone, Odin, Panchthar, (Right side of the road).

Thinly bedded fine grained highly fractured green phyllite of Seti Formation is overlying white grey gneiss of Himal Formation (Photo-24). Both the gneiss and phyllites are highly weathered. The phyllites are found to be very brittle. The gneiss comes out as loose sands when hammered and phyllites as small angular pieces. At the contact, a crushed zone of 10 to 30cm is developed. The crushed zone consists of layers of clay, silt and highly crushed phyllites. The clay and silt layers resemble brown bauxite. The outcrop occurs north of MCT zone and order of superposition of stratigraphy is reverse to the general trend in the area, so the contact should be a locally overturned structure. The thrust contact has trend of N70^{0}E and dips 35^0 toward south.

Photo 24: Dirty green phyllites of Seti Formation overlying white weathered gneiss of Himal Formation.

Spot No. 25, (142. .85km): Garnet Phyllite, Mathilogau, Panchthar, (Right side of the road).

Light greenish grey to yellowish green foliated, soft and weathered phyllite of Seti Formation is present in this area. The phyllite in this area contains 0.2 to 0.8cm diameter brown garnets. The garnetiferous band is 1m thick. The garnets might have been developed due to effect of the Main Central Thrust, which lies less than 100m south of the exposure. The rocks contain 1 to 2cm thick quartz veins. The phyllites also contain 10 to 20 cm thick weathered sericitic white quartzite band. About 4m wide zone of the phyllite exposure is deeply weathered into yellowish brown color (bauxite soil) (Photo-25). The phyllite has attitude of N55^{0}E and dips 60^0 toward south.

Photo 25: Originally green phyllites of Seti Formation in the process of formation of yellowish brown bauxite soil.

5. ACKNOWLEDGEMENT

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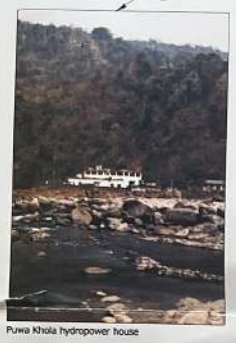
GEOLOGICAL SECTION OF MECHI HIGHWAY (Charali-Ilam-PhidimRoad)

CHARALI-ILAM SECTION



Purwa Khola hydropower house

Granite with xenolith at 49.25 Km.

Mechi highway passing through Kanyam Tea Estate

Flow folding in quartize

Faulting displacing the fold axis

Barne Tea Estate, Jhapa

Prepared by:
U.B. Pradhananga

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ADM Carto Consult and Map Publisher (P.) Ltd.

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Tel: 4414740, 4414806

SCALE 1:50,000

KM 0 0.5 1 2 3 4 5 KM

LOCATION DIAGRAM

LEGEND

SURFACIAL DEPOSIT (Quaternary To Recent)

- q — **Alluvial Deposits :** Sand, silt, clay, gravel and boulders

SEDIMENTARY COMPLEX
SIWALIK GROUP (Middle Miocene-Pleistocene)

- us — **Upper Siwalik Formation:** Conglomerate with sub-ordinate sandstone and mudstone.
- ms1 — **Upper Middle Siwalik Formation:** Medium to coarse grained sandstone, pebbly sandstone with siltstone, mudstone and relicts of sandstone
- ms2 — **Lower Middle Siwalik Formation:** Fine to medium grained sandstone with interbeds of siltstone and mudstone, coaly materials and plant fossils are present.

METASEDIMENTARY COMPLEX
MIDLAND GROUP, LAKHARPATA SUB GROUP (Upper-Pre-Cambrian-Late Paleozoic)

- st — **Seti Formation :** Seti Formation- Fine to medium grained, medium to thick bedded, light grey to dark grey, dark greenish grey chloritic phyllite, silicious phyllite, gritty phyllite and quartzites.

METAMORPHIC COMPLEX
KATHMANDU GROUP (Pre-Cambrian)

- sk — **Sarung Khola Formation :** Fine textured, dark grey to greenish grey biotite schist, quartz-feldspar biotite schists, garnetiferous schists, kyanite gneisses and schists (k), quartzites, calc silicates, marbles and intrusion of pegmatite and granite (gr).
- sp — **Shipring Khola Formation :** Coarse textured garnetiferous muscovite-biotite schists, calc-silicates, chlorite-muscovite schists, kyanite gneisses and schists (k), meta- basic rocks and intrusion of pegmatite and granite (gr).

HIMAL GROUP (Pre-Cambrian)

- hm — **Himal Formation :** Two mica gneisses, muscovite-biotite schists, garnetiferous schists, crystalline quartzite, marbles, kyanite bearing gneisses and schists (k), granitic gneisses, migmatites and granites (gr).

STRUCTURE		PHYSIOGRAPHIC FEATURES	
Geological contact	• 1433	Elevation in meter	Bridge
Thrust		River and drainage	Landslide
Fault plane		Flow direction of river	Distance of road in kilometer
Anticlinal Axis		Settlement	Petrol pump, Hotel
Synclinal Axis		Village	Hospital
Attitude of bed		Highway	Hydropower station
		Trail	Spot location

First Edition 2010

Map-2

GEOLOGICAL SECTION OF MECHI HIGHWAY (Charali-Ilam-PhidimRoad)

ILAM-PHIDIM SECTION

Phyllites of Seti Formation overlying gneiss of Himal Formation

Landslide south of Pauwa Bhanjyang

Sand quarry in weathered gneiss

Highly jointed white gneiss

LEGEND

SURFACIAL DEPOSIT (Quaternary To Recent)

- q — **Alluvial Deposits :** Sand, silt, clay, gravel and boulders

SEDIMENTARY COMPLEX
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- us — **Upper Siwalik Formation:** Conglomerate with sub-ordinate sandstone and mudstone.
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METASEDIMENTARY COMPLEX
MIDLAND GROUP, LAKHARPATA SUB GROUP (Upper-Pre-Cambrian-Late Paleozoic)

- st — **Seti Formation :** Seti Formation- Fine to medium grained, medium to thick bedded, light grey to dark grey; dark greenish grey chloritic phyllite, silicious phyllite, gritty phyllite and quartzites.

METAMORPHIC COMPLEX
KATHMANDU GROUP (Pre-Cambrian)

- sk — **Sarung Khola Formation :** Fine textured, dark grey to greenish grey biotite schist, quartz-feldspar biotite schists, garnetiferous schists, kyanite gneisses and schists (k), quartzites, calc silicates, marbles and intrusion of pegmatite and granite (gr).
- sp — **Shipring Khola Formation :** Coarse textured garnetiferous muscovite-biotite schists, calo-silicates, chlorite-muscovite schists, kyanite gneisses and schists (k), meta- basic rocks and intrusion of pegmatite and granite (gr).

HIMAL GROUP (Pre-Cambrian)

- hm — **Himal Formation :** Two mica gneisses, muscovite-biotite schists, garnetiferous schists, crystalline quartzite, marbles, kyanite bearing gneisses and schists (k), granitic gneisses, migmatites and granites (gr).

STRUCTURE	PHYSIOGRAPHIC FEATURES	
Geological contact	• 1433 Elevation in meter	Bridge
Thrust	River and drainage	Landslide
Fault plane	Flow direction of river	Distance of road in kilometer
Anticlinal Axis	Settlement	Petrol pump, Hotel
Synclinal Axis	Village	Hospital
45° Attitude of bed	Highway	Hydropower station
	Trail	S15 Spot location

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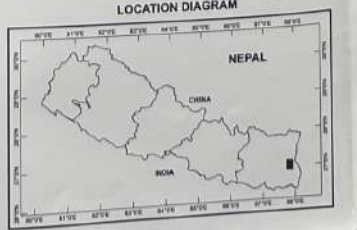
SCALE 1:50,000

KM 0 0.5 1 2 3 4 5 KM

LOCATION DIAGRAM



Flow folding in quartzite

Kanyam Tea Estate Ilam