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Geology of the Kharidhunga–Thokarpa area, Central Nepal, Lesser Himalaya

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ABSTRACT

In the Kharidhunga–Thokarpa area, the rocks of Lower Nawakot Group are exposed. The lowermost unit of the study area is the Kuncha Formation. It is composed of a more than 2,500 m thick monotonous sequence of grey to green phyllite, quartzite, and 'gritty' phyllite. Green-grey quartzite is seen in the upper part of the formation. Small (0.5 mm) garnets of brown colour occur in the upper part of the formation. The Fagfog Quartzite has a sharp contact with the underlying Kuncha Formation and consists of fine- to coarse-grained pure white quartzite with thin to very thin bands of grey and green phyllite. The Dandagaon Phyllite follows the Fagfog Quartzite and contains mainly thin bands of grey-green and dark grey phyllite. The Nourpul Formation is separated from the underlying Dandagaon Phyllite by a yellow quartzite band. The Nourpul Formation consists of dark grey carbonaceous slate and phyllite with some intercalations of calcareous phyllite and calcareous quartzite in the upper part. The augen gneiss, granitic gneiss, and banded gneiss are found within the Nourpul Formation mainly in the eastern part of the study area. The Dhading Dolomite overlies the Nourpul Formation and is found mainly around the Kharidhunga area as wavy and massive beds and lenses of dolomite, magnesite, and talc with sporadic quartzite bands. The rock is highly fractured and crystalline. The Pheda Khola and Ghatte Khola Faults have a significant control on the landscape of the study area.

The Quaternary deposits of the Kharidhunga area are classified into the Balephi, Thumpakhar, Dandapakhar, Bonch, Rolekharka, and Dangdunge Formations, respectively from bottom to top. Of which, the first two formations correspond to debris flow and river channel deposits, whereas the remaining ones represent the deposits of retreating glacier. Generally, the cohesion and plasticity of these sediments increases with their increasing geological age.

INTRODUCTION

The Kharidhunga–Thokarpa area lies in the inner Lesser Himalaya of Central Nepal between longitudes 86°45' and 86°60' E, and latitude 27°37' and 27°45' N. The Kharidhunga magnesite deposit, which is one of the world's largest magnesite deposits, lies in this area (Fig. 1). This paper highlights the geological and engineering geological studies carried out at Kharidhunga and in its surrounding area. The study also focuses on the rock and soil types and their engineering geological properties.

Hagen (1969) was the first to record the magnesite mineralisation at Kharidhunga. Manandhar (1965) and a group of German geologists (Grundstofftechnik GmBh 1973) carried out detailed economic geological investigations and paved the way for establishing the first magnesite mine in Nepal. Maruo et al. (1973) included the 'gritty' phyllites of the area in their Chaunri Sandstone–Phyllite Zone and the gneiss and schist in the Melung Augen Gneiss. Poudyal and Shrestha (1977), while studying the geology and geochemistry of the Dolkha, Ramechhap, and Solukhumbu areas, included the rocks into the low-grade and high-grade zones. Sharma (1980) mapped the area and introduced seven rock units. He also showed a large magnesite deposit.

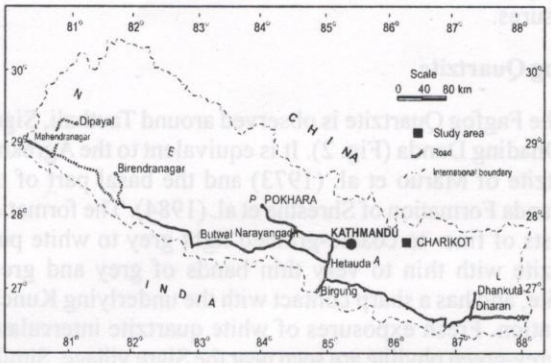


Fig. 1: Location map of the study area

Shrestha et al. (1984) complied a regional geological map of Central Nepal and included the 'gritty' phyllite, slate, and dolomite in their Ranimatta Formation, and the gneiss and schist in the Ulleri Gneiss Formation. Jnawali (1987) carried out geological mapping in the eastern portion of the study area and divided the rocks into the Central Crystalline Group, MCT Group, Upper Nawakot Group, and Lower Nawakot Group. Dangol (1992) studied the mineralogical and geochemical characteristics of the talc and magnesite deposits of the area, and classified talc of the Kharidhunga magnesite deposit into syngenetic and epigenetic types.

REGIONAL GEOLOGY

The rocks of the study area belong to the Lower Nawakot Group (Stöcklin and Bhattarai 1977). It consists of the following formations from bottom to top, respectively (Fig. 2; Table 1).

Kuncha Formation

The Kuncha Formation (Stöcklin and Bhattarai 1977) is distributed mainly in the western part of the study area. This formation was initially reported from west Nepal by Bordet (1961) as "Serie de Kunchha". It was included in the Chaunri Sandstone–Phyllite Zone of Maruo et al. (1973) and the Ranimatta Formation of Shrestha et al. (1984).

The Kuncha Formation is considered the oldest rock unit of the study area. It is exposed around the Balephi, Pakhar, Thokarpa, and Chaubas villages (Fig. 2). The formation is composed of more than 2,500 m thick quite monotonous sequence of grey to green phyllite, quartzite, and 'gritty' phyllite. The proportion of quartzite is higher at the Thumpakhar, Balephi, and Thokarpa villages whereas phyllite predominates at the Dandapakhar, Thulopakhar, Tamche, and Lisankhu villages. Quartz veins (up to 80 cm wide) are frequently found in the phyllite, and most of them are injected along the foliation. Green-grey quartzite is seen in the upper part of the formation, especially around Thulopakhar and Sundanda. Small (0.5 mm) grains of brown garnet are also encountered in the upper part of the formation, especially around Tauthali and in the lower Sildhunga Bazaar area. There is a significant lateral variation in grain size of the 'gritty' phyllite and quartzite. The rocks are intensely folded into a number of small-scale folds. A conspicuous lineation developed essentially in NE–SW direction is seen in many exposures.

Fagfog Quartzite

The Fagfog Quartzite is observed around Tauthali, Sigre, and Dhading Danda (Fig. 2). It is equivalent to the Agrekhar Quartzite of Maruo et al. (1973) and the basal part of the Naudanda Formation of Shrestha et al. (1984). The formation consists of fine- to coarse-grained light grey to white pure quartzite with thin to very thin bands of grey and green phyllite, and has a sharp contact with the underlying Kuncha Formation. Fresh exposures of white quartzite intercalated with grey-green phyllite are seen near the Sigre village. Similar rocks are also exposed in the Dhading Danda village and the Gotang Khola. Thin bands of grey-green phyllite are observed in the middle part of the formation at Tauthali, Sigre, and Dhading Danda. On the way to Gairigaon from Tauthali, graded bedding is seen. The Fagfog Quartzite ranges in thickness from 250 to 800 m and it almost pinches out in the Sildhunga area.

Dandagaon Phyllite

The lithology of the Dandagaon Phyllite in the Kharidhunga area is slightly different from that of the type area in Central Nepal, where it is made up of a phyllite-dominated succession (Stöcklin and Bhattarai 1977). The formation is equivalent to the Deurali Limestone of Maruo et al. (1973) and the upper part of the Naudanda Formation of Shrestha et al. (1984).

This formation is made up essentially of thin bands of grey-green and dark grey phyllite. Light grey and grey siliceous dolomite is also observed in this formation at Sildhunga and Dhading Danda. Thin to thick beds of dolomite are present at Sildhunga and at the lower part of the Tauthali village. The siliceous dolomite contains laminae of grey dolomite alternating with quartzite and calcareous phyllite. Micaceous partings in quartzite and dolomite are very common. The Dandagaon Phyllite ranges in thickness from 300 to 800 m.

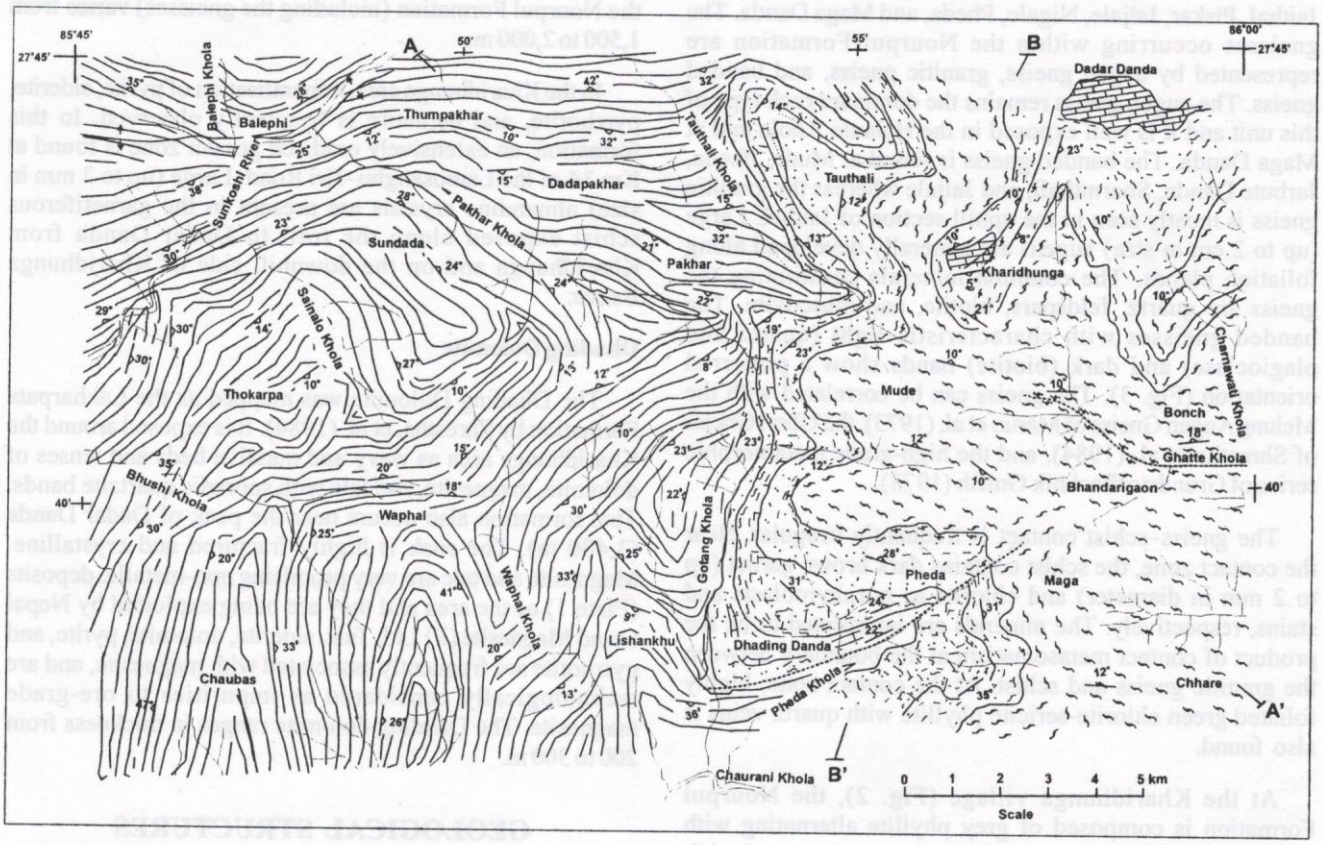
Nourpul Formation

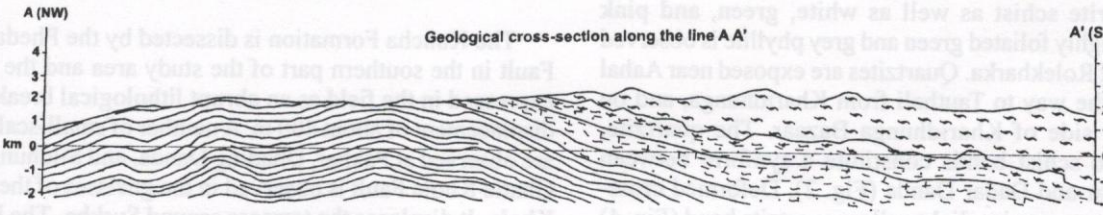
The Nourpul Formation is equivalent to the Ghanapokhara Formation of Shrestha et al. (1984) and the upper part of the Deurali Limestone of Maruo et al. (1973). It is separated from the Dandagaon Phyllite by a yellow quartzite band. This formation consists of dark grey carbonaceous slate and phyllite with intercalations of calcareous phyllite and calcareous quartzite in the upper part. Some bands of white crystalline quartzite with micaceous parting are also present in this formation. The Nourpul Formation is exposed around Sildhunga and Tauthali, Dhading Danda, and in the southern part of the Pheda village. The rocks are highly crushed and jointed. Quartz veins (up to 75 cm) are developed along the foliation.

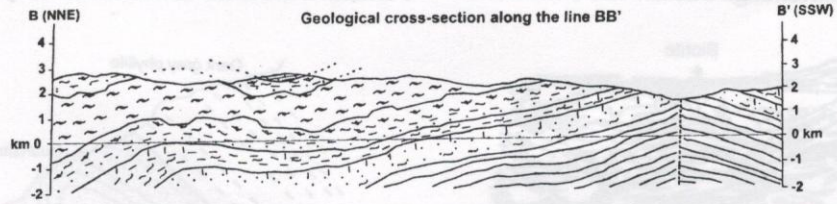
Most of the eastern part of the study area is occupied by gneisses, which are typically seen at the Mude village on the Lamosanghu–Jiri Road (at Km 25) and also at Tauthali,

Table 1: Lithostratigraphy of the Kharidhunga–Thokarpa area, Central Nepal

Geological age	Formation	Lithology	Thickness, m
Precambrian	Dhading Dolomite	Grey dolomite with magnesite and talc	200–300
	Nourpul Formation with banded and augen gneiss	Dark grey slate and quartzite with banded and augen gneiss	1,500– 2,000
	Dandagaon Phyllite	Grey-green and dark grey phyllite with a few bands of light grey siliceous dolomite	300–800
	Fagfog Quartzite	Light grey to white quartzite	250–800
	Kuncha	Grey and green-grey phyllite and quartzite	>2,500







Legend

Dhading Dolomite
Irregular massive beds and tongues of dolomite, magnesite, and talc with occasional quartzite bands

Nourpul Formation
Pink and yellow quartzite, dark gery slate and phyllite with intercalation of calcareous phyllite and quartzite, banded gneiss and augen gneiss in middle portion of the formation

Dandagaon Phyllite
Thin beds of grey-green phyllite and dark grey phyllite, siliceous dolomite and grey phyllite

Fagfog Quartzite
Dominantly white quartzite intercalated with grey pbyllite

Kuncha Formation
Greenish grey gritty phyllite and grey quartzite with a few bands of white quartzite

Anticline

Syncline

Fault

Geological contact

Foliation

Fig. 2: Geological map and cross-sections of the Kharidhunga–Thokarpa area

Jaithal, Piskar, Jaljale, Nigale, Pheda, and Maga Danda. The gneisses occurring within the Nourpul Formation are represented by augen gneiss, granitic gneiss, and banded gneiss. The augen gneiss remains the dominant rock type of this unit and it is well exposed in the Halaule Khola and at Maga Danda. The banded gneiss is found at Mude, Pheda, Jarbute Danda, Sharmthali, and Jaljale whereas the granitic gneiss is mostly seen in the uphill section of Jaithal. Large (up to 2 cm in size) augens are generally developed along foliation planes. The common minerals constituting the gneiss are quartz, feldspars, biotite, and muscovite. The banded gneisses with characteristic light (quartz and plagioclase) and dark (biotite) bands show a preferred orientation (Fig. 3). The gneiss can be correlated with the Melung Augen Gneiss of Maruo et al. (1973), the Ulleri Gneiss of Shrestha et al. (1984), and the high-grade metamorphic series of Grundstofftechnik GmBh (1973).

The gneiss–schist contact is frequently irregular. Near the contact zone, the schist contains dark brown garnet (up to 2 mm in diameter) and chlorite as porphyroblasts and stains, respectively. The minerals are interpreted to be the product of contact metasomatism at the boundary between the granitic gneiss and schist. At the contact zone, highly foliated green chlorite-sericite phyllite with quartz veins is also found.

At the Kharidhunga village (Fig. 2), the Nourpul Formation is composed of grey phyllite alternating with garnet-chlorite schist as well as white, green, and pink quartzite. Highly foliated green and grey phyllite is observed southwest of Rolekharka. Quartzites are exposed near Aahal Bazaar, on the way to Tauthali from Kharidhunga, and on the western side of Kharidhunga Bazaar. The quartzite, phyllite, and schist bands constitute a synform between Aahal Bazaar and Dadar Danda (Fig. 2). Deformed cross-laminations are seen in a light yellow quartzite band (Fig. 4) exposed northeast of Kharidhunga Bazaar. The thickness of the Nourpul Formation (including the gneisses) varies from 1,500 to 2,000 m.

In the Kharidhunga area, mineralisation of pyrite, siderite, pyrrhotite, and hematite is frequently observed. In this formation, an extensively oxidised gossan zone is found at Km 34 of the Lamosanghu–Jiri Road. Large (up to 3 mm in size) almandine crystals are present in the garnetiferous schist exposed along the trail to Dadar Danda from Kharidhunga and on the downhill side of Kharidhunga Bazaar.

Dhading Dolomite

The Dhading Dolomite was mapped as the Lakharpata Formation by Shrestha, et al. (1984). It is exposed around the Kharidhunga area as wavy and massive beds and lenses of dolomite, magnesite, and talc with sporadic quartzite bands. This formation also occurs near the peak of Dadar Danda (3,400 m). The rock is highly fractured and crystalline. Magnesite and talc are very promising non-metallic deposits (Plate 1) of the area and they are being exploited by Nepal Orind Magnesite (P) Ltd. Talc, siderite, dolomite, pyrite, and pyrrhotite are frequently associated with magnesite, and are technologically considered as impurities to ore-grade magnesite. The Dhading dolomite ranges in thickness from 200 to 300 m.

GEOLOGICAL STRUCTURES

The Kuncha Formation is dissected by the Pheda Khola Fault in the southern part of the study area and the fault is expressed in the field as an abrupt lithological break with a displacement of about 400 m. A number of small-scale faults are observed at Pakhar, Dhading Danda, and Sildhunga. The Ghatte Khola Fault is observed in the gneisses of the Ghatte Khola. It displaces the terraces around Surkhe. The Kuncha Formation accommodates a series of synforms and antiforms

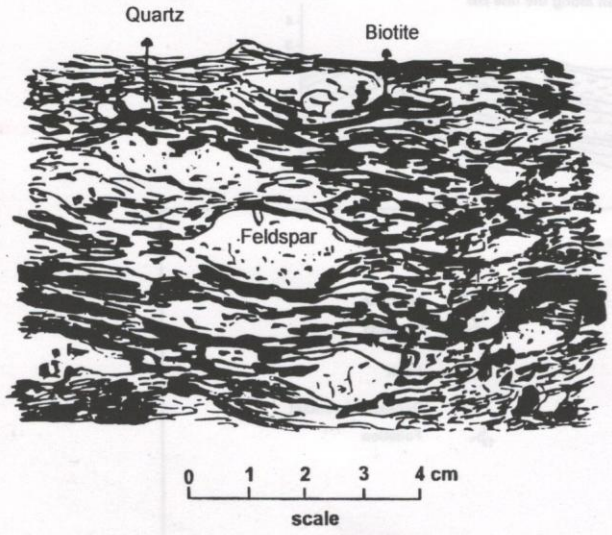


Fig. 3: Banded gneiss with augens of feldspar in the Halaule Khola

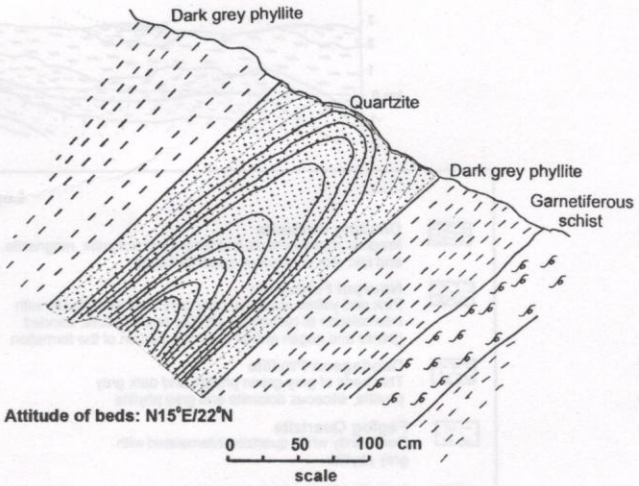
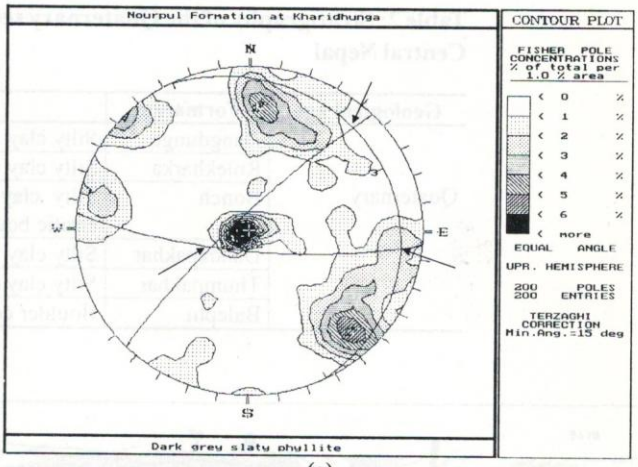


Fig. 4: Deformed cross laminae in the quartzite of the Nourpul Formation at Kharidhunga

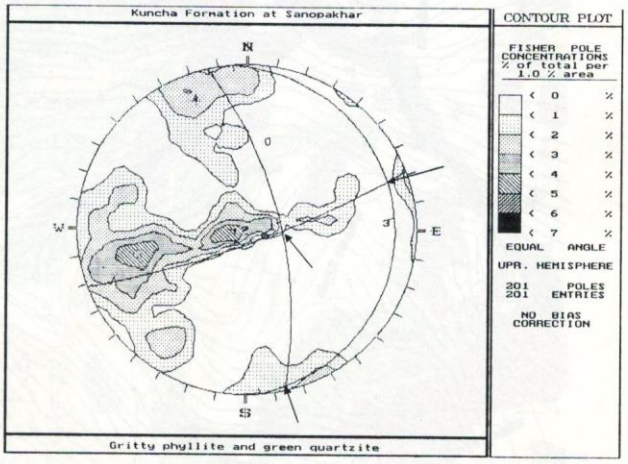
Plate 1: The Kharidhunga Magnesite Mine *(view towards SW)*

of various wavelengths. A large antiform parallel to the Sunkoshi River is observed around Kothe, Balephi, and Kadambas. Small-scale folding is extensively developed at Dandapakhar, Thokarpa, and Chaubas. The Kharidhunga Syncline runs along the trail from Kharidhunga to Dadar Danda and it is about 550 m long. Magnesite mineralisation of Kharidhunga is observed in the synclinal core.

Extensive joints found in each formation are the main triggers of slope failure. Three prominent joint sets are common in all formations of which one is parallel to the foliation, the other is across the foliation, and the third is a random set (Fig. 5). More than 200 joints were measured at Kharidhunga and Sanopakhar and they were statistically analysed. Fig. 5a and b represent the stereographic projection of joints from eastern and western parts of the area, respectively.



(a)



(b)

Fig. 5: Stereographic projection of joints measured in the Nourpul Formation and the Kuncha Formation at Kharidhunga and Sanopakhar. Fig. 5a and b also show most prominent joint sets of eastern and western parts of the study area, respectively.

QUATERNARY DEPOSITS

The Quaternary deposits of the study area are classified into the following formations, respectively from bottom to top (Table 2, Fig. 6).

Balephi Formation

The formation represents pale yellow and pink coloured old river channel deposits and debris flows at an altitude of less than 750 m in the Sunkoshi Valley. The type locality for this formation is set at the Balephi village, which is at Km 70 of the Arniko Highway. Boulder conglomerate is the main sediment type of the formation. It contains sandy clay matrix with subangular to subrounded pebbles, cobbles, and boulders. In the conglomerate, some of the boulders are huge (>7 m) and there are also some pockets of clay. Various erosional features (e.g. palaeo-channels) in this formation indicate several episodes of debris flow.

Thumpakhar Formation

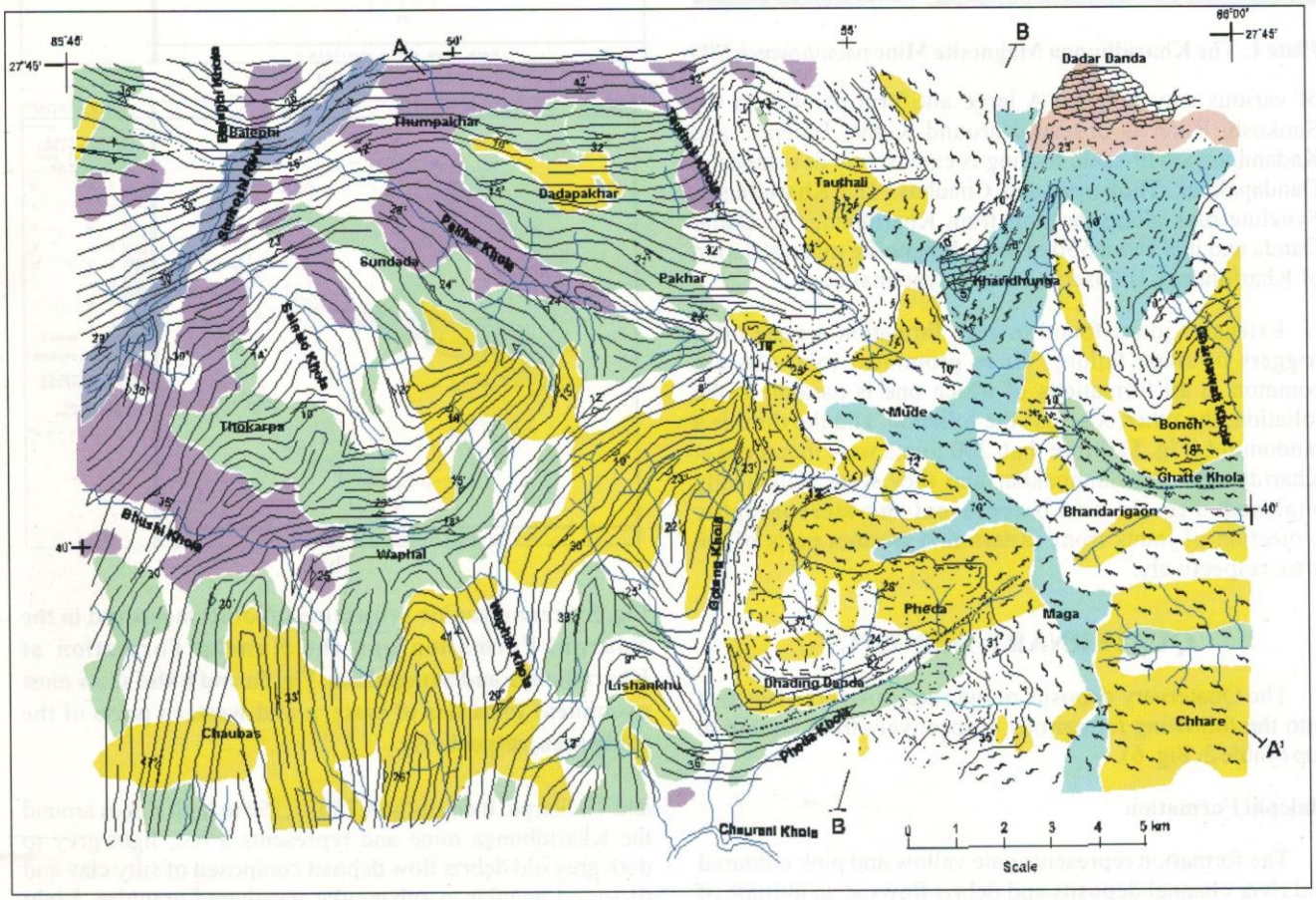
Its type locality is at the Thumpakhar village, which is about 11 km SE of the Lamosanghu–Jiri Road. The Thumpakhar Formation is also distributed at Jagireyamna and Thokarpa. It constitutes 750–1,350 m high ridges around the Kharidhunga mine and represents a red, light grey to dark grey old debris flow deposit composed of silty clay and ill-sorted angular to subangular weathered granules. Light grey and dark grey silty soil with gravels, pebbles, and boulders is found around Jagireyamna and Thumpakhar.

Dandapakhar Formation

The Dandapakhar Formation is widely distributed around the village of Dandapakhar and constitutes the terraces ranging in height from 1,350 to 1,800 m. The formation is composed mainly of silty clay of cream and light brown colour with some gravel and pebbles. The Dandapakhar Formation is distributed on the uphill side of Thokarpa, and also at Bhoteyamna, Waphal Bhanjyang, Dandapakhar, Thulopakhar, Gairigaon and Piskar. It shows stepped landscape formed by a retreating glacier and can be observed around the Thulopakhar, Pakhar, Waphal Bhanjyang, and Bhoteyamna

Table 2: Stratigraphy of the Quaternary sediments in the Kharidhunga–Thokarpa area, Central Nepal

Geological age	Formation	Lithology	Thickness, m
Quaternary	Dangdunge	Silty clay	8
	Rolekharka	Silty clay with a little gravel	6
	Bonch	Silty clay with a little gravel and a few erratic boulders	10
	Dandapakhar	Silty clay with some gravel and pebbles	7.5
	Thumpakhar	Silty clay and gravel	12
	Balephi	Boulder conglomerate	> 8



Legend

Dangdunge Formation
Cream and brown colouredsilty clay
distributed at an altitude of 2,900 - 3,300 m

Rolekharka Formation
Cream and brown coloured silty clay with little gravel
distributed in at an altitude of 2,300 - 2,900 m

Bonch Formation
Cream and grey silty clay, and gravel
distributed at an altitude of 1,800 - 2,300 m

Dandapakhar Formation
Cream and light brown silty clay with gravel
distributed at an altitude of 1,350 - 1,800 m

Thumpakhar Formation
Red, light grey, and dark grey conglomerate (slope deposit with silty clay and ill sorted angular weathered granules
distributed at an altitude of 750 - 1,350 m

Balephi Boulder Formation
Pale yellow and pink gravel (debris flow deposit)
distributed at and altitude of <750 m

(See Fig. 2 for other legends.)

Fig. 6: Quaternary geological map of the Kharidhunga–Thokarpa area

area. At Korkha of the Chaubas village, the formation is found as a transported mass in the form of slope deposits.

Bonch Formation

The type locality for the Bonch Formation is set at the Bonch village situated at Km 45 of the Lamosanghu–Jiri Road. It is also distributed around Tauthali, Jaithal Jaljale, Gogani Danda, Dhading Danda, Chaubas, Tamche, and Bersa. It constitutes the terraces ranging in height from 1,800 to 2,300 m and is composed of cream and grey coloured silty clay with a little gravel and a few erratic boulders (up to 4 m in diameter). Stepped micro-landscape, formed by retreating glaciers, carving the formation is commonly found on the Bhandarigaon ridge.

Rolekharka Formation

The Rolekharka Formation is typically exposed at the village of Rolekharka, which is situated at Km 34 of the Lamosanghu–Jiri Road. It is also distributed at Kharidhunga, Mude, Nigale, Maga Danda, and Khanigaon (mainly in the eastern part of study area). This formation constitutes the terraces ranging in height from 2,300 to 2,900 m. The formation is composed mainly of cream and brown silty clay with a little gravel. The Rolekharka Formation shows good evidences of glacial retreat. A stepping micro-landscape is also seen on the Rolekharka Formation, and the Rolekharka village itself lies on one of such steps of a retreating glacier (Fig. 7). Till and glacio-lacustrine deposits have covered almost all convex mountain slope as seen on the northeast of Rolekharka. Well-stratified soil of this formation is also seen on the Lamosanghu–Jiri Road, near Rolekharka (Plate 2).

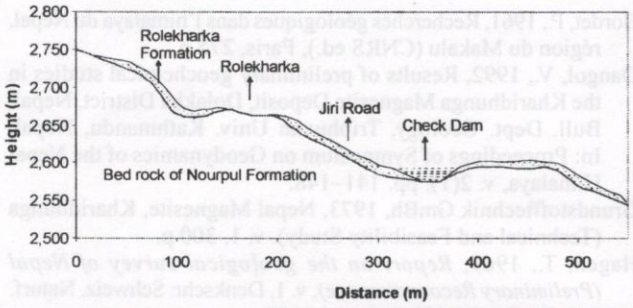


Fig. 7: Terraces observed on the Rolekharka Formation, near Rolekharka

Dangdunge Formation

The Dangdunge Formation is well exposed at the Dangdunge Chaur (pasture) of Dadar Danda at an altitude of 3,350 m where it is made up of cream and light brown silty clay. The formation is mostly found at an altitude of 2,900–3,350 m. It is the youngest formation of the area and represents the final stage of glacial retreat.

ENGINEERING PROPERTIES OF SOILS

Soils from all six formations were analysed for Atterberg limits. Their scatter plots (Fig. 8) of liquid limit (LL) and plasticity index (PI) indicate that most of them belong to ML (inorganic silty clay of low plasticity) type according to the

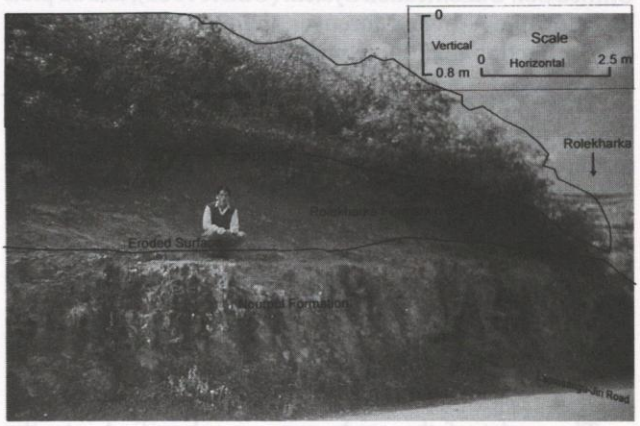


Plate 2: The Rolekharka Formation developed on the Nourpul Formation near Rolekhara *(view towards SW)*

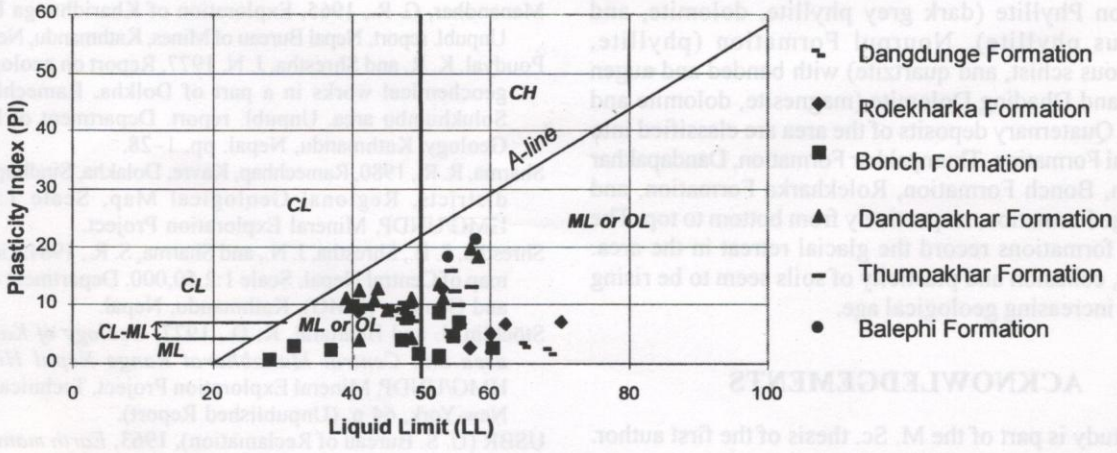


Fig. 8: Plasticity chart of the soils based on the Unified Soil Classification System

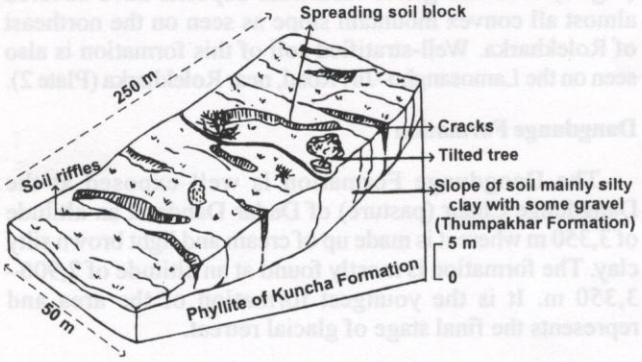


Fig. 9: Sketch of soil creep at Damaigaon on the Thumpakhar Formation

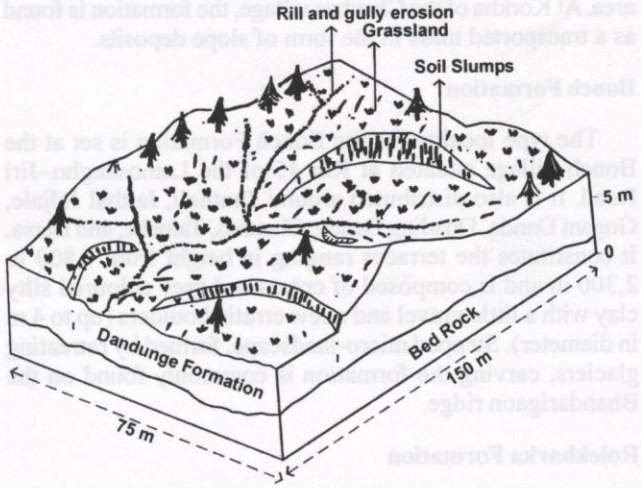


Fig. 10: Sketch of soil slumps at Dangdunge Chaur on the Dangdunge Formation

Unified Soil Classification System (USBR 1963), and all plots lie below the A-Line. Moreover, the older soils have more course fraction than the younger ones.

These soils are susceptible to creep (Fig. 9). The soils of Bonch Formation exhibit low PI but their distribution is rather scattered. Some of the fine sandy clays show quite high PI. The Dandapakhar and Thumpakhar Formations show higher values of PI, PL, and LL. As a result of oxidation, colloids have formed in the soil and they have significantly reduced its permeability. Consequently, slumps are frequently observed (Fig. 10).

CONCLUSIONS

The rocks of the study area are classified into the following formations from bottom to top, respectively: the Kuncha Formation (gritty phyllite and grey quartzite), Fagfog Quartzite (white quartzite with thin green phyllite bands), Dandagaon Phyllite (dark grey phyllite, dolomite, and calcareous phyllite), Nourpul Formation (phyllite, garnetiferous schist, and quartzite) with banded and augen gneisses, and Dhading Dolomite (magnesite, dolomite and talc). The Quaternary deposits of the area are classified into the Balephi Formation, Thumpakhar Formation, Dandapakhar Formation, Bonch Formation, Rolekharka Formation, and Dangdunge Formation, respectively from bottom to top. The last three formations record the glacial retreat in the area. Generally, cohesion and plasticity of soils seem to be rising with their increasing geological age.

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