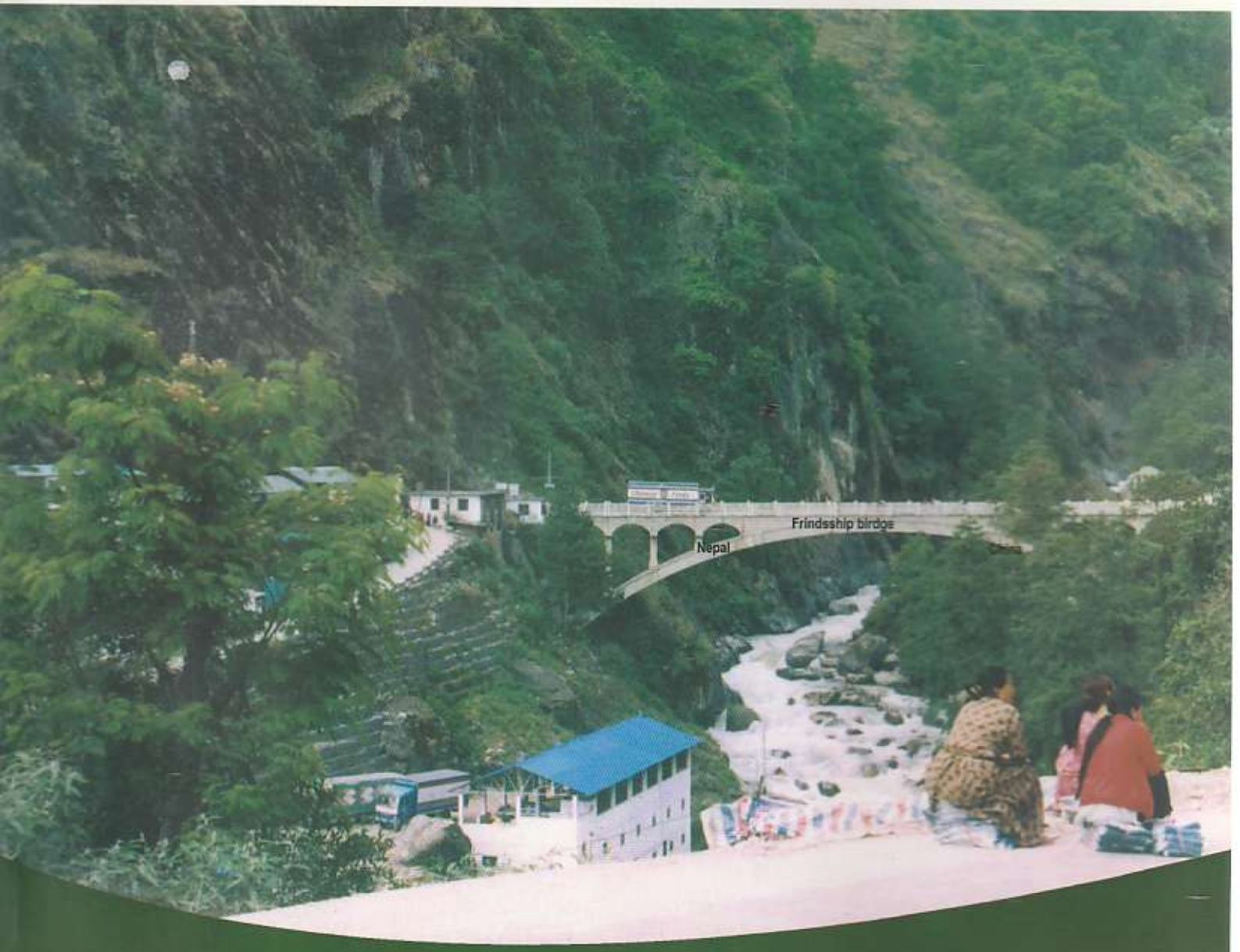
A GUIDE BOOK ON
GEOLOGICAL SECTION ALONG ARNIKO HIGHWAY (KATHMANDU – KODARI ROAD), CENTRAL NEPAL



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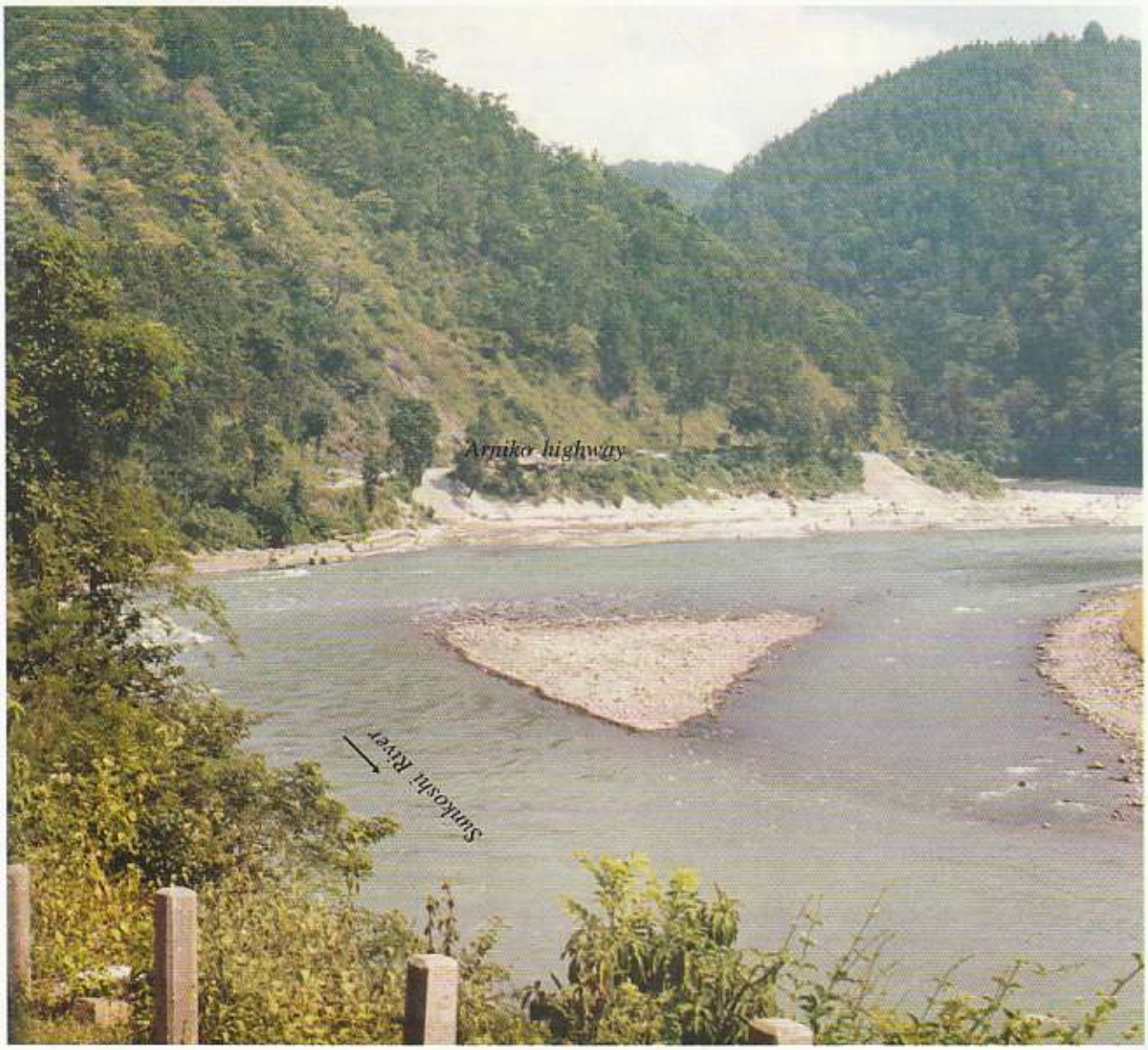

Arniko highway on the right bank of Sunkoshi River

A GUIDE BOOK ON GEOLOGICAL SECTION ALONG ARNIKO HIGHWAY (KATHMANDU – KODARI ROAD), CENTRAL NEPAL

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PREFACE

Many geo-scientists, researchers, tourists and other people interested in geology have desire to see and understand the geology of the Himalayas. However, it may not be possible for general visitors to get a qualified geologist/guide who can explain geological information of the area. Realizing such necessities, Department of Mines and Geology has planned to make available geological and geomorphological (including natural hazards) information of the major roads and Highways. The main aim is to help the engineers, Planners, Students, general people, trekkers and visitors to make themselves understand the geology and natural hazards of the area beside other touristic information. As a part of the program, the Department is going to publish the Guide Book of Arniko Highway.

The Arniko (Kathmandu – Kodari) Highway not only connects Kathmandu, the capital city of Nepal with Tibet Autonomous Region of the People's Republic of China, but also presents a geological section of the northern parts of the Midland Mountains and parts of the Higher Himalayas. Besides, this highway is going to be one of the Transit Route between Tibet and India.

This booklet contains general geological information about the Nepal Himalaya as well as brief information about the geomorphology and natural hazards along the road. Typical outcrop of geological formation, structure as well as other spot of general interest are briefly described with photograph. This guide book is prepared on the basis of existing geological maps, reports and field observations.

We express our sincere gratitude to Mr. N.R. Sthapit, Director General, for his inspiring advice, the facilities provided for the field observation and the publication of this guide book. We wish to extend our thanks to Mrs. Shova Singh for her contribution in preparation of the map by GIS tools.

1. GENERAL GEOLOGY OF NEPAL

Geology of Nepal Himalaya

The greater Himalaya extends for about 2500km from east to west. It is 230 to 320km in width and bounded between the Indogangetic Plain in the south and Tibetan Plateau in the north. Nepal Himalaya occupies almost 1/3rd part of the Himalaya range (about 800km). Nepal Himalaya can be divided into five distinct morpho-geotectonic zones from south to the north. Each of these zones/belts is clearly identified by their morphological, geological and tectonic features.

A. The Terai (Indogangatic Plain)

It is the alluvial plain in southern most part of Nepal. The sedimentary deposits of this plain belong to the last phase of the Himalayan upheaval and concealed beneath them are the northern fringe of Peninsular India and the southern fringe of the Himalaya. The area comprises Quaternary (Pleistocene to Recent) sediment deposits that consist of gravel, boulders, pebbles, sands, silt and clay with some remains of organic materials. The thickness varies from few hundred to over 1000m. This is the potential area for ground water. At greater depth, there are some chances to find petroleum and natural gas.

B. Sub-Himalaya (Churia Range/ Siwalik Hills)

This part of the Himalaya is bounded by Main Frontal Thrust (MFT) to the south and by Main Boundary Thrust (MBT) to the north. The MFT, however, is not clearly defined in most of the places rather it is concealed below the colluvial debris derived from the Siwalik Foothills and Gangetic alluvium. The Sub-Himalayan belt is 10 to 30km in width. It comprises of a thick sequence of molasses type sediments, which are largely fluviatile. The age assigned to these rocks is Mid-Miocene to Early Pleistocene.

The main rock types present in the Siwalik region are sandstone, mudstone, siltstone, shale and conglomerate. Some of the rock horizons/beds are fairly rich in plant as well as vertebrate and invertebrate fossils. Few coal lenses and small bodies of uranium ore are also recorded in Siwalik snndstone. This area could also be the possible source /reservoir area for natural gas and petroleum.

C.The Lesser Himalaya:

This part of the Himalaya is confined within Main Boundary Thrust (MBT) in the south and Main Central Thrust (MCT) to the north. This zone is 60 to 100km wide. It comprises of thick succession of largely unfossiliferous metasedimentary rock of Pre-Cambrian age and crystalline nappe intruded by a number of granite bodies of Ordovician Age. At places, like in Tansen and Surkhet area, some fossiliferous sedimentary rocks of Permo-Carboniferous to Oligocene age are recorded. This region is fairly complicated due to the presence of numerous folds, faults and thrust sheet structures.

The main rock types encountered in the Lesser Himalaya are limestone, dolomite, shale, sandstone, slate, phyllite, quartzite, schist, gneiss, granite, pegmatite and amphibolite. This part of the Himalaya is potential for metallic minerals like iron, copper, lead, zinc, nickel, cobalt, tin, tungsten, silver and gold. Similarly Nonmetallic/ Industrial minerals like limestone, dolomite, magnesite, phosphorite, marble, talc and fuel minerals like coal, natural gas and petroleum are potential in this area.

D. The Higher Himalaya

This part of the Himalaya is bounded to the south by Main Central Thrust (MCT) and to the north by South Tibetan Detachment Fault System (STDFS). This part of the Nepal Himalaya comprises mainly of high grade metamorphic rocks like garnet mica schist, kyanite/ sillimanite schist, quartzofeldspathic schist, gneisses, migmatite, quartzite and marble of Pre-Cambrian age and leucograintes of Tertiary age. It is believed that the Higher Himalaya is the root zone of the Crystalline nappe (eg. Kathmandu nappe) of the Lesser Himalaya.

A number of lead and zinc prospects/ deposits are recorded in the crystalline carbonate rocks and Ruby in calcareous schist.

E.The Inner Himalaya (Tibetan Tethys Zone)

It is bounded to the north by Tsangpo Suture Zone and to the south by STDFS. The rocks of this zone are represented by sandstone, limestone, dolomite and shale. These rocks are fairly rich in invertebrate fossils, especially cephalopods, gastropods and other micro fossils of Late Paleozoic to early Cenozoic age. Fossils of Carboniferous to Cretaceous age are more common in Mustang, Manang and Dolpa region.

This part of Nepal Himalaya appears to be prospective for brine water (salt), gypsum, natural gas and petroleum. Existence of burning natural gas in Muktinath and gas and oil seepage in Padukasthan, Dailekh are some of the examples. The northern boundary of Tethys sedimentary rock is marked by Indus-Tsangpo Suture, which signifies the collision trace of the Indian Subcontinent with Eurasia.

2. GEOMORPHOLOGY, NATURAL HAZARDS AND GEOLOGY OF THE AREA

2.1 GEOMORPHOLOGY

The Arniko highway passes through the middle mountains of the Nepal Himalayas. The road starts from Kathmandu (altitude of 1300m). After crossing a small hillock at Sanga, the road enters in to Banepa Valley. After about 29km. (Kathmandu, Banepa), the road passes through hilly part from Dhulikhel and ascends to Bhamarkot. From Bhamarkot, the road descends to Panch khal Valley. In Panch khal Valley, the soil has been deeply weathered to lateritic red clay. From Panchkhal Valley, the road again ascends to Lamidada. At Lamidada, the road for Melamchi goes toward north, the road for Palanchok Bhagawati goes toward south and main road continues toward east to Dolalghat, along southern bank of Cha khola. At Dolal ghat, Cha Khola, joins Indrawati River and then Indrawati joins Sun kosi River. Dolalghat bridge site is the lowest point of the Arniko Highway. After Dolalghat the road follows the river bank of the Sunkosi and Bhotekosi Rivers. At Friendship bridge, the end point of the road, the height is 1720m, while at Bhairab Kund peak, toward west is 4364m.

2.2 NATURAL HAZARDS

From Lamidada onwards the road passes through the soft rock of Benighat Slate and then passes through Mahabharat thrust. In this part, the slope of the mountain, through which the road passes is unstable. Inproper road cutting in soft and highly weathered rock and tectonic activity (fault/ thrust, frequent rock fall/ landslide during monsoon) toe cutting by the river and disturbance by the heavy traffic are causing the road unstable from time to time.

Besides, flash floods, debris flow had swept away tens of kilometers of roads and bridges. One of the historic example of debris flow is the presence of big gneiss boulder in the middle of Sun Kosi River bed. The size of the boulder seems to be bigger than present day width of the Sun Kosi River at some of its courses upstream. The boulder must have been brought to the present position by debris flow event in the past, when the river course was at much higher level.

Events of major glacier lake outburst floods (GLOF) took place on the Poique River (i.e. Bhote- Sun Kosi river in Nepal) in Xizang (Tibet), China in 1964 and 1981, (XuDaoming,1985). In 1964, the lake burst out by piping through the terminal moraine, the magnitude of the flow was not so big. At midnight on 11 July 1981, again, the lake burst out suddenly with much larger magnitude. The main flood lasted about 60 minutes and the amount of water was estimated to be 19 million m3. As a result of the flood Arniko Highway was washed out at many places, Sun Kosi Hydropower plant was partly damaged, the Friendship bridge and Phulping bridge were destroyed. The repair work was expensive as long stretches of the highway had to be raised above the GLOF flow level.

Sun Kosi River Flood of 30 June/ 1 July, 1987

The flood originated most likely from very intense precipitation. As a result, runoff, rill erosion, debris flow with large amount of gravels and boulders moved down to the confluence of Sun Kosi River with Bhote Kosi River and blocked the confluence creating a temporarty dam. The impounded water suddenly broke the temporary dam resulting to a flood with lot of debris. The flood had damaged the diversion structure and power house of the Sun Kosi Power Plant.

2.3 GEOLOGY

Hundred and fifteen km long Arniko Highway starts from the Kathmandu city and extends to Kodari the border line between Nepal and People's Republic of China. The highway passes through the Lesser Himalayan Metasediments, Central Crystallines and Quaternary Deposits of Kathmandu, Banepa and Panchkhal valley.

The Lesser Himalayan Metasediments are grouped into Nawakot Complex and Kathmandu Complex. (Stocklin,1981) Nawakot Complex is divided into the Lower and Upper Nawakot Groups and Kathmandu Complex is divided into Bhimphedi Group and Phulchauki Group. The Kathmandu Crystallines (Complex) is thrusted over the Nawakot Complex along the Mahabharat Thrust. The Kathmandu Nappe forms a synclinorium structure, the core of which is represented by the Phulchoki Syncline.

The rocks of Bhimphedi Group of Kathmandu Complex are exposed between Sanga Bhanjyang and south of Tatopani. This group is represented by the rocks of relatively higher grade of metamorphism as compared to the tectonically underlying Nawakot Complex . The grade of metamorphism gradually decreases upwards with the least effects of metamorphism in the upper most Tistung Formation, which consists of phyllites, meta-sandstones and minor limestones. A sense of increase in metamorphism can be recorded by studying the succeding lower members. The underlying Kulekhani Formation is composed of fine grained micaceous quartzites and biotite schists. At places small sized garnets are present. The increase in the grade of metamorphism is indicated by the increase in grain sizes, dominance of biotite and coarser grained garnet porphyroblasts in the schists of Kalitar Formation and the Crystalline Bhainse Dobhan Marbles. The lowermost member of the Bhimphedi Group is the Raduwa Formation with Chak Quartzites. The Raduwa Formation consists of coarse grained garnetiferous biotitic schists and micaceous quartzites. A band of gneissic rock is present in the Raduwa Formation near the Mahabharat Thrust. The effect of Mahabharat Thrust is also shown by the underlying Benighat Slate in the form of folding and intense crushing. Benighat Slate consists of dark grey to black slate, phyllite, carbonaceous slate and some limestone bands (Jhiku Carbonate bands).

The tectonically underlying Benighat Slate is folded intensely. As a result, a doubly plunging Syncline fold in the Mandan Danda (the

hill north of Cha khola), and a nearly westerly plunging syncline in the Palanchok Danda (the hill south of Cha khola) are present. They are separated by a very tight anticline, whose axis runs roughly along the Cha Khola course.

A regional fault which is known as Indrawati- Sun Kosi Fault has brought in juxtaposition the Benighat slate, the rocks of Upper Nawakot Group with the Kunchha Formation, which is the lower most member of the Lower Nawakot Group and consists light green to grey phyllites, phyllitic quartzites and metasandstone with occasional basic rocks. The rocks of Kunchha Formation are folded into a regional anticlinal structure, whose axis passes through Balephi area.

In the northern area, a near complete succession of the Nawakot Complex is believed to exist, although the rocks have been much altered by the effects of metamorphism associated with the Main Central Thrust. The Central Crystallines are well exposed just after MCT in the north of Tatopani area.

Stratigraphy of Central Nepal (after Stocklin &Bhattarai 1977)

Kathmandu Complex

Unit	Main Lithology	Approx.thic-kness (m)	Age.
2. Phulchauki Group.			
(d) Godavari Limestone.	Limestone, dolomite	300	Devonion.
(c) Chitlang Formation.	Slate	1,000	Silurian.
(b) Chandragiri Limestone.	Limestone	2,000	Cambri.-Ordov.
(a) Sopyang Formation.	Slate, Calc-phyllite	200	?Cambrian.
---------- Transitional contict ----------			
1. Bhimphedi Group.			
(g) Tistung Formation.	Metasandst.,Phyll.	3,000	Early Cambr.or,Late Precambr.
(f) Markhu Formation	Marble,Schist	1,000	Precambrian
(e) Kulikhani Formation	Quartzite,schist	2,000	Precambrian
(d) Chisapani Quartzite	White quartzite	400	Precambrian
(c) Kalitar formation	Schist,quartzitePart-ly garnetiferous.	2,000	Precambrian
(b) Bhaisedobhan Marble	Marble	800	Precambrian
(a) Raduwa Formation	Garnet-schist	1,000	Precambrian

---------- **Mahabharat Thrust**----------

Nawakot Complex

Upper Nuwakot Group			
(c) Robang Phyllites with Dunga Quarzites	Phyll., quartzite	200-1,00?	Palaeozoic
(b) Malekhu Limestone	Limestone,dolomite	800	Palaeozoic
(a) Benighat slates with Jhiku carbonate beds	Flate, Argill. Dolomite	500-3000	Palaeozoic
----------	Unconformity?----	----------	----------
Lower Nuwakot Group			
(e) Dhading dolomite	Slate,argill.dolomite	500-1,000	Late Precambrian
(d) Nourpul Formation	Phyll.,quartzite,dolomite	800	Late Precambrian
(c) Dandagaon Phyllites	Phyllite	1,000	Late Precambrian
(b) Fagfog quartzite	White quartzite	400	Late Precambrian
(a) Kuncha Formation	Phyll.,quartzite,gritstone & conglomerate	3,000+	Late Precambrian
---------- **Main Boundary Thrust** ----------			
A. SIWALIK GROUP			
(undifferentiated)	Shale, Sandstone, mudstones, congl.	Several Kilometres.	Neogene.

3. GEOLOGY ALONG THE ARNIKO HIGHWAY

On the basis of geology along the Arniko Highway, the Highway is divided into nine sectors.

Kathmandu valley

In this area, the highway passes mostly along the flat terrain of the Kathmandu valley. The Kathmandu valley is filled with fluvio-lacustrine sediments of Quaternary age. This sequence of slightly consolidated fluvio-lacustrine sediments of up to 600 m thickness, consists of peat, clay, silt, carbonaceous clay, sand and gravel. These sediments rest unconformably on Precambrian basement represented by metamorphic rocks.

The Kathmandu valley fill sediments is divided into eight stratigraphic units. Many vertebrate fossils such as *Hexaprotodon sivalensis, Elephas planifrons, Stegodon ganesa and Crocodylus sp.* and carbonised fossil wood, pollen are reported in these sediments.

Kathmandu - Sanga sector.

In this stretch of the highway mostly the rocks of the Tistung Formation are exposed. It is the youngest unit of the Bhimphedi Group. This formation consists of a fine clastic sequence of metasandstones, phyllites and sandy limestones with ripple marks and cross beddings. In this rock, though sericite and chlorite are the main metamorphic minerals, some biotites are also seen in the lower part of the formation.

Sanga - Dhulikhel sector

In this sector, the highway passes through the Banepa valley filled with Quaternary sediments and talus deposits along the valley edge. Rocks of Tistung Formation are exposed on the surrounding mountains

Dhulikhel - Panchkhal sector

The rock units of the Bhimphedi Group are exposed in this segment of the road. These rocks are metasandstones, phyllites and sandy limestones of the Tistung Formation, biotitic schists with impure marbles and quartzites of Markhu Formation and well bedded alternation of fine grained biotitic schists and impure micaceous light green, grey coloured quartzites of Kulekhani Formation.

Panchkhal valley

The road crosses the Panchkhal valley through its north-western part. The valley is filled with alluvial and partly lacustrine (?) deposits. Red clay is developed intensively in its northern sides.

Panchkhal - Cha Khola Fault (Mahabharat Thrust) sector

The rocks of the Bhimphedi Group are exposed in this segment of the road . Rocks of the Kulekhani Formation are underlain by those of the Chisapani, Kalitar, Bhainse Dobhan Marble and Raduwa Formations thus exposing the lower sequence of the rocks of the Bhimphedi Group. Chisapani Quartzite is composed predominantly of thinly bedded white, fine grained cross bedded quartzites while the Kalitar Formation is represented by two mica schists with ill differentiated intercalations of impure strongly micaceous quartzites. Garnet and amphibole minerals are common in the lower parts. Bhinsedobhan Marbles are coarsely crystalline well bedded to massive occassionaly containing fine mica. Coarse crystalline strongly garnetiferous two mica schists with several quartzite intercalations are the major rocks of the Raduwa Formation. Amphibole and pyroxene minerals are frequently associated. A band of coarse grained two mica gneiss is also associated with the Raduwa Formation

Cha Khola Fault - Indrawati Fault sector

In this stretch of the road the upper part of the Nuwakot Group namely the Benighat slates and Jhiku carbonates are exposed. Dark argillaceous slates / phyllites containing frequent intercalations of carbonaceous slates constitute the Benighat slates. Dark grey to black limestones, argillaceous limestones and dolomites occur as Jhiku beds, which form lenticular bodies within the Benighat slates.

Indrawati Fault - MCT sector

In this segment of the road the whole sequence of rocks of the Nuwakot Group are exposed. In this area, the Indrawati fault brings Kuncha Formation, oldest rock unit of the Nuwakot Complex in contact with the with Benighat slates.

Kuncha Formation comprises of phyllites, phylllitic metasandstones, gritty-phyllites and fine quartz-conglomerates of light green-grey colour. Layers of diabasic volcanic material are also locally recorded. Rocks of the Kunchha Formation are the most dominant rock type in this road section covering about 40 km of the road length. Fagfog quartzite is a fine to coarse grained white grey orthoquartzitte with several phyllite intercalations. The Dandagaon phyllites are distinctly darker than rocks of the Kuncha Formation mainly due to the presence of carbonaceous materials in the form of laminated calc-phyllites and occasional thin beds of dolomite.

The Nourpul Formation has white to pink strongly ripple marked quartzite, varigated slates and pink dolomites. The Dhading dolomite is well-bedded to massive light bluish grey, dense to fine crystalline dolomite containing stromatolites at many levels.
The Dhading dolomite is succeeded by the Benighat slates which is overlain by the Malekhu limestone composed of thin platy yellow

dense siliceous limestone beds with pale-green sericitic partings. The Robang Formation is predominantly phyllite and quartzite with chloloritic and amphibolitic metadiabases.

MCT - Nepal/China Border sector

This last stretch of the road passes through the rocks lying above the Main Central Thrust. These high grade metamorphic rocks are designated as the Central Crystallines. Just above MCT a band of Hadi Khola Schist occurs, which consists thin to medium bedded medium grained garnet-biotite schist, calc-schist with layers of quartzite and gneissic band. Hadi Khola Schist is overlain by thick pile of Dhad Khola Gneiss, which consists of porpyhroblastic gneiss, augen gneiss with thin bands of quartzites, schists and migmatitic gneiss.

4. OUTCROP (SPOT) DESCRIPTION

In the outcrop description, right side of the road indicates right side while driving from Kathmandu to Kodari. While driving from Kathmandu to Kodari, many interesting geological and geomorphological features like different rock types, folds/ faults and geohazards like landslides can be seen. Some of them are described below.

Spot No 1, (11 Km). Thimi Formation, Thimi (Left side of the road)

A huge outcrop of the sand, silt and clay (fluvio-lacustrine) sequences of Thimi Formation occurs in this point. The top 1.5-2 m thick soil sequence is composed of diatomatic clay, which is white in color and very light in density. Photo in map A.

Spot No 2, (31.00 Km.) Tistung Formation, (Right side of the road)

Light grey metasandstone with pinkish tints is well exposed at this point. Current beddings, graded beddings and ripple marks can be well observed at places. Occasionally intercalation of thin calcareous beds are reported at this point. At this point the trend of the bed is N80° W and dipping toward south by 55°.

Fine grainedMetasandstone of Tistung Formation.

Spot No. 3, (41.00 Km.): Kulekhani Formation, Dulalthok, (Left side of the road)

Medium to coarse grained, dark gray coloured muscovite, biotite schists. Minor cross-beddings and graded beddings can be seen in the quartzite. Beddings and schistosity planes of the schists show a strong luster and distinct crenulations and lineations. Elsewhere thin lenticular carbonate beds have been noticed. The attitude is N40° W and dipping toward south by 70°.

Steep dipping muscovite-biotite schist of Kulekhani Formation.

Spot No 4, (45.00 Km.) Laterite Deposit, Panch Khal valley.

Laterite (red clay) has been developed by deep weathering of the Panch Khal valley sediments. The country rock is Bhainsedovan Marble. Red Clay can be seen on both sides of the road.

Red Lateritic Soil in Panch Khal valley

Spot No 5, (46.00 Km.): Bhainsedovan Marble, Lamidanda bazar, (Right side of the road)

Coarse, compact, thick bedded white to gray coloured marble interbedded with weathered muscovite, biotite schists. The marble is massive in appearance but reveals fine layerings or poorly developed foliations when closely observed. It commonly contains micas and few pyrite, magnetite and galena. Thin garnetiferous schist bands have also been observed at places.

Bhainsedobhan marble out crop at Lamidanda Bazar.

Spot No 6, (47.30 Km.): Chak Quartzite of Raduwa Formation, (Right side of the road)

Light bluish grey to pinkish grey, fine grained, thin bedded Chak Quartzite occurs within the garnetiferous schist of Raduwa Formation. The quartzite has attitude of N30 W and dip toward west by 40°. In its upper part, the quartzite is found to be thrusted over the thick bedded schist of the Raduwa Formation. The underlying schist is striking at N40 W and dipping toward west by 42°.

Chak Quartzit of Raduwa Formation.

Thinly bedded Chak Quartzite thrusted over thick bedded schist of Raduwa Formation.

Spot No 7, (49.00 Km.): Slide Zone, Kalimati, (Right side of the road)

This spot was a heavily slided zone a few years back. Intensive slide protection works such as bioengineering works, tree plantation and drainage development with civil construction works were able to stabilize the slide (photos).

Landslide in highly sheared and crushed black slate of Benighat Slate. The landslide is the result of the Mahabharat Thrust, which passes through this area.

Same area after the stabilization of the landslide by using bio-engineering and civil structures.

Spot No 8 (54.00 Km.) Benighat Slates, (Right side of the road)

Thinly bedded calcareous black slates with white salt coating at the surface. Drag folds with axis 220°/30° and axial plane 170°/40° are seen.

Benighat Slate with white salt coating on the surface.

Spot No 9, (56.50 Km.) Jhiku Carbonates (Right side of the road)

Light gray brownish thinly bedded carbonate beds interbedded with shales. Carbonate beds up to 1 m thick can be seen along the road. The attitude of the bed is NS/35°W.

Limestone of Jhikhu carbonate bed at Dolalghat at the right bank of Indrawati River.

Spot No 10, (58.00 Km.) Indrawati Fault (Right side of the road)

One of the major faults of this region is the Indrawati fault which is clearly seen near the culvert. The fault separates the black slates of Benighat Slate from the green gritty phyllites and quartzites of the Kunchha Formation. The actual fault zone is about 10 m thick. At this spot black slates have attitude N20°W/35°NE and phyllites have N40°W/65°SW.

Indrawati Fault separating the overlying Kunchha Formation from underlying Benighat Slate.

Spot No. 11. (61.5 Km.) Kunchha Formation, (Left side of the road)

The exposure is of green to greenish gray hard and compact gritty phyllites of Kunchha Formation. Individual bed is 0.5 to 1 m thick. Grits size varying from 0.5-2 mm are seen specially in the left corner of the outcrop. The attitude of the rock is N65°E/55°S.

Gritty Phyllites of Kunchha Formation.

Spot No 12 (61.7 Km,) Simle

Bio-engineering works to stabilize the landslide along with limited civil works such as retaining walls and drainage have been highly successful in controlling the landslides along the highway.

Bio-engineering activities to stalibilize the landslide along the Arniko high way at 61.7km.

Spot No 13, 71.00 Km, Large boulder brought by GLOF, Bhainse, (Right side of the road)

At this spot at a distance of about 50-100 m from the road, a large boulder of more than 15m diameter of granitic gneiss is seen. The size of the boulder seems to be bigger than some part of the Bhote Kosi river course at present. The boulder is believed to be brought down by past GLOF/debris flow events along the Bhote Kosi River.

Big boulder of gneissic granite in the middle of the Sun Kosi river bed.

Spot No. 14 (98.00 km) Fagfog Quartzites-

Light green, massive thin to medium bedded (10-30 cm), compact, hard fine to medium grained quartzite. Ripple marks, mostly assymmetrical, are noted with height 3-4 mm and width-0.5-1 cm. Quartzite is micaceous along bedding plane. Green and gray phyllites are intercalated towards southern or lower contact. Total thickness of the unit is less than-100m. The attitude is N80°W dipping toward N by 15°.

Cliff of Fagfog Quartzite overlying Kunchha Formation.

Spot No.15, (99.50 Km,) Dandagaon Phyllite (Right side of the road)

Green to greenish gray phyllite with fine grained light grey to greenish grey quartzite. Rock in general is compact, highly foliated. At places boudinage-like structures of phyllite surrounded by quartzite layers, are seen.

Greenish grey phyllite of Dandagaon Phyllite.

Spot No 16 (102.00 Km.) Nourpul Formation, Chaku khola, (Right side of the road)

White to milky white, compact, fine to medium grained, massive, at places cryptocrystalline calcareous quartzite. Beds are thin (10 to 20cm) to thick (0.5-1m). White quartzite with brownish gray phyllitic laminations are frequently seen. purple color is represented only by slightly pinkish tint in some layers of quartzite. The rock forms a steep cliff forming gorge of about 2 km.long. The attitude is N50°W dipping toward N by 10°.

Cliff of milky white quartzite of Nourpul Formation at 102.km.

Spot No 17, (103.00 Km.) Dhading Dolomite, North of Chak khola, (Right side)

Gray to light gray, white, siliceous dolomite, fine to cryptocrystlline, compact, hard medium to thick bedded dolomite. Rock is not typical Dhading. It is more siliceous at places almost quartzitie. The attitude is N50°W dipping toward N by 10°.

Grey dolomite cliff of Dhading Dolomite

Spot No 18, (109.30 Km.) New Larcha Cause way

A bridge on Larcha Khola, police station and a small market were washed out by flash floods of Bhairab Kund Khola in 1997, leaving only small foundation part of the bridge. In the photo remnants of previous bridge and police station can be seen.

Larcha Cause way with remnants of previous bridge and police station.

Spot No 19 (110.00 Km.): Malekhu Limestone, Larcha, (Left side of the road)

Gray to greenish gray, fine to medium grained limestones interbedded with thin, gray to dark gray chloritic phyllite. The intercalation is homogenous both near the upper & lower contact zones while the thickness of dolomite beds reaches up to 1m in the central part of the formation. Near the upper part limestone and phyllite are 1 to 2 cm thick and intercalated (like calc schist). The attitude of the beds is N80°E dipping toward N by 30°.

Thin bedded limestone intercalated with chloritic phyllites, beds are thicker toward north.

Spot No 20A (110.30 Km.) Debris Flow Deposit, (Larcha)

Debris Flow deposit, deposited by a small tributary of Bhote Kosi River on the other side of the Bhote Kosi Hydro Power Intake site. If preventive measures are not taken in time, future debris flow may endanger the life of the Bhote Kosi Hydro Power Plant. The debris flow reoccurred on 4th of Jestha, 063 and wiped out about 60m of the road and deposited the debris consisting of big boulders, gravels and clay in the place. The debris flow blocked the road for at least two days.

Debris flow deposit, Larcha.

Debris flow is going to block Bhote Kosi River and damage the intake site of Bhote Kosi Hydro Power, power house.

Spot No 20B , 110.30 Km. Bhote Kosi Hydro Power Intake site.

Bhote Kosi intake site.

Spot No 21, (111.00 Km.): Robang Phyllite, Tatopani, (Left side of the road)

Dark gray to almost black, sometimes greenish gray thin bedded phyllite with intercalations of medium to fine grained white quartzite beds in the upper part. Siliceous beds are common. Rock is weathered. In this area Robang formation looks more like Benighat Slate with white salt encrustation on the surface.

Robang Phyllite

Spot 21 B (111.5km) Boulder Fall on the road.

The hill slope, west of the road, is covered by scree of previous landslide. The scree consists of gravels to big boulders. A heavy rain on 4th of Jestha, 2063 caused the rolling down of a boulder of more than 2.5m diameter. The boulder landed on the road, Just 1.5m. to the small house on the road side.

Boulder fall on the road, near Tato Pani.

Spot No 22 (112.00 Km.). Main Central Thrust Zone, Tatopani, (Left side of the Kathmandu to Kodari Road).

At this point the MCT zone is 150m thick. On the basis of the rock types the Main Central Thrust Zone (MCT) has been grouped into 3 units.

Unit1. At the southern end of Tatopani Bazar, black carbonaceous phyllite (Robang Phyllite) is overlain by greenish grey to dark grey chloritic schist, biotitic schist with bands of white grey often with pinkish tint quartzite bands. The biotites in the schist are generally fine grained.

Unit2. The chlorite-biotite shist is overlain by fine to coarse grained muscovite-biotite schist with fine grains of feldspar. MCT 1 has been referred in between Unit1 and Unit2.

Unit3. Further north Unit 2 is overlain by hard, greyish white (silicious) and dark grey (biotitic) augen gneiss interbedded with light grey to dark grey medium grained schist. Silica rich schist band is light grey whereas biotite rich schist band is dark grey in color. It also contains thin to medium bedded white grey quartzite bands. MCT2 has been referred in between Unit 2 and Unit 3. Famous Tatopani (hot spring) occurs in Unit 3 in this area.

Main Central Thrust Zone, Tatopani Bazar, left side.

Spot No 23, (114.00 Km). Dhad Khola Gneiss Formation, Near Miteree Sangu, (Left side of the road)

Highly compact medium to coarse grained thick bedded biotite-muscovite gneiss, augen gneiss are interbedded with 20-40 cm thick beds of medium to coarse grained garnetiferous schist. The attitude of the foliation is N50W°/40°N.

Exposure of thick bedded kyanite bearing gneiss.

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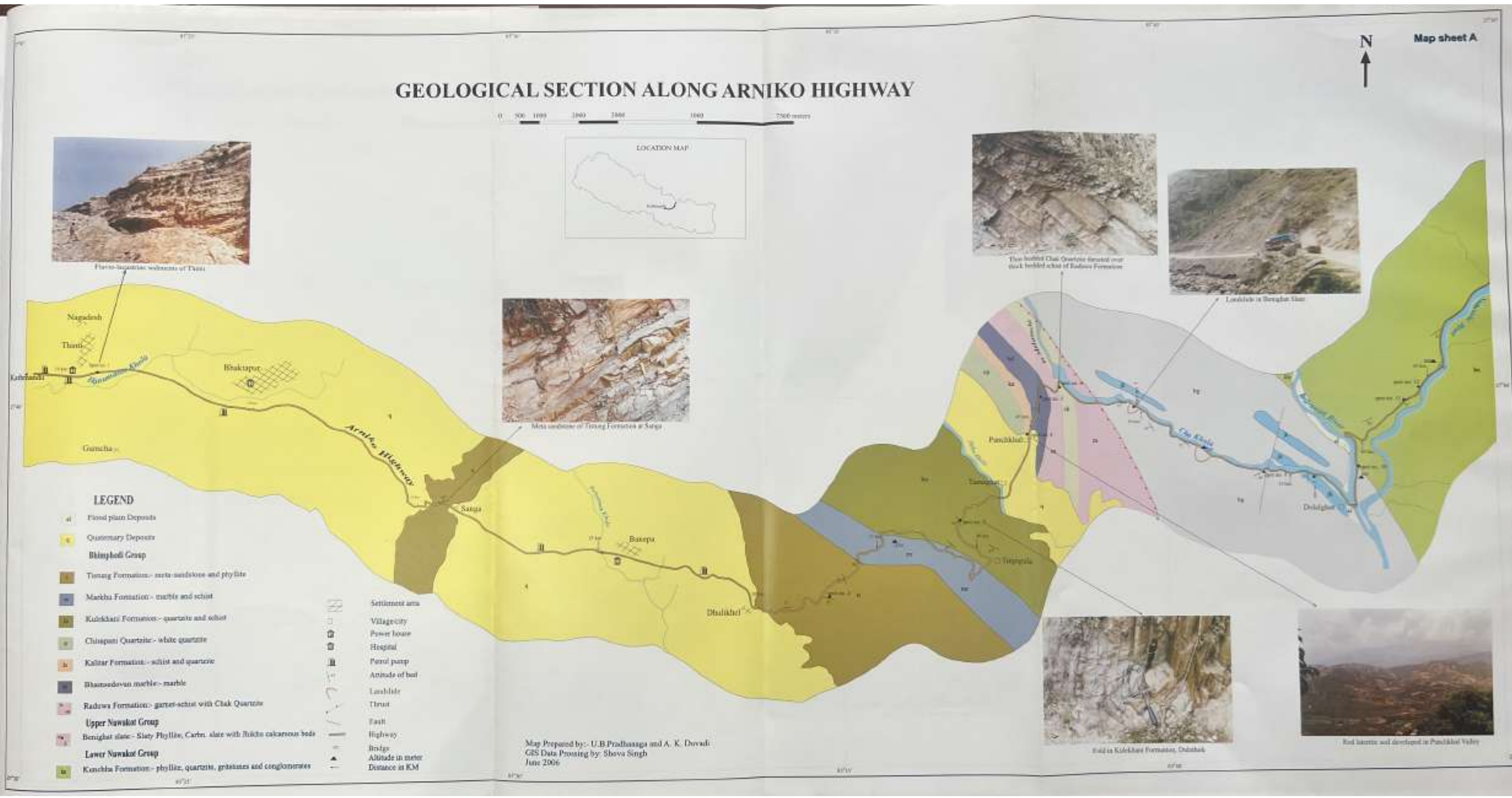

Map sheet A
N
GEOLOGICAL SECTION ALONG ARNIKO HIGHWAY
LOCATION MAP
Fluvio-lacustrine sediments of Thimi
Meta sandstone of Tistung Formation at Sanga
Thin bedded Chak Quartzite thrusted over thick bedded schist of Raduwa Formation
Landslide in Benighat Slate
Fold in Kulekhani Formation, Dhulikhel
Red lateritic soil developed in Panchkhal Valley
Nagadesh
Thimi
Kathmandu
Bhaktapur
Arniko Highway
Gurucha
Sanga
Banepa
Dhulikhel
Panchkhal
Dolalghat
LEGEND
Flood plain Deposits
Quaternary Deposits
Bhimphedi Group
Tistung Formation:- meta-sandstone and phyllite
Markhu Formation:- marble and schist
Kulekhani Formation:- quartzite and schist
Chisapani Quartzite:- white quartzite
Kalitar Formation:- schist and quartzite
Bhainsedovan marble:- marble
Raduwa Formation:- garnet-schist with Chak Quartzite
Upper Nuwakot Group
Benighat slate:- Slaty Phyllite, Carbn. slate with Jhiku calcareous beds
Lower Nuwakot Group
Kunchha Formation:- phyllite, quartzite, gritstones and conglomerates
Settlement area
Village/city
Power house
Hospital
Petrol pump
Attitude of bed
Landslide
Thrust
Fault
Highway
Bridge
Altitude in meter
Distance in KM
Map Prepared by:- U.B Pradhanaga and A. K. Duvadi
GIS Data Prosing by: Shova Singh
June 2006

GEOLOGICAL SECTION ALONG ARNIKO HIGHWAY

Map sheet B

N

0 500 1000 2000 3000 5000 7500 meters

LOCATION MAP

LEGEND

Upper Nuwakot Group

- rb — Robang Phyllite:- phllite and quartzite
- ml — Malekhu Limestone:- limestone and dolomite
- bg / jk — Benighat slate:- Slaty Phyllite, Carbn. slate with Jhikhu calcareous beds

Lower Nuwakot Group

- db — Dhading Dolomite:- stromatolitic dolomite
- np — Nourpul Formation:- phyllite, quartzite and dolomite
- da — Dandagaon phyllite:- phyllite
- fg — Fagfog quartzite:- white quartzite
- kn — Kunchha Formation:- phyllite, quartzite, gritstones and conglomerates

Crystalline Group

- hdk — Hadi Khola Schist:- garnet-biotite schist, calcareous schist with quartzite and gneiss bands
- dhd — Dhad Khola Gneiss:- porphyroblastic gneiss, augen gneiss with quartzite and schist and migmatitic gneiss

- Village/City
- Dead burnt magnesite plant
- Bangi jump
- Power house
- Petrol pump
- Altitude of bed
- Syncline
- Anticline
- Landslide
- MCT — Main Central Thrust
- Thrust
- Highway
- Talc Deposit
- Altitude in meter
- Distance in KM
- Bridge

Hot spring of Tatopani area

Waterfall at 113.0 Km

Debris flow deposit (01/10/05) Debris flow deposit (19/05/06) wiping out the existing road

Dead burnt magnesite plant at Lamosangu

Big boulder of gneissic granite in the middle of the Sankoshi River

Barhabise
Khadichaur
Lamosangu
Balephi
Sakuta

Map Prepared by:- U.B.Pradhanaga and A. K. Duvadi
GIS Data Processing by: Shova Singh
2006

Waterfall at 113.0 Km

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