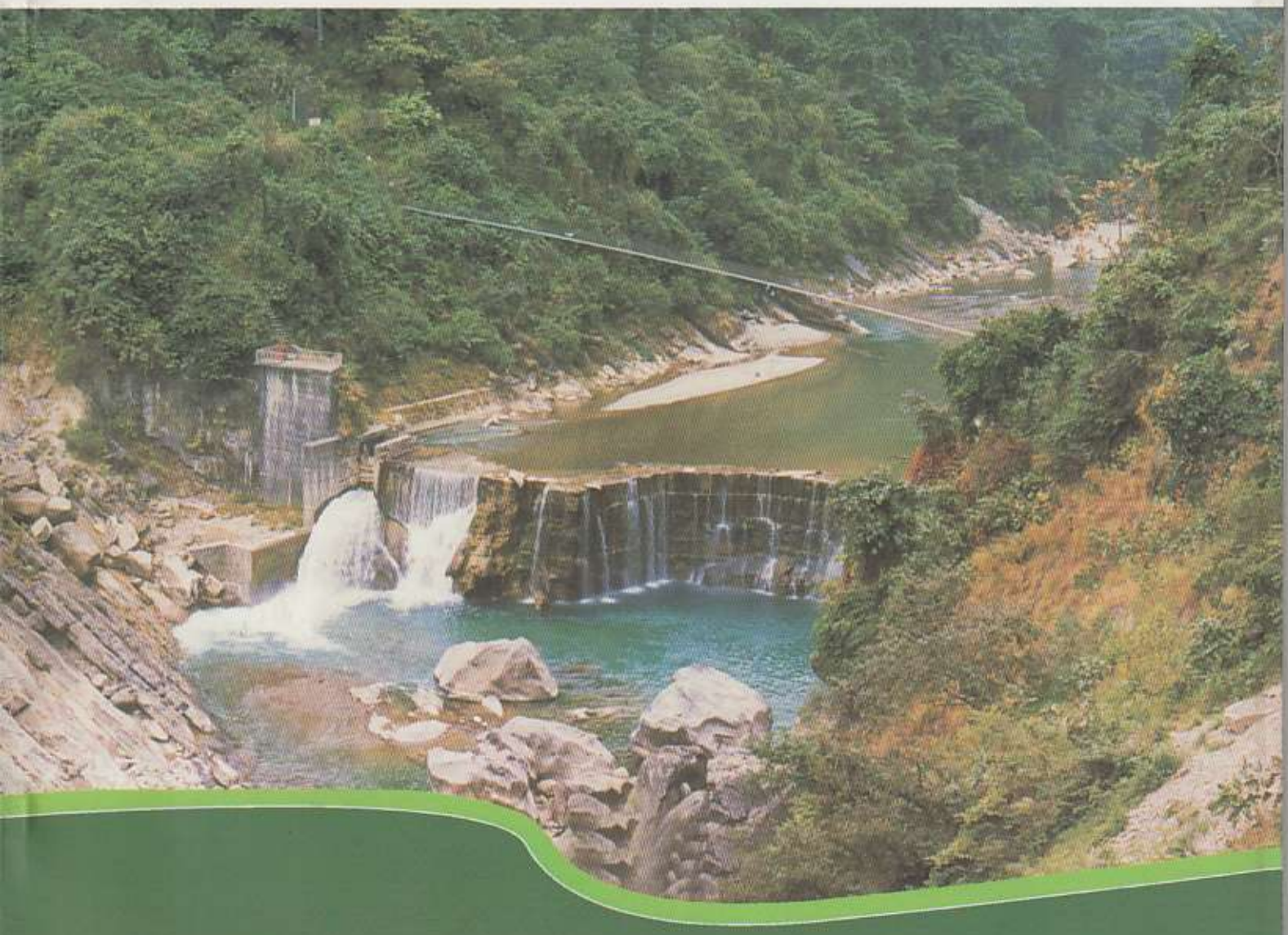
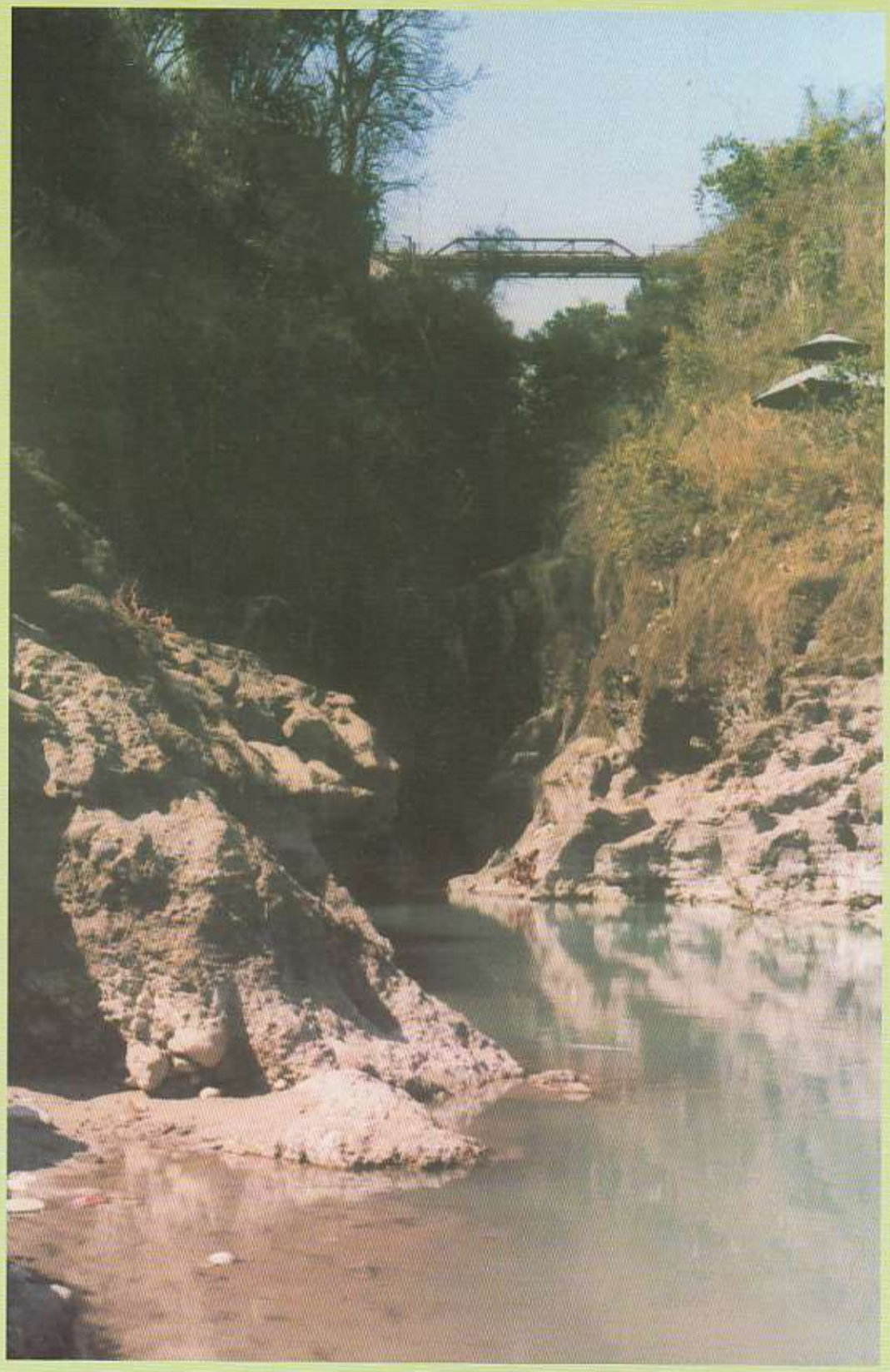
A GUIDE BOOK ON GEOLOGICAL SECTION OF SIDHARTHA HIGHWAY (BUTWAL TO POKHARA), WESTERN NEPAL



Government of Nepal
Ministry of Industry, Commerce and Supplies
Department of Mines and Geology
Lainchaur, Kathmandu, Nepal
June, 2007



Seti Gorge Ramghat, Pokhara

A GUIDE BOOK ON GEOLOGICAL SECTION OF SIDHARTHA HIGHWAY (BUTWAL TO POKHARA), WESTERN NEPAL

By

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PREFACE

Many geo-scientists, researchers of other disciplines, tourists and trekkers interested in geology may have a great desire to observe and understand the geology of Nepal Himalaya. But it may not be possible for them to get a qualified geologist as a guide who can give proper geological information of the area. Realising such necessity, the Department of Mines and Geology (DMG) has started to prepare geological section along the highways and publish geological guidebooks with information on geology, geomorphology and natural hazards. The main aim is to provide geological information to the concerned people and agencies and also to help the common people, trekkers and visitors to make them understand by themselves the geology and natural hazards of the area beside other touristic information. As a part of the annual program for the F.Y. 2006/07, the Department has prepared and published a guide book on geological section along Sidhartha Highway from Butwal to Pokhara. In this connection, two-weeks field study of Butwal – Pokhara Road Section was carried out in the fiscal year 2005/06. The area lies in Survey of India toposheet no 62P/16, 63M/6, 63M/9 and 63M/13, 1:63360 scale and sheet numbers 099-05, 099-06, 099-09, 098-12, 2783-03B 2783-04A, 2883-16A, 2883-16B, 2883-16C, and 2883-16D in 1:25000 scale topographic maps published by Survey Department, Government of Nepal. The area is bounded by latitudes 27° 41' 53" to 28°12' 30"N and longitudes 83° 28' 00" to 84° 00' 00" E.

The Sidhartha or Butwal - Pokhara Highway not only connects Pokhara from Butwal, but also presents a geological section of the southern parts of the Midland Mountains and the Churia Range. This is one of the vital roads that connect Kathmandu with Western and Far Western Nepal.

The geological section and the guide book has been prepared on the basis of field study and existing topographic maps, geological maps and reports of the area. Published geological maps of Department of Mines and Geology have been referred for the Lesser Himalayan area and unpublished maps of Petroleum Exploration Promotion Project, DMG, have been referred for the Siwalik region. Besides, Dhital, et. al, (1988), Sakai, (1982), Hirayama, et. al, (1988) and others have worked in this area. This guidebook contains general geological information about Nepal Himalaya and geology, geomorphology and natural hazards along the road section. Typical outcrops of geological formations, geological structures and natural hazards like landslides, flood effects as well as other spots of general interest are described with photographs. Besides, other information like locations of hotel facilities, hospitals, petrol pumps etc are shown in the geological section (Map Sheet I and II)

1. GENERAL GEOLOGY OF NEPAL

1.1 Geology

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. From south to the north, they are: 1. Terai (Indo-Gangetic plain) 2. Sub Himalaya or the Churia Range 3. Lesser Himalaya 4.Higher Himalaya 5.Tibetan Tethys Zone (Inner Himalaya). Each zone is separated by major longitudinal thrust/fault. The Main Frontal Thrust (MFT) separates the Sub Himalaya from the Terai Zone, the Main Boundary Thrust (MBT) separates the Lesser Himalaya from the Sub Himalaya, the Main Central Thrust (MCT) separates the Higher Himalaya from the Lesser Himalaya, and similarly South Tibetan Detachment Fault System (STDFS) separates the Tibetan Tethys Zone from the Higher Himalaya.

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 represented by gravel, sand, silt and clay. It is believed that the Terai is slightly tilted (2-5°) towards south and southwest. Total thickness of this deposit is more than a km.

Sub Himalaya or Churia Range

Siwalik range forms the southern part or outer belt of the Himalayan Range. Various terrigenous rocks such as shales, claystone, mudstone, sandstones and conglomerates constitute the Siwalik Group. In general, coarsening upward is the characteristic of the rocks of the Siwalik Group. Based on various plant and animal fossil evidence, age of this group is considered to be from Middle Miocene to Early Pleistocene.

The Lesser Himalaya

It is confined within the Main Boundary Thrust (MBT) in the south and Main Central Thrust (MCT) to the north. The rock units of this group are the most widely distributed rocks in Nepal. They form the Central Midland Zone of the Himalayan range. It comprises mostly of limestones,dolomites, shale, phyllites, schists and quartzites. They form a thick pile (8- 10 km thick) of unfossiliferous rocks. Stromatolites are the only known fossil evidences. Tentatively their age is given as Pre-Cambriam to Early Paleozoic. Along the southern margin of the Midland, a thin belt of fossiliferous rock unit called Surkhet Group is present. Various coloured shales, sandstones and limestones of this group contain fossils. The ages range from Carboniferous to Miocene. Klippes of high grade metamorphic rocks (with root zone lying to the north in the Higher Himalayan region) are present within this zone.

The Higher Himalaya

It is confined within the Main Central Thrust in the south and South Tibetan Detachment Fault System to the north. Higher Himalayan rocks form the base of the Great Himalayan Mountain Range. They are thought to be the basement rocks thrusted over the rocks of the Lesser Himalaya along the Main Central Thrust, with root zone lying somewhere north in Tibet. The Higher Himalaya is composed mostly of high grade metamorphic rocks such as gneiss, calc-gneiss, migmatite, garnet schist, kyanite sillimanite schists, quartzites and marbles.

The Tethys Zone (The Inner Himalaya)

This zone is bounded by South Tibetan Detachment Fault System (STDFS) to the south and Tsangpo Suture Zone to the north. Mostly weakly metamorphosed or non-metamorphosed sedimentary rocks with fossils represent the zone. The main rock types are various coloured limestones, sandstones and shale. In general a tendency of decrease in calcareous materials towards top is noticed. Fossil evidences show that their age ranges from Ordovician to Cretaceous. At places the rocks form NW-SE trending fold structures.

1.2 Structure

Main Central Thrust (MCT), Main Boundary Thrust (MBT) and Main Frontal Thrust (MFT) are the major linear geological structures that run from east to west throughout Nepal and separate the geologically distinct lithological units. All these thrust structures dip towards north. These structures are successively younger towards south. Rocks of Higher Himalayan Group are characterized by monoclinal rocks dipping towards north, whereas, the central part of Nepal (Midland) is generally characterized by open fold of NW-SE trend. This part shows several thrust sheets and klippen structures composed either of high-grade metamorphic rocks of the Higher Himalayan Group or different units of the Midland itself. Rocks of both Siwalik.and Tethys Zone are characterized by open NW-SE trending folds and block faulting.

2. GEOLOGY, GEOMORPHOLOGY AND NATURAL HAZARDS OF THE AREA

2.1 Geology

Sidhartha Highway starts from Sunauli, a border town in India, and passes through Bhairahawa (Siddhartha Nagar), Butwal, Syangja and extends up to Pokhara Valley, a touristic town in Western Nepal. The highway passes through sedimentary rocks of Siwalik Hills, Lesser Himalayan Metasediments including Metasediments of the Tansen Group, flood plain deposits of different streams and rivers and Quaternary Debris Flow deposits of the Pokhara valley.

The Siwalik Group is divided into 1.Lower Siwalik, 2.Middle Siwalik and 3. Upper Siwalik. The Middle Siwalik is further divided into i. Lower Middle Siwalik and ii. Upper Middle Siwalik. The Lesser Himalayan Metasediments are divided into Nawakot Complex and Kathmandu Complex (Stocklin, 1981). Nawakot Complex is divided into the Lower and Upper Nawakot Groups. Similarly the Kathmandu Complex is divided into Bhimphedi Group and Phulchauki Group. The Kathmandu Crystalline Complex is thrust over the Nawakot Complex along the Mahabharat Thrust (MT).

The rocks of the Siwalik Group are exposed between Chidiya Khola in the south to the Main Boundary Thrust (MBT) in the north (Map Sheet No.I). This group consists of relatively young unmetamorphosed sedimentary rocks. In this road section only the rocks of Lower and Middle Siwalik are encountered. Rocks of the Tansen Group are distributed from Charghare in the south to Aryabhanjyang area in the north (Map Sheet No.I). Tansen Group consists of fossiliferous sedimentary rocks. It is the only fossiliferous rock sequence in this part of the Lesser Himalaya. Some rocks of the Benighat Slate and Nourpul Formation are encountered as Inlier within the rocks of the Tansen Group. From Aryabhanjyang in the south to Naudanda in the north, rocks of Benighat Slate of Upper Nuwakot Group and Dandagaon Phyllite, Nourpul Formation and Dhading Dolomite of Lower Nuwakot Group are present. They have general trend of E-W in the southern part and NE-SW trend in the northern part. They are repeated a number of times as tectonic slices. In Naudanda area, a band of Fagfog Quartzite is recorded. It is underlain by thick sequence of gritty phyllites and quartzites of Kunchha Formation (map sheet II). Rocks of the Kunchha Formation extend up to the south-western part of the Pokhara Valley, whereas Debris Flow Deposit covers north-eastern part of the valley.

2.2 Geomorphology

The study area, Butwal – Pokhara road, starts from Indo-Gangetic plain with an altitude of 176m in the south and passes through the Siwalik (Sub-Himalaya) and the Lesser Himalaya. The road has NW-SE alignment. After 2.5 km on the plain, the road following the left bank of Tinau Khola, starts climbing upward toward the north in the Siwalik hill. At Kerabari, the road reaches the height of 653.5m. The road follows the left bank of Tinau Khola up to Dobhan village. Then the road follows the right bank of the Tinau Khola up to the confluence of Tinau and Hulandi Khola (south of Pipal Danda). From this confluence, the road follows the bank of Hulandi Khola and ascends up to 1131.6m, east of Tansen. From that area, the road passes along the south facing hill slope toward east and after reaching Arya-bhanjyang, it descends along the bank of Ramdi Khola up to Ramdighat with an altitude of 401.9m. From Ramdi, after crossing Kaligandaki bridge, the road passes along the left bank of Kaligandaki River for few kilometers, and then it ascends to Galyang Bazar, a local market at an altitude of 720m. Galyang Bazar acts as water divide between Andhi Khola in the north and Kaligandaki River in the south. After Galyang Bazar, the road follows the hill slope on the left side of Andhi Khola and passes through Waling Bazar (716m) and Syangja Bazar (857m.), head quarter of Syangja district. The highest point, through which the road passes, is Kubhinde Bhanjyang (1180m.), the border between Syangja and Kaski districts. From Kubhinde Bhanjyang the road descends to Pokhara Valley with an altitude of 800m. (Map Sheet No.II)

2.3 Natural Hazards

From Chidiya khola (spot no.1) in the south to Main Boundary Thrust in the north, the road passes through the rocks of Siwalik Group. Rocks of the Siwalik Group are very prone to weathering, erosion, block fall and landslide. Besides, the Central Churia Thrust (CCT)

passing through Tinau Khola at Dobhan is accelerating the erosion process. As a result, rock falls and landslides are quite common in this area. Soft and weathered nature of the rock, tectonic activity, disturbance by the heavy traffic and heavy monsoon rain make the hill slope unstable. At the same time the current of the river is cutting the toe part of the slope, making the road unstable from time to time. Besides, frequent flash floods had swept away some parts of the road. A big landslide on the hill, east of Butwal, is affecting the north-eastern part of the city from time to time. The MBT passes through south of Kerabari. The rocks lying at the vicinity of MBT are highly disturbed and crushed (photo-9), which help to trigger landslides.

This part of the road is very unstable due lot of landslides and rock falls. From Kerabari onward, most parts of the road pass through well maintained hill slope and terraces. Only some minor creeps and minor landslides are present in the area. In many cases they are caused by the reactivation of the old landslides and deforestation (spot 19, 22, and 24).

4. OUTCROP (SPOT) DESCRIPTION

For the purpose of outcrop description, right side of the road means the right side while driving from Butwal to Pokhara. While driving from Butwal to Pokhara, many interesting geological and geomorphological features like different rock types, and geological structures like folds, faults, thrusts as well as geohazards like landslides, rock fall and river bank cutting and flood prone areas etc. can be observed. Some of the typical features/ structures are described below along with photographs.

Spot No.1, (2.00 Km): Lower Siwalik Formation, Chidiya Khola (Right side of the road)

It is the place where well exposed rock outcrops are seen for the first time while driving from Butwal toward north along Sidhartha Highway. Thick piles of repeated beds of sandstone, shale and mudstone of Lower Siwaliks are exposed in this area. The rocks are 1 to 3m thick, light grey, fine grained sandstone interbedded with soft purplish and greenish grey shale and mudstone (photo1). The attitude of the bed is N80°W and dip 25° towards N.

Photo 1: Thick bedded sandstone with green / purple shale intercalation at Chidiya Khola.

Spot No.2, (4.00Km): Hydro-electric Power Dam site north of Chidiya Khola, (Left side of the road)

On the left side of the road, an old dam for hydropower intake is situated on the thickly bedded medium to coarse grained, compact sandstone of Lower Middle Siwalik Formation (photo 2). The dam is 65m long. Intake of the tunnel lies on the right side of the Tinau Khola. The Tunnel is 2462m long and generates 1000 kilowatt electricity.

Photo 2: A hydro-electric power dam at 4km from Butwal.

Spot No.3, (4.50 Km): Upper Middle Siwalik (ms2) Formation, (Right side of the road)

Light grey, thickly bedded, hard, compact, fine to medium grained sandstone with bands of greenish grey shale and mudstone (photo 3) of Upper Middle Siwalik Formation (ms2) occurs in this area. The sandstone being hard stands out in the outcrop, whereas the soft shales are easily eroded. The sandstones are fractured and jointed as a result rocks are detached into blocks and slide down hill as rock falls. Such phenomena are quite common in this road section. The beds are striking N80°W and dipping 55° toward N.

Photo 3: Thick bedded fine to medium grained sandstone.

Spot No.4, (9.50 Km): A slope protection wall in Siwalik area. (Left side of the road).

Slope protection walls made up of stone reinforced by cement or gabion wall (photo 4) are quite common in the

Siwalik area, because the rocks of the Siwalik are very prone to landslides and rock fall causing frequent disruption of the traffic in this part of the road mainly during rainy season.

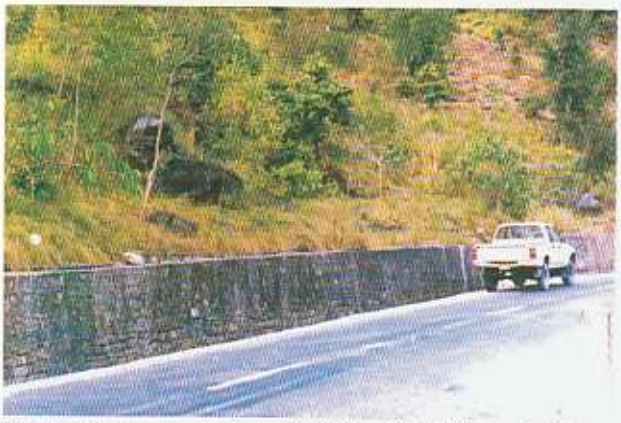

Photo 4: A slope protection wall at 200m NE of Jhumsa bridge.

Spot No.5A, (13.00 Km): Black carbonaceous slate, (Left side of the road)

About 60m thick, white salt encrusted black carbonaceous slate occurs just above the Main Boundary Thrust (photo 5). The slates are highly fractured due to the effect of the underlying MBT. Light grey carbonate unit (Dhading Dolomite?) is overlying the black slate (photo 6). The contact between the dolomite and slate is conformable but sharp. Stratigraphic position of the underlying slate shows that it belongs to Nourpul Formation, but the lithology shows the nature of the Benighat Slate. General trend of the black slate is N75°W and dipping 75° toward N.

Photo 5: White salt encrusted black slate exposed at MBT zone.

Photo 6: Limestone and dolomite of Dhading Dolomite overlying black carbonaceous slate with sharp but conformable contact.

Spot No.5B, (13.00 Km): Main Boundary Thrust (MBT) (Left side of the road)

Thick bedded green, fine to medium grained sandstone of Upper Middle Siwalik (ms2) is overlain by the crushed materials of the overlying black slate. The exposure gap between the underlying light greenish grey sandstone and overlying black slate is about 7m along the road section. Main Boundary Thrust is passing through the crushed materials (photo 7). Due to the effect of the thrust, the underlying green sandstones are highly fractured and overlying slates are highly crushed. The exposure lies about 100m uphill toward NW from the road.

Photo 7: Main Boundary Thrust at 13km.

Spot No.6, (13.50 Km): Limestone Quarry at Kerabari, (Left side of the road)

Spot No. 6 shows the quarrying of limestone at Kerabari at a distance of 13.5km from Butwal. Thin bedded limestone, occurring within Dhading Dolomite at Kerabari area, is quarried and supplied to local cement industries. The quarry site lies about 200m up hill (NW) from the road (photo 8). As the rocks are highly fractured even crushed at places, limestones are quarried manually by using shovel and pick only, without using any heavy machine.

Photo 8: Limestone quarry at Kerabari at 13.5km.

Spot No.7, (14.20 Km): Dhading Dolomite at Kerabari (Left side of the road).

Dark grey to white grey, thinly banded limestone and dolomite of Dhading Dolomite are well exposed in this spot. The limestones/dolomites are highly jointed and displaced along numerous local fault/joint planes (photo 9) due to the effect of the underlying Main Boundary Thrust. The fracture planes are highly weathered and soil has been developed on most of these fracture planes. Unlike Dhading Dolomite of other area, the rocks in this area consist more of thinly bedded limestone/dolomite and no stromatolite as such is seen in the dolomite.

Photo 9: Thinly banded limestone and dolomite of Dhading Dolomite at 14.2km.

Spot No. 8, (19.00 Km): Sisne Formation, Charghare, (Left side of the road)

Thinly bedded dark grey to black gritty shale /diamictite with medium to coarse-grained sand size grits occur in this area. The grits are generally found to be consisted of quartz and feldspar. Rocks are hard and compact.

Photo 10: Diamictite outcrop at 18.5km.

Spot No.9, (20.00 Km): Taltung Formation, Hulandi Khola, (Left side of the road)

In this area, rocks of the Taltung Formation are represented by thick bedded, hard, highly jointed, dark grey, medium grained sandstone with black shale intercalations (photo-11). Shales are highly weathered and contain yellow sulphur leaching on the surface. The attitude of the bed is N60°E dipping 65° toward S.

Photo 11: Sandstone of Taltung Formation at 20km.

Spot No.10 (22.00 Km): Dumre Formation, (Right side of the road)

At this spot on the right side of the road, thick bedded, hard, compact green sandstone interbedded with bands of purple shale and dark grey shale of Dumre Formation are well exposed (photo- 12). Presence of thick bands of Dumre Formation is recognizable from distance, as the hill slope is covered by purple coloured colluvial materials. The rocks eroded on the ridge are deposited as colluvial fan deposit in the Hulandi Khola at 20km (photo13).

Photo 12: Green sandstone and purple shale of Dumre Formation at 22.0 km.

Photo 13: Colluvial Materials of Green sandstone and purple shale of Dumre Formation exposed at NW of Tinau-Bhaiskatta khola confluence.

Spot No.11 (23.30 Km): Fossiliferous Bhainskati Formation at Tallo Dumre (Right side of the road)

Massive, dark grey, soft mudstone (shale) of Bhainskati Formation is exposed in this area. The mudstone contains nummulites, turritella and other fossils (photo 14). Fossils are found in the rock lying on the middle of the small stream.

Photo 14: Fossiliferous mudstone of Bhainskati Formation at 23.3km.

Spot No.12, (27.30Km): Benighat Slate (Left side of the road).

Dark grey to black, laminated shaly slate of the Benighat Slate are exposed in this area. Laminations are more prominent on weathered surface (photo-15). On weathering, black laminations change to dark grey color and dark grey slate changes into yellowish grey slate. The surface of the outcrop is smoothened due to erosion. The bed has attitude of N50°W/ 45°N.

Photo 15: Dark grey to black slate of Benighat Slate at 27.3km.

Spot No13, (44.50 Km). Madi Phat (Right side of the road).

This is an alluvial valley developed by Tinau Khola and its tributaries like Sisne Khola, Dhobadi Khola, Rithe Khola, Sukhaura Khola etc. The valley consists of wide flat land and is known as Madi Phat (photo 16). It is the grain basket of Palpa district. The valley is more than 6km long in east-west direction and more than 4km in north south along the river valley. Hill spurs are present in between river vallies along the marginal parts of the valley. The photo is as seen from 44.5km from Butwal that is from northern ridge of the valley.

Photo16: Madi Phat of Palpa.

Spot No. 14, (56.00 km): Fold in Nourpul Formation, (Right side of the road).

Locally folded rocks of Nourpul Formation are exposed in this area. It consists of 5-15 cm thick banded white grey, pink calcareous quartzite interbedded with purple slate. Rocks are folded into local anticline and syncline (photo 17). The anticlinal axes are faulted. The local fault on the left side of photo has attitude of N60°E / 70°N and fault on the right side of photo has N80° W / 25°N. Continuation of the folding can be seen on the opposite side of the tributary.

Photo 17: Tight folding and faulting in Nourpul Formation.

Spot No.15, (72.00 Km): Benighat Slate, South of Galyang Bazar, (Left side of the road)

Fresh outcrop of thinly bedded dark grey to dark bluish grey, fine grained shaly slate with black laminations are well exposed in a small tributary, adjoining to the road

(photo-18). The beds are striking N80°W and dipping 30° toward North. Benighat Slates are widely distributed around Galyang area.

Photo18: Black slate of Benighat Slate exposed at 72.0 km.

Spot No.16, (83.50Km): Dhading Dolomite, (Right side of the road)

Vertical cliff of Dhading Dolomite is present in this spot (photo 19). This unit consists of white grey, light grey to dark grey fine grained, thick bedded (at places massive) dolomite. The exposure is more than 30m thick. Unlike limestone dominant Dhading Dolomite in the Kerabari area, dolomite is the dominant rock type in this area. The rock bed has general trend of N45°E dipping 15° toward NW.

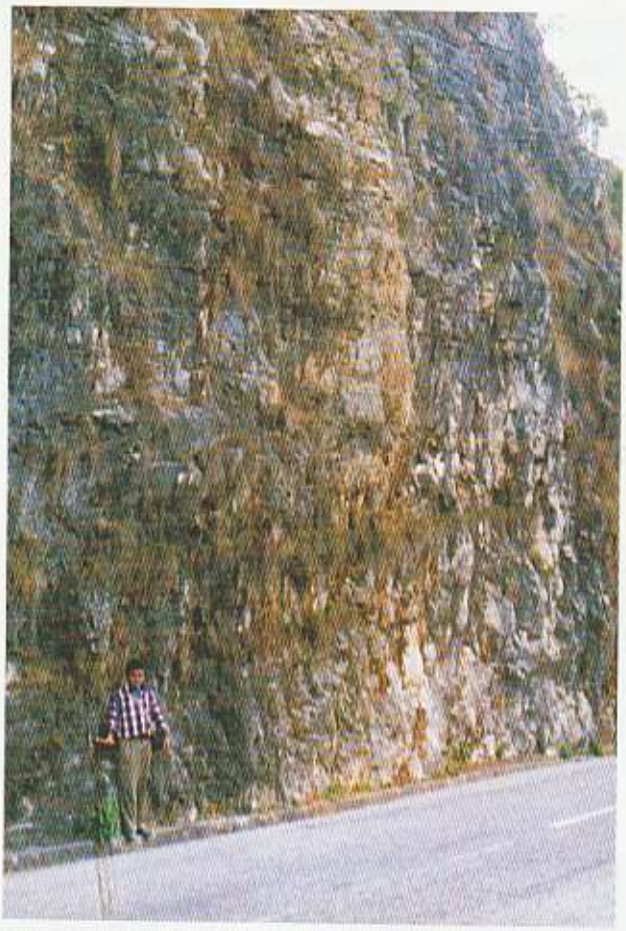

Photo 19: Vertical cliff of thick bedded dolomite exposed at 83.5km from Butwal.

Spot No.17, (107.50Km): Dandagaon Phyllite, (Right side of the road),

Medium bedded fine grained, green chloritic phyllite, at places phyllitic slate is exposed in this area (photo 20). The attitude of the bed is N60°W/ 30°N.

Photo 20: Green phyllite of Dandagaon Phyllite exposed at 107.5 km.

Spot No.18, (124.00Km): Quartzite of Dandagaon Phyllite, (Right side of the road)

Quartzite of Dandagaon Phyllite is well exposed in this spot. It consists of medium to thick bedded whitish grey, greenish grey quartzite with green slate intercalation (photo 21). The quartzite exposure is about 40m thick and is overlain by green phyllite. The rocks are highly jointed that cause frequent rock falls to the road. A retaining wall is constructed at the base of the jointed quartzite exposure (photo 21). The quartzite has trend of N75°W and dip 60° toward south.

Photo 21: Highly jointed quartzite with slate intercalation.

Spot No.19, (126.70Km): Soil Creep at Haripala, (Right side of the road),

In Haripala area, gabion wall is partly protruding out toward the road due to the effect of soil creep. The trees on the right side are tilted (affected by the creep) but the bamboos on the left side are not affected. Compared to reinforced cement concrete support wall, the gabion wall is less affected by creep as it has more flexibility and more water escape facilities.

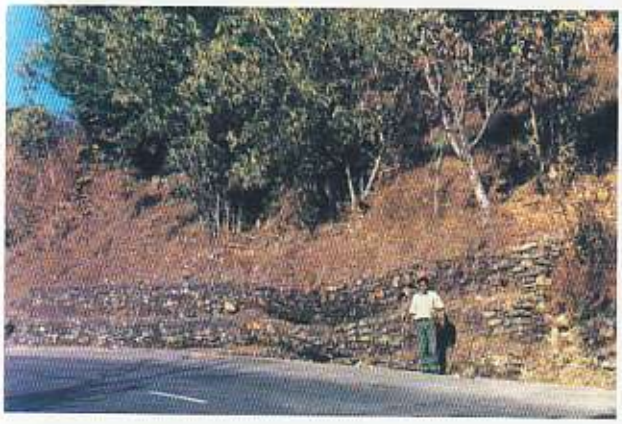

Photo 22: Bulging gabion wall due to soil creep.

Spot No.20, (129.50 Km): Fagfog Quartzite, east of Naudanda, (Right side of the road)

Thin to thick bedded, medium to coarse grained faint yellowish white to pinkish white crystalline quartzite (Fagfog Quartzite) is exposed on the right side of the road. Ripple marks are widely developed on this quartzite, which can be seen on the road cut section and quartzite blocks used in the road side drainage pavement. The quartzite beds have general trend of N70°W dipping 30°S. A number of criss cross fractures/ joints are present in the quartzite (photo-23).

Photo 23: Medium to thick bedded and jointed quartzite.

Spot No 21, (130.50 Km): Fagfog Quartzite , Right side of the road.

Ripple marks are developed in thickly bedded, yellowish grey; medium grained Fagfog Quartzite (photo24). The distance between ripples (from crest to crest) is 4-5cm, crest to trough height is 1cm. The ripple marks are of oscillation type with rounded crest. Weathered parts of the rocks break into fine yellowish sugary powder on hammering the rock. But on opposite side of the hill, where the rocks are less exposed to sun light, the rocks are not so weathered and soft. The whole mountain in this spot is made of Fagfog Quartzite and due to low susceptibility of the quartzite to soil formation, there is no vegetation at all or only sparsely vegetated in this mountain, called Bhalu Pahad (photo 25). As the rocks are highly jointed, the streams passing through the Fagfog Quartzite are found to contain numerous boulders and huge blocks of quartzite.

Photo 24: Ripple marks developed in Fagfog Quartzite

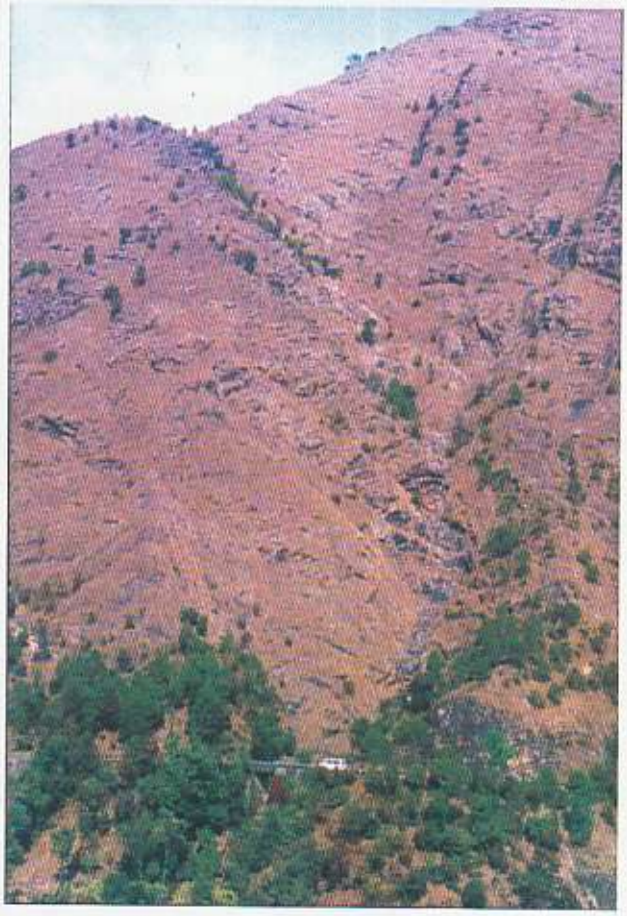

Photo 25: Bhalu Pahad made of Fagfog Quartzite with sparse vegetation.

Spot No. 22, (131.00Km): Reactivated Landslide in the process of stabilization, (Right side of the road)

This spot shows a part of old landslide, which was stabilized by tree plantation. After few years time the landslide was reactivated and once again it is in the process of stabilization, with the construction of about 30m long stone wall at the toe of the slide along the road (photo-26). Recent stabilization of the slide is indicated by the vertically standing small tree and bush in the slide area.

Photo 26: Landslide with protection wall at the toe of the slide.

Spot No. 23, (145.50 Km): Kunchha Formation (Left side of the road)

Thick piles of rocks of Kunchha Formation are exposed in this Spot No. 23. They consist of medium to thick bedded light greenish grey phyllites with dark grey laminations, argillaceous phyllites and gritty quartzitic phyllites with quartzite bands (photo-27). The phyllite beds are striking N45°W and dipping 15° toward south.

Photo 27: Medium to thick bedded light greenish grey phyllite.

Spot No. 24, (152.00 Km): Soil Creep at Bagaltari, (Left side of the road),

Creeping soil mass is pushing 1m wide, 2.5m high and 2 to 4m long reinforced cement concrete retaining wall towards the road side. The creep could have been started due to lack of adequate water outlet in the wall, creating high pore pressure in the soil, and poor foundation of the wall. There are few cm gaps between the blocks but no holes within the block (photo 28).

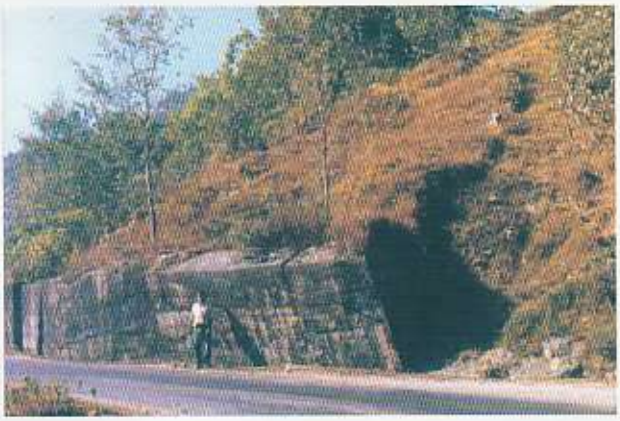

Photo 28: Soil creep pushing out the protection wall.

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Sheet II

GEOLOGICAL SECTION OF BUTWAL- POKHARA HIGHWAY (SIDDHARTHA RAJMARGA)
MOHORIYA - POKHARA PART

0 500 1000 2000 3000 5000 7500 meters

Synoptic view of Phewa lake of Pokhara

Medium bedded light greenish grey phyllite of Kunchha Formation.

Oscillation ripple marks in Fagfog Quartzite.

Green phyllite of Dandagoan Phyllite.

Soil Creep pushing out the protection wall.

Highly jointed quartzite of Dandagaon Phyllite.

LEGEND

SURFACIAL DEPOSITS (Quaternary to Recent)

- Flood Plain Deposits - Sand, silt, clay, gravel and boulder
- q — Quaternary Deposit- Sand, silt, gravel and clay
- db — Debris flow Deposits - Moderately cemented silty, sandy conglomerate consisting limestone, quartzite, schist, gneiss and granite

UPPER NUWAKOT GROUP (Palaeozoic)

- bg — Benighat Slate - Black and yellowish grey banded slate, black carbonaceous slate with grey limestone (jk)

LOWER NUWAKOT GROUP (Late Pre-Cambrian)

- dh — Dhading Dolomite- Grey dolomite, silicious dolomite with stromatolites
- np — Nourpul Formation - Grey, green and purple shaly slate with pinkish quartzite, grey to pink dolomites. Ripple marks and mudcracks are present
- ds — Dandagaon Phyllite:- Greyish green to silver grey phyllite, slate with quartzite..
- fg — Fagfog Quartzite:-White quartzite with reddish tints Ripple marks are present.
- kn — Kunchha Formation:- Greenish grey argillaceous/siliceous phyllites, gritty quartzitic phyllite with occassional quartzite beds.

- Settlement
- Fault
- Thrust
- Highway
- River with flood plain
- Syncline
- Anticline
- Lithological contact
- Hospital
- Petrol pump
- Hotel
- Location of places
- Spot height in meter
- Spot location
- Distance of road in kilometer
- Attitude of bed
- Flow direction of river

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Sheet 1

GEOLOGICAL SECTION OF BUTWAL- POKHARA HIGHWAY (SIDDHARTHA RAJMARGA)
BUTWAL- MOHORIYA PART

0 500 1000 2000 3000 5000 7500 meters

Fan deposit of purple shale and green sandstone of Dumre Formation.

Limestone Quarry.

Locally folded and faulted pink calc-quartzite and purple slate of Nourpul Formation.

Synoptic view of Madi phant from 44.5km

Black carbonaceous slate overlain by white grey limestone and dolomite.

A hydro-power dam in Tinau River at 4km.

Thick bedded sandstone of Lower Siwalik Formation.

LEGEND

SURFACIAL DEPOSITS (Quaternary to Recent)

- Flood Plain Deposits - Sand, silt, clay, gravel and boulder
- Quaternary Deposit- Sand, silt, gravel and clay

SIWALIK GROUP (Upper Miocene to Lower Pleistocene)

- Upper Middle Siwalik:- Medium to coarse grained sandstone, pebbly sandstone with siltstone mudstone and shale. Sandstone predominates.
- Lower Middle Siwalik:- Medium grained sandstone with siltstone and mudstone.
- Lower Siwalik:- coloured mudstone, siltstone with fine grey sandstone. Mudstone predominates.

TANSEN GROUP (Permo - Carboniferous to Oligocene)

- Dumre Formation:- Greenish grey sandstone with purplish and dark grey shale
- Bhainsekati Formation:- Mainly black shale with green and purple shale
- Amile Formation:- Dominantly sandstone with subordinate alternating sandstone shale, shale and limestone.
- Taltung Formation:- Sandstone, silty shale, tuffaceous shale, conglomerate
- Sisne Formation:- Diamictite, grey and purplish shale with sandstone and conglomerate

UPPER NUWAKOT GROUP (Palaeozoic)

- Benighat Slate - Black and yellowish grey banded slate, black carbonaceous slate with grey limestone (Jk)

LOWER NUWAKOT GROUP (Late Pre-Cambrian)

- Dhading Dolomites:- Grey dolomite silicious dolomites with stromatolites
- Nourpul Formation:- Grey, green and purple shaly slate with pinkish quartzite, grey to pink dolomites. Ripple marks and mudcracks present
- Dandagaon Phyllite:- Greyish green to silver grey phyllite, slate with quartzite
- Fegfog Quartzite:- White quartzite with reddish tints. Ripple marks are present
- Kunchha Formation:- Greenish grey argillaceous/siliceous phyllites, gritty quartzitic phyllite with occassional quartzite beds.

- Settlement
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- Thrust
- Highway
- River with flood plain
- Syncline
- Anticline
- Lithological contact
- Landslide
- Cliff
- Hospital
- Petrol pump
- Hotel
- Location of places
- Spot height in meter
- Spot location
- Distance of road in kilometer
- Attitude of bed
- Flow direction of river
- Suspension bridge
- Bridge

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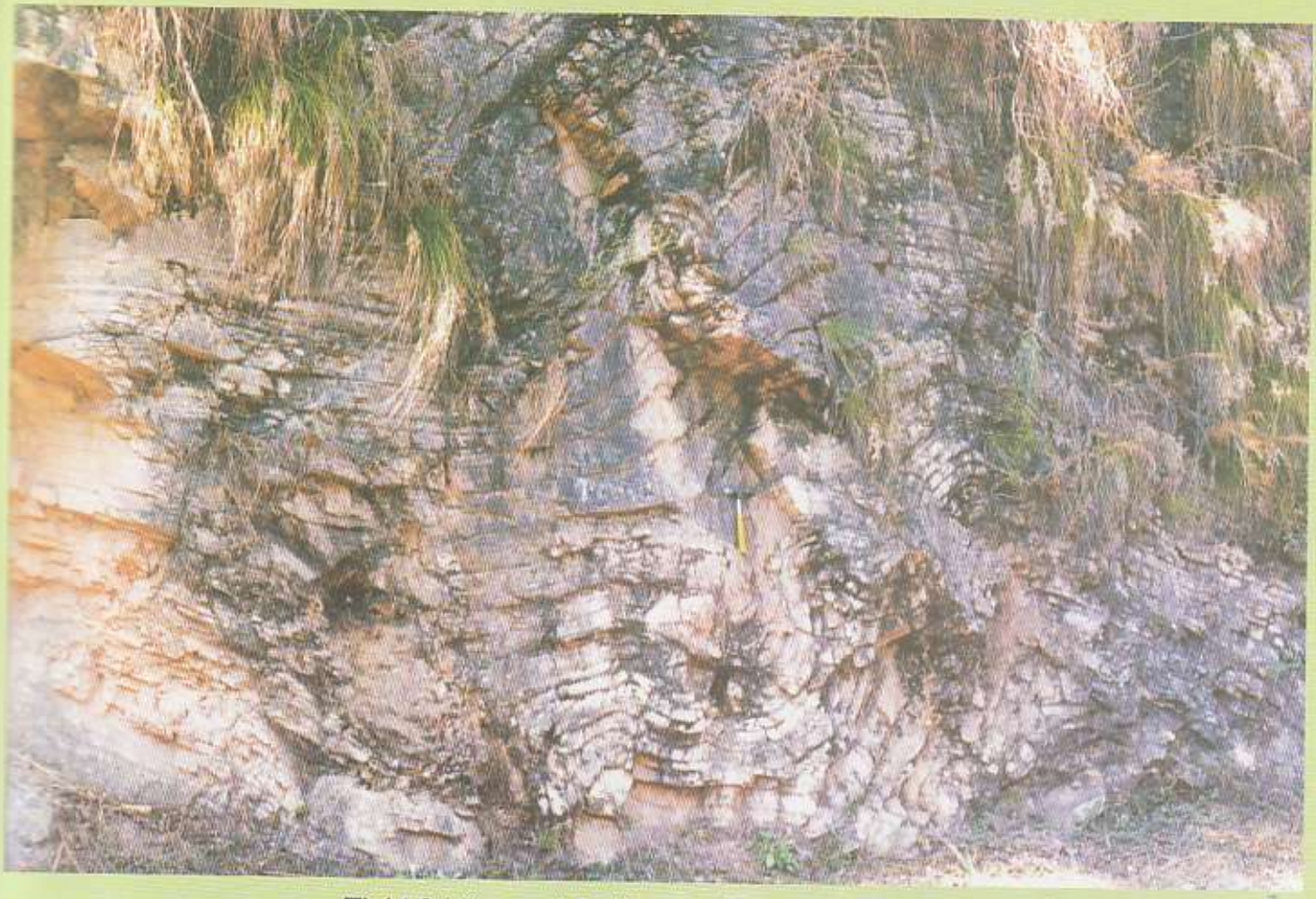

Tight folding and faulting in Nourpul Formation

David Fall, Pokhara

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Ministry of Industry, Commerce and Supplies
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June, 2007