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Geological study along Sipaghat-Panchkhal-Sukute area, Kavreplanchowk and Sindhupalchowk districts, Lesser Himalaya, central Nepal

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ABSTRACT

A detailed geological study has been carried out in the Lesser Himalayan rocks distributed in Panchkhal-Dolalghat-Sukute area in Kavre Palanchowk and Sindupalchowk districts. The study area belongs to Kuncha Formation of Lower Nawakot Group, Benighat Slate of Upper Nawakot Group, Nawakot Complex; Raduwa Formation, Bhaisedobhan Marble, Kalitar Formation, Chisapani Quartzite, Kulikhani Formation, and Markhu Formation of Bhimphedi Group and Tistung Formation of Phulchauki Group, Kathmandu Complex. These two complexes are separated by the Main Central Thrust (MCT). Four lithounits of the Lower Nawakot Group (i.e., Fagfog Quartzite, Dandagaon Phyllite, Nourpul Formation and Dhading Dolomite) and two lithological units (Malekhu Limestone, Robang Formation) of the Upper Nawakot Group are missing in the area. The area comprises intercalation of coarse-grained, thick bedded quartzite and gritty phyllite of Kuncha Formation, dark argillaceous slates with Jhiku Carbonate beds including sporadic amphibolite of the Benighat Slate. The Bhimphedi Group of the Kathmandu Complex comprises mainly micaceous schist, marble, metasandstone and augen gneiss whereas the Phulchauki Group comprises of metasandstone and granite. The lithological units strike NW-SE and dip towards south forming the eastern closure of the Mahabharat Synclinorium in the northern limb.

Keywords: Main central thrust (MCT), protolith, recrystallization

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INTRODUCTION

The Kathmandu Nappe which is located in the core of the Mahabharat Synclinorium (Hagen, 1969). The Kathmandu Complex is a part of the Lesser Himalayan Crystalline but includes fossiliferous sediments of early-middle Palaeozoic age on top, occupying the large of the synclinorium and the Nawakot Complex belongs to the Lesser Himalayan sediments and form the peripheral parts of the structure (Stöcklin, 1980). The study area comprises the Kathmandu and Nawakot Complexes. The Kathmandu Complex is divided into two groups (Phulchauki and Bhimphedi groups), similar the Nawakot Complex into (The Lower Nawakot and Upper Nawakot Groups). Underneath the succession of allochthonous units of crystalline rock is the Nawakot Complex, and the thrusting is known as the Mahabharat Thrust (MT). In central Nepal, the MT is the southward extension of the MCT (Stöcklin and Bhattarai, 1977; Stöcklin, 1980). Subedi and Achary (2016) carried out the study in the southern part of Kathmandu. They concluded that autochthonous and allochthonous sequences are separated by the MT through the study of microscopic deformational features. Stöcklin (1980) prepared a geological map and subdivided into Kathmandu and Nawakot complexes.

GEOLOGY OF THE PANCHKHAL-DOLALGHAT-SUKUTE AREA

The study area lies in the central part of Nepal where about 60 km toward east from Kathmandu (Fig. 1). The rocks of the area can be assigned to Kathmandu Complex and Nawakot Complex (Table 1). These two complexes are separated by Chak-Roshi Thrust which is a part of Mahabharat Thrust (MT) (Stöcklin and Bhattarai, 1977). The geological map of the study area is shown in Figure 2 and the generalized lithostratigraphic succession is given in Figure 3.

Stratigraphy

The stratigraphic nomenclature for this study is adopted from Stöcklin and Bhattarai (1977) and outcropped geological formations are described as:

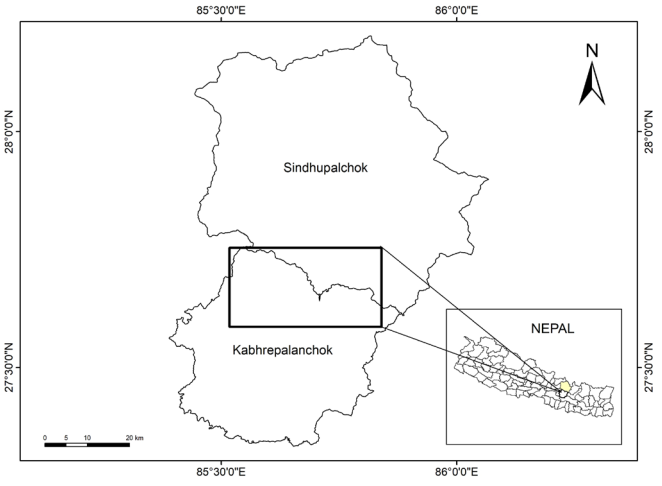

Fig. 1: Location map of the study area.

Kuncha Formation: Along the Arniko Highway between Dolalghat and Sukute, an outcrop of the Kuncha Formation is well exposed. The exposure consists of intercalation of light grey, coarse-grained, thick bedded quartzite and bluish grey gritty phyllite. Phyllite is gritty with maximum thickness of 0.9 m. The phyllite from this lithounit has a definite soapy touch on surface. Thickness of this unit attains about 3000 m. About 500 m NE of Dolalghat along the Arniko Highway, very thin band of the Fagfog Quartzite leached by calcareous material can be traced, however it cannot be mapped to scale.

Benighat Slate: This lithounit is well exposed along the Arniko Highway about 2 km ahead from Zero Kilo to Dolalghat area. The Benighat Slate consists of sporadic amphibolite, calcareous graphitic slate, psammitic schist, dark grey slate, phyllite, sandstone and quartzite. Sporadic amphibolite of carbonate protolith are in the vicinity of the MT. The exposure of fine-grained, thickly bedded sandstone intercalated with slate and phyllite can be observed in Dadathok. Sandstones have crenulated structure. The Jhiku Carbonate beds are about 200 m thick. Limestone is highly porous and are interbedded with sandstone. Stalactites structures are frequent in limestone. The distribution of the Jhiku Carbonate rocks from Lamidanda to Sathighar Bhagwati have varied lithology of limestone, light grey dolomite and marble. Black graphitic slate with quartz vein is dominant in north part of the study area. Massive folding structures can be found close to the MT. Thickness of the Benighat Slate is about 1100 m.

Raduwa Formation: The outcrops of the Raduwa Formation are exposed at Ojhatar and Serabesi in the south; Phedi, Mandandeupur, Dhaitar towards north. Garnetiferous micaschist, micaschist with some micaceous, light yellow, thin to thick bedded, weathered quartzite bands are main rock types. Schist is dark grey and foliated. Banded gneiss can be observed along Helambu Road section, heading NW of Sipaghat. The formation is not exposed in Panchkhal area and around Mahadevsthan between the confluence of the Cha Khola and Asi Khola due to quaternary deposits. Total thickness of the Raduwa Formation is about 1200 m.

Bhainsedobhan Marble: The Bhainsedobhan Marble is well exposed at Bhedabari, Ojhatar, Baluwa, Bakultar in south and Salthati, Kalse and Gairibisauna to the north. It has transitional contact with the Raduwa Formation. The northern and southern part of the lithounit consists of banded white marble intercalated with quartzite. Dark grey, calcareous, mica bearing quartzites are found in middle part of the litho-unit. The maximum thickness of the Bhaisedobhan Marble is about 260 m. The main rocks of this unit are crystalline marble, mica schist and quartzite. The pure white calcareous beds of marble having only calcite minerals can be observed along Sipaghat-Sankhu Road section.

Kalitar Formation: The main rock type of this unit are psammitic schists and micaceous quartzites. The psammitic schists are medium to coarse grained and is intercalated with quartzites. Micaceous quartzites are strongly foliated. The rocks of the Kalitar Formation are exposed around the Charuwa, Karketar, Ranipani in the south and Rampur, Devisthan and Kotyangau to the north. The intrusion of augen gneisses and granitic gneisses are present around Chainpur and between Kotyangau and Judigau, respectively. The Kalitar Formation attains thickness of 700 m.

Chisapani Quartzite: The Chisapani Quartzite is well exposed at Jhiku Khola, Okhar Khola, Ranipani, Dhunganabesi, Pipaltar, Tamghat in the south to Besigau, Sallebas in the north. It consists of thin to thick bedded, highly fractured, slabby, white to grey crystalline quartzite which is good marker between much darker quartzites and schists of underlying the Kalitar Formation. The individual slab of quartzite varies from

Table 1: Stratigraphic subdivision of Kathmandu and Nawakot Complexes, central Nepal Lesser Himalaya (Stöcklin and Bhattarai, 1977; Stöcklin, 1980).

Complex	Group	Formation	Main Lithology	Thickness (m)	Age
KATHMANDU	Phulchauki	Godavari Limestone	Limestone	300-400	Devonian
		Chitlang Formation	Slate, Quartzite	1,000	Silurian
		Chandragiri Limestone	Limestone	2,000	Cambrian
		Sopyang Formation	Slate, calc. phyllite	200	Early Cambrian
		Tistung Formation	Metasandstone, Phyllite	300	
	Bhimphedi	Markhu Formation	Marble, schist	1,000	
		Kulikhani Formation	Quartzite, schist	2,000	
		Chisapani Quartzite	Quartzite	400	Pre-Cambrian
		Kalitar Formation	Schist, quartzite	2,000	
		Bhaisedobhan Marble	Marble	800	
		Raduwa Formation	Garnet-Schist	1,000	
..... *Mahabharat Thrust (southward extension of MCT)*.....					
NAWAKOT	Upper Nawakot	Robang Formation	Phyllite, Quartzite	200-1,000	Early Palaeozoic
		Malekhu Limestone	Limestone, Dolomite	800	
	Lower Nawakot	Benighat Slates	Slate, Argillites	3,000	Pre-Cambrian
		Dhading Dolomite	Stromatolitic Dolomite	500-1,000	
		Norpul Formation	Phyllite, Metasandstone	800	
		Dandagaon Phyllite	Phyllite	1,000	
		Fagfog Quartzite	White Quartzite	400	
		Kuncha Formation	Phyllite, Quartzite	3,000	

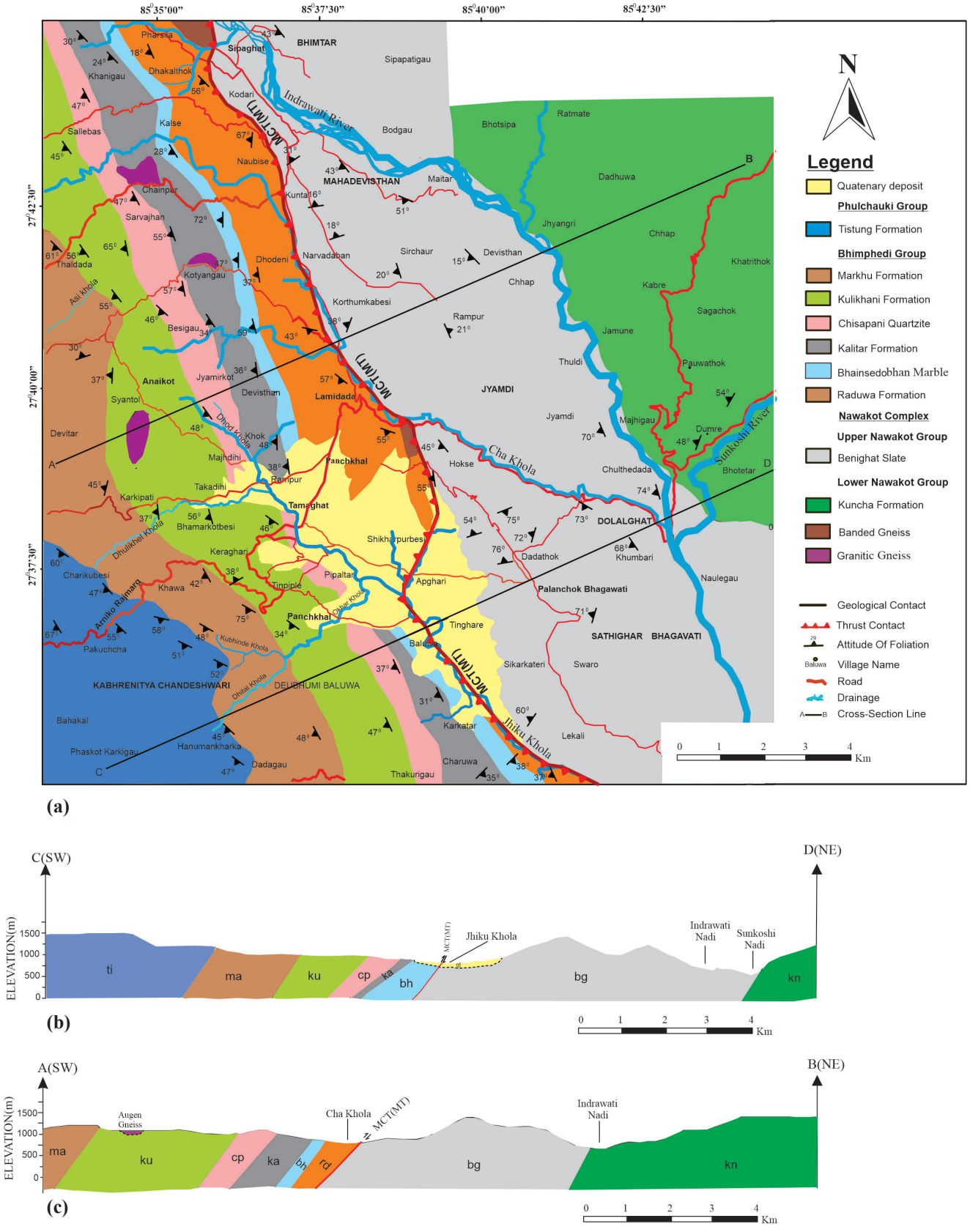

Fig. 2: (a) Geological map of Sipaghat-Panchkhal-Sukute area, Lesser Himalaya, central Nepal, (b) geological cross-section along C-D, (c) geological cross-section along A-B.

2 to 14 cm. Maximum thickness of the Chisapani Quartzite attains 400 m.

Kulikhani Formation: The formation is extensively distributed in Belathumka, Ghairenidada, Pathakdihi, Jyamdelbesi, Lamdihi, and confluence of Dhulikhel Khola and Kakre Khola at Takadihi in southern part to Anaikot, Nayagau in the northern part. It consists of laminated, dark grey finely crystalline micaceous quartzites and schists. Psammatic schists are grey and foliated. Quartzites are calcareous when subjected to strong acid. The intrusion of pegmatite is present around Syantol village. The Kulikhani Formation is 1550 m thick.

Markhu Formation: This lithounit is composed essentially of light grey, massive bedded, fine-grained, calcareous schists and calcareous micaceous quartzites. The calcareous quartzites consist of veins and lenses of granite-pegmatite. The outcrops of this unit are well exposed along the Kubhinde Khola, Dhital Khola, along the Arniko Highway in Khawa, Bhamarkot and north of Devitar. Thickness of Markhu Formation attains about 1500 m.

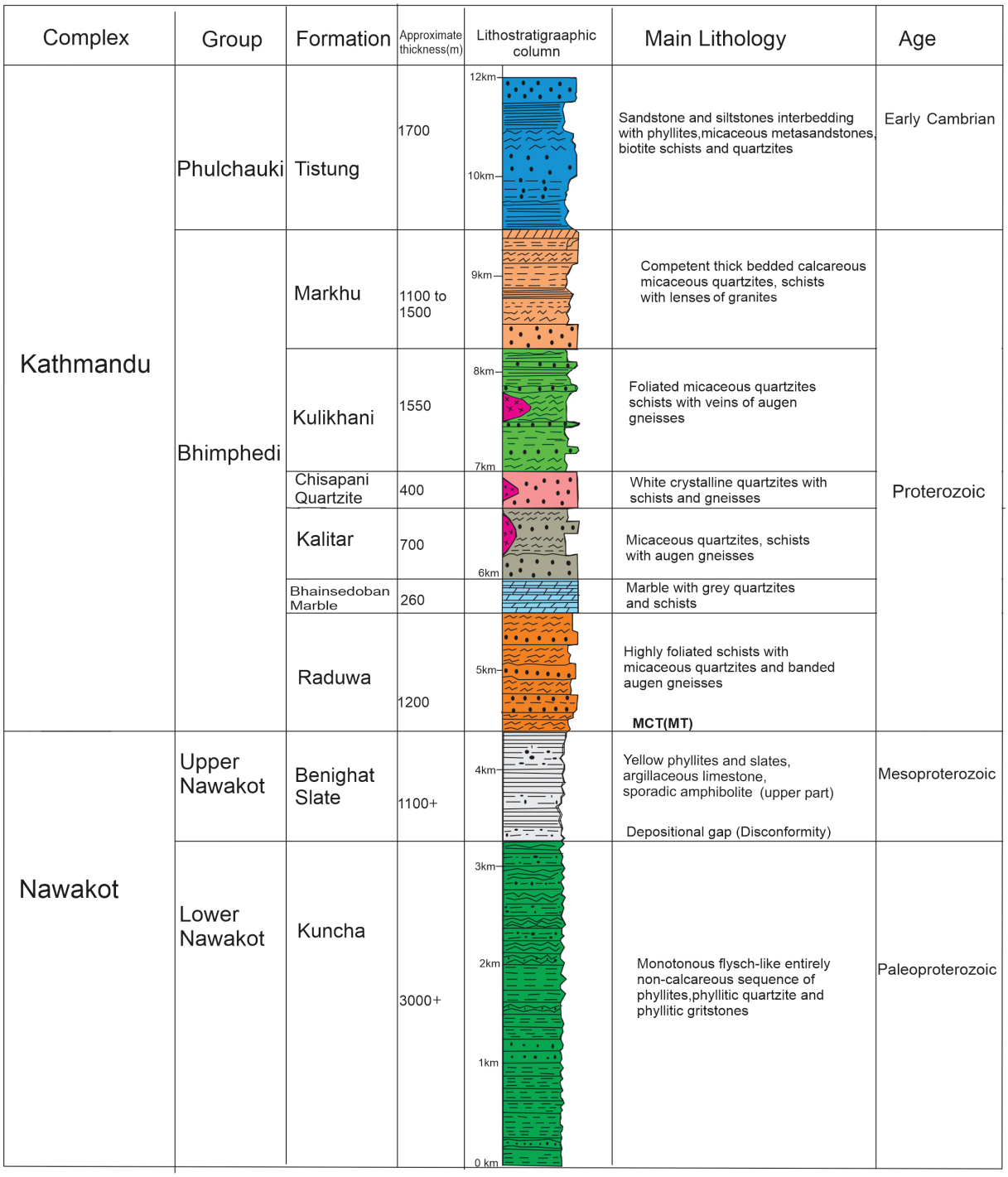

Fig. 3: Generalized lithostratigraphic column of the Sipaghat-Panchkhal-Sukute area, Kavrepalanchowk and Sindhupalchowk districts, Lesser Himalaya, central Nepal.

Tistung Formation: The Tistung Formation is widely distributed along the Arniko Highway from Dhulikhel to Khawa village, around Badalgau, Darimbot, and north of Thakle and Charikubesi. It mainly consists of metasandstones with quartz veins, metasiltstones, phyllites and slates. Phyllites are interbedded in a few strata of calcareous metasandstones. The maximum thickness of the Tistung Formation is about 1700 m.

Quaternary deposits: Quaternary deposits are widely distributed in the study area. Along the Jhiku Khola, Okhar Khola, Dhulikhel Khola, and in the western section of Dhulikhel at Panchkhal, Tamaghat, Shikharoubesi, and Tinghare, the terrain is mostly covered by clay, sand, and slit sediments. It is an intermontane basins of quaternary sediments in central Nepal (Timsina and Adhikary, 2007). The quaternary deposits are represented by terraces and debris flow at the different elevations including thick buried black clay which is formed by neotectonics.

Geological structure

Mahabharat Thrust (MT) is also called Main Central Thrust (MCT) which is controversial in itself as none of the standard MCT mapping requirement theories are still relevant. The inverted metamorphism in the Kathmandu nappe is mentioned by (Auden, 1935). Based on the metamorphic grade, (Hagen, 1969) categorized the rocks into the Kathmandu and Nawakot Complexes, and are separated by MCT. In Panchkhal-Sipaghat area, Mahabharat Thrust (MT) is mapped upto Dhand Khola (Stöcklin and Bhattarai, 1977; Stöcklin, 1980), and its extension to Majhitar is inferred. They added that the MT in South in Central Nepal is the continuing thrust fault of the MCT. Dhital et al. (2002) has shown in recent investigations that MT straight continues to the north and becomes MCT. The stratigraphic break between the Kathmandu and the Nawakot complexes, the metamorphic grade, and structural factors are used to categorize the rocks in the study area. This form of basis is used to trace exact position of the MT. It is NW-SE trending thrust. It runs along Indrawati river near Sipaghat (Fig. 4a) and slightly bends from Dhad Khola bridge to east of Garuwa village (Fig. 4b). The further extension is to the Cha Khola (Fig. 4c), bends to Sobarne Khola between Hokse and Shikharpur to Deubhumibaluwa and continues along the Jhiku Khola in the south-east.

Field verification: Within the study area, the thrust zone is exposed near Dhad Khola Bridge along the Sipaghat-Sankhu Road Section about 600 m west from Helambhu Highway. The disturbed zone of about 850 m contains crushed rocks (about 4 m) with all mixed lithology of the Benighat Slate and Raduwa Formation. The inverted metamorphism is well observed, especially in the hanging wall of the MT. The footwall of the MT is made of slate and phyllite and has a much low-grade of metamorphism than the hanging wall. The bedrocks of the Benighat Slate below the MCT dip with 45–60° towards NW and the Raduwa Formation above MCT dip with 28–30° towards SW. About 1.50 km east of Zero Kilo, the route of about 90 m is traced along the section of Arniko Highway (Fig. 5). The exposure of banded marble, banded gneiss and alteration of quartzites and gneissose schists are frequent. The other route of about 700 m is mapped along road section from Lamidanda towards Palanchowk Bhagwati (Fig. 6),

Fig. 4: Contacts between (a) the Benighat Slate and Raduwa Formation on the Indrawati River section (view towards west), (b) the Benighat Slate and Raduwa Formation on the Dhad Khola section (view towards south), (c) the Benighat Slate and Raduwa Formation on the Cha Khola section (view towards west).

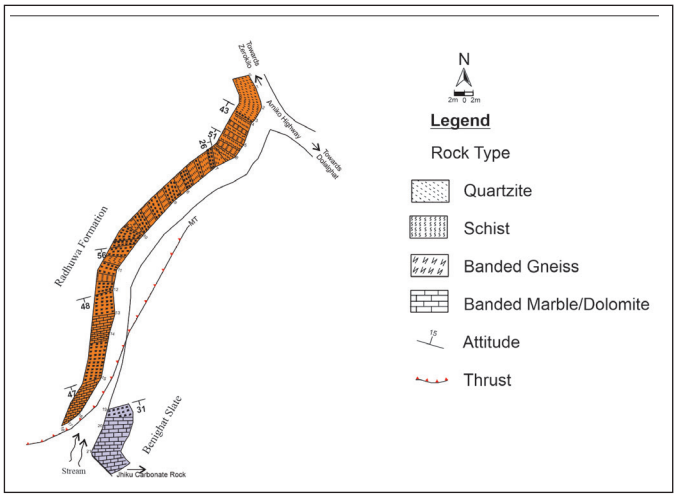

Fig. 5: Route map along the section of Arniko Highway, about 1.5 km east of Zero Kilo.

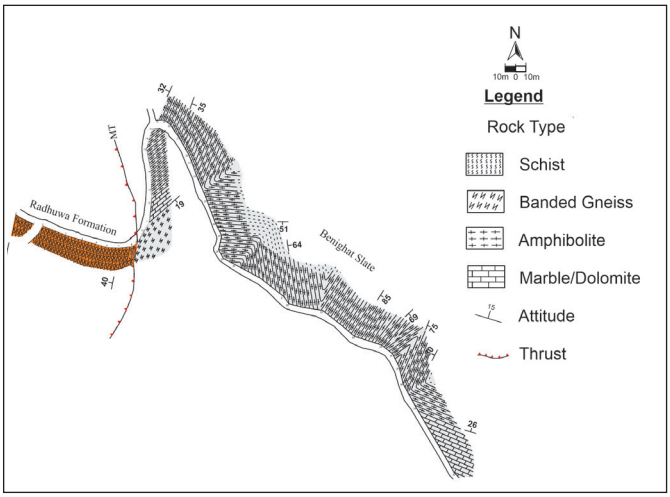

Fig. 6: Route map along the road section from Lamidada towards Palanchowk Bhagwati, approx. 7 km SE of Lamidanda.

which is located approximately 7 km southeast of Lamidanda. Weathered schist, mica schist, banded gneiss, marble, sporadic amphibolite and dolomite are well exposed. Several anticline and syncline structures are also predominant along the route. Thickness of each sequence of route mapped is shown in Figure 7.

Other structure: Many small- to large-scales mesoscopic folds are observed in the Lesser Himalayan Sequence of the study area. Due to the action of the MT, numerous S-type fold and Z-type fold prevails the area (Fig. 8). The disharmonic fold (Fig. 8d), decollement fold (Fig. 8e), chevron fold (Fig. 8f), represent deformational regimes. Also, several minor structure like boudinage appear in shear zone near MT (Fig. 9).

Petrography

Kuncha Formation: Phyllite is frequently found along the Arniko Highway, about 8.8 km east of Dolalghat Bazaar towards Sukute. The sample specimen (Fig.10a) is grey, lineated and crenulated phyllite. A tentative modal composition is estimated as muscovite and sericite-55%, quartz-38%, biotite 6% and other 1%. Quartz clasts are up to 0.7 mm in diameter. K-feldspar clasts are rounded and are up to 0.5 mm in diameter. Muscovite grains are smaller than 0.30 mm.

Benighat Slate: About 5.8 km east of Mahadevsthan towards Raybari, slate of Benighat is silver grey to black in color. Due to carbon being released, slate is black in color. Black slate contains quartz veins with slaty cleavage. The mineral grains of psammitic schist (Fig.10b) are fine-grained, composed of quartz-45%, carbonaceous materials-25% and others-30%. Strongly aligned minerals of slate (Fig.10c) (i.e., flowage structure) provide evidence of shearing in the study area.

Raduwa Formation: Along Sipaghat-Sakhu Road section the modal composition of garnetiferous mica schist (Fig.10d) is estimated as quartz 40%, biotite 20%, muscovite 15%, feldspar 15%, and other 10%. Quartz is subedral to anhedral, elongated. Preferred orientation of mica and quartz represent foliation. Several microfold structures within mineral grains provide the evidences of tectonics.

Micaceous quartzite (Fig.10e) of Raduwa Formation is observed along Helambu Highway about 871 m north from Zero Kilo. A tentative modal composition is found as quartz-80%, muscovite-9%, biotite-3% and others-8%. Most minerals range from subhedral to anhedral in shape. The quartz crystals are long. Mica and elongated quartz grains are indicators of foliation.

Kalitar Formation: Granitic gneiss (Fig.10f) of the Kalitar Formation is light grey in color and has banded structure. A tentative modal composition is estimated as quartz 40%, orthoclase 30%, biotite 15%, plagioclase 5%, and others 10%. Quartz grains are coarse and fractured. Mineral grains are anhedral to subhedral. Typically, the bands of a mineral grain alternate between lighter and darker shades.

Augen structure are dominant in gneiss of Chainpur. The sample of augen gneiss (Fig. 11a) has modal composition of: orthoclase 30%, quartz 30%, plagioclase 10%, biotite 10% and others 20%. Quartz grains are subhedral to anhedral and are fractured. Porphyritic texture is dominant in mineral grains.

Chisapani Quartzite: About 1.5 km NW from Phedi towards Kotyangau, white quartzite (Fig.11b) consists predominantly of quartz and subordinately of biotite and muscovite. A tentative modal composition is estimated as quartz 65%, muscovite 14%, biotite 14%, feldspar 5% and others 2%. The mineral grains are euhedral to anhedral, medium-to coarse-grained. Foliation is determined by the preferred orientation of quartz and mica.

Kulikhani Formation: The Kulikhani Quartzite (Fig. 11c) of the Kulikhani Formation is widely distributed along the Arniko Highway near Keraghari. Under microscope (4×10), the mineral grains are subhedral to anhedral, medium-to coarse-grained. Feldspar and quartz grains are in ellipsoidal form and oriented in the same direction. The modal composition is; quartz-40%, biotite-30%, muscovite-20%, feldspar-3%, chlorite-2% and others-5%.

Tistung Formation: About 1.2 km east of Dhulikhel along the Arniko Highway, the sample of metasandstone (Fig. 11d) has a modal composition of quartz 70%, mica 20%, chlorite 5%, feldspar 1% and others 4%. Quartz grains are more or less spherical, whereas feldspar grains are distorted into an ellipsoidal shape.

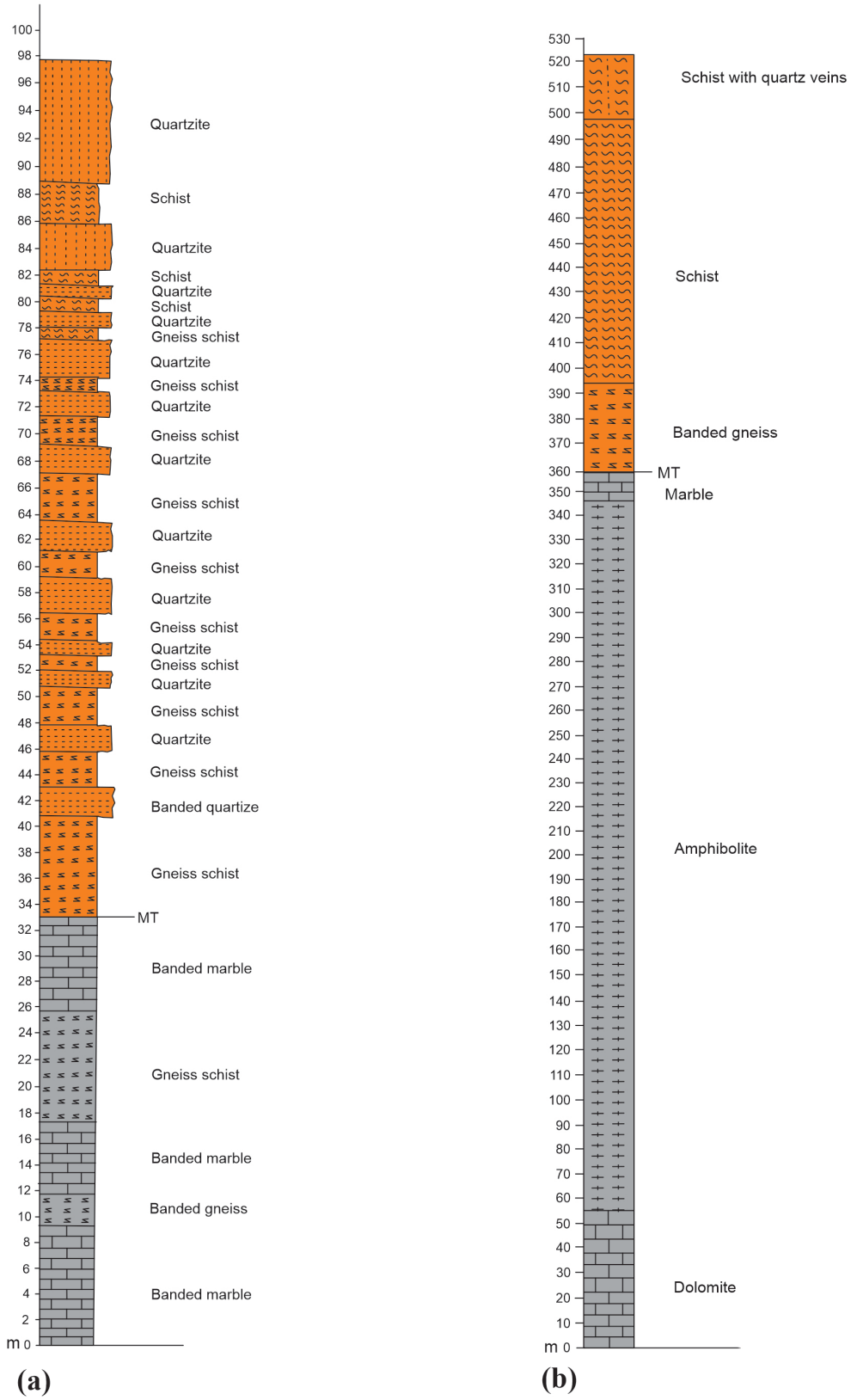

Fig. 7: Columnar sections (a) along the section of the Arniko Highway about 1.5 km east of Zero Kilo, (b) along the road section from Lamidada towards Palanchowk Bhagwati.

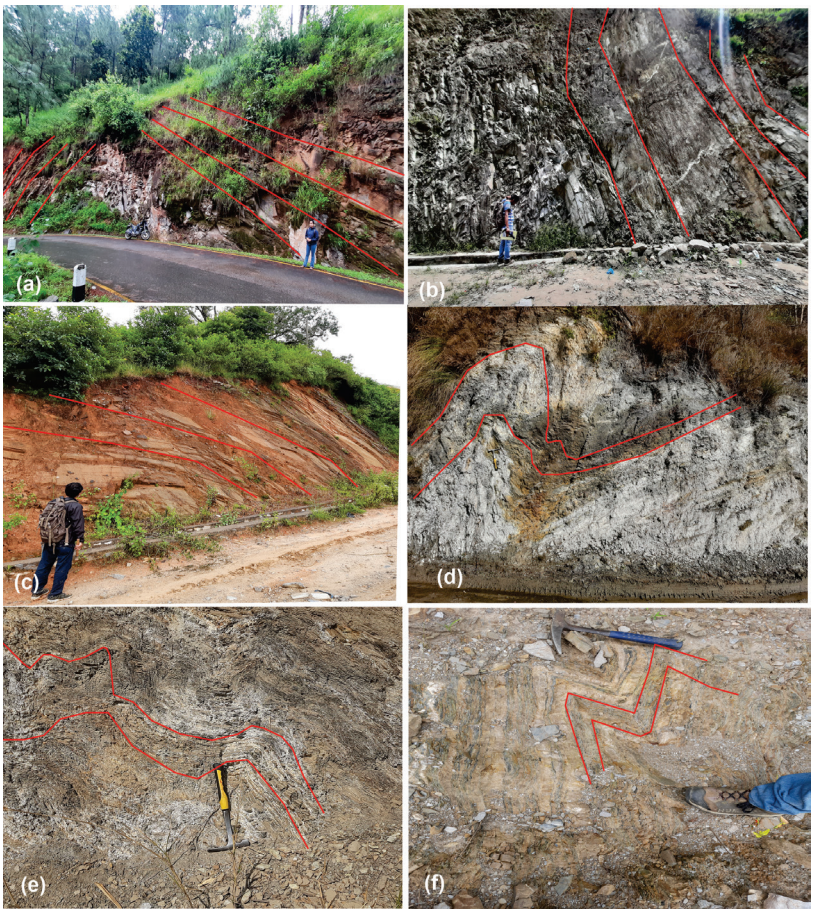

Fig. 8: Minor fold structures (a) plunging fold observed in the Benighat Slate near MT along Lamidanda to Palanchowk Bhagawati (view towards NE), (b) fold observed in the Chisapani Quartzite along Jhiku Khola (View towards south), (c) fold observed in the Chisapani Quartzite near Nayagau (view towards SWW), (d) disharmonic fold observed in the Benighat Slate near MT at Sipaghat (view towards NNE), (e) decollement fold observed in the Benighat Slate near MT at Sipaghat (view towards NNE), (f) chevron fold observed in the Benighat Slate along Arniko Highway near Dhondra Khola (view towards south).

Fig. 9: Crushed zones (a) observed in the Benighat Slate along the Arniko Highway near Dhondra Khola (view towards west), (b) observed in the Benighat Slate at Maitar (view towards west), (c) crushed zone observed in the Benighat Slate along Sipaghat-Sakhu Road section (view towards south), (d) boudinage structure observed in the Benighat Slate near Cha Khola (view towards north).

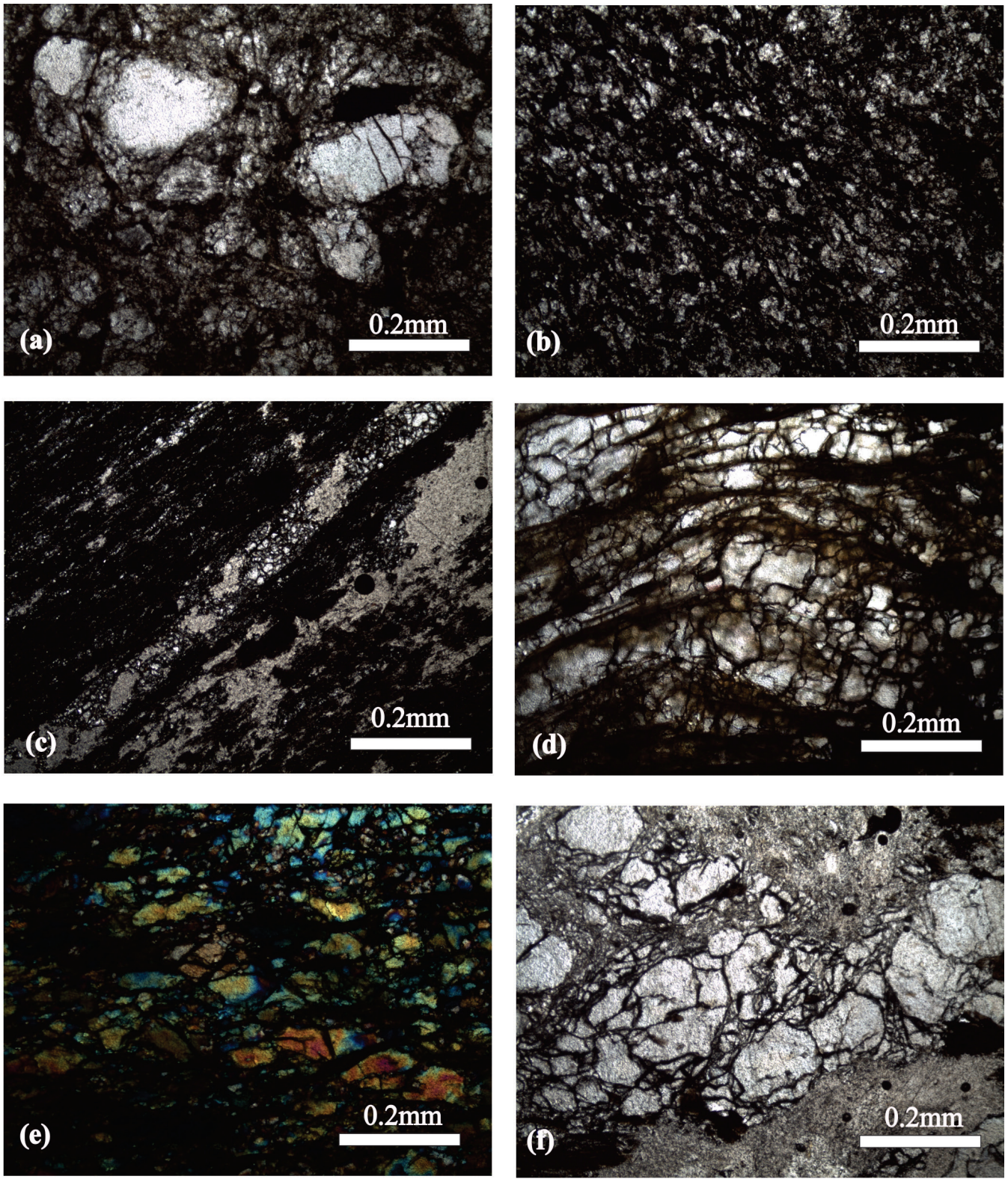

Fig. 10: Photomicrograph (a) gritty phyllite from the Kuncha Formation showing muscovite, sericite, quartz grain, (b) photomicrograph of psammitic schist with fine recrystallized mineral grains, (c) slate showing cleavage and strongly aligned minerals in Benighat Slate, (d) gartnetiferous mica schist from the Raduwa Formation showing composition of quartz, biotite, muscovite, feldspar and micro-fold structure, (e) photomicrograph of micaceous quartzite from the Raduwa Formation showing the composition of quartz, muscovite, biotite and others, (f) granitic gneiss from the Kalitar Formation showing composition of quartzite, orthoclase, biotite, plagioclase and others.

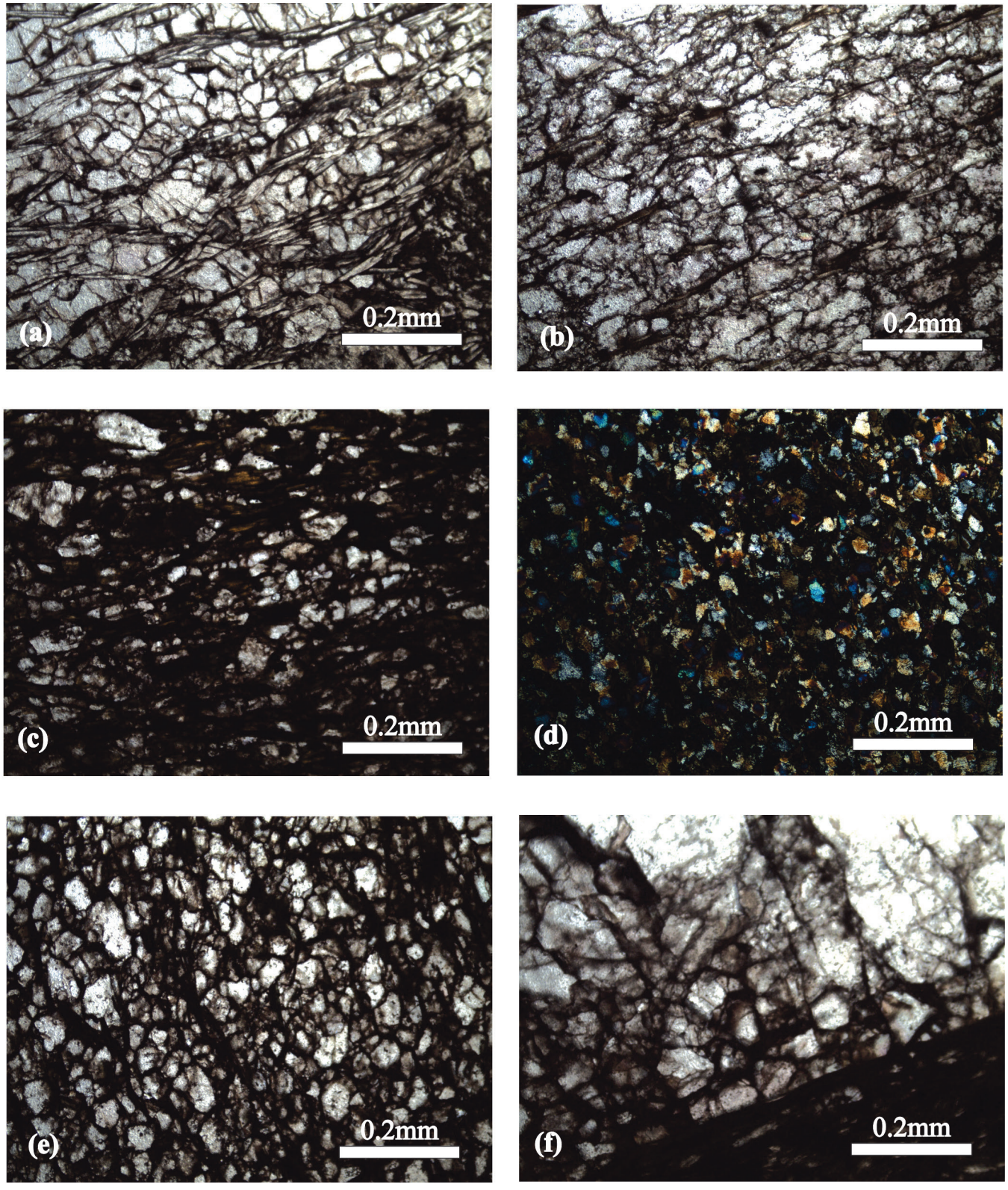

Fig. 11: Photomicrograph (a) augen gneiss from the Kalitar Formation showing composition of orthoclase, quartz, plagioclase, biotite and others, (b) quartzite from the Chisapani Formation showing composition of quartzite, muscovite, biotite, feldspar, and other, (c) quartzite from the Kulikhani Formation showing composition of quartz, muscovite, biotite, feldspar, chlorite and others, (d) metasandstone from the Tistung Formation showing composition of quartz, mica, chlorite, feldspar and others, (e) amphibolite from the Benighat Slate showing recrystallization of minerals, (f) gneissose schist from the Raduwa Formation.

Petrography of samples near MT: The degree of metamorphism and deformation in the rocks of thrust zone is higher than in the surrounding rocks, and thus gradually decreases away from the MT zone. The main rock types of study area near MT are sporadic amphibolite, gneissose schist and marble.

Amphibolite (Benighat Slate): About 7 km from Lamidanda, on the road section leading towards Palanchowk Bhagwati, sporadic amphibolite (Fig. 11e) of carbonate protolith (Jhiku Carbonate bed) are present near the MT. The amphibolite is calcareous and blue to black in color. The mineral composition of amphibolite is mostly hornblende and plagioclase with varying proportions of mica, quartz, epidote, etc.

Gneissose schist (Raduwa Formation): In Raduwa Formation, the gneisses are observed in frequent layers within mica schist (Fig. 11f) near the MT. The rock shows more content of quartz and less feldspar. Rock exhibits recrystallized aggregates of quartz parallelly arranged with flakes of mica particles. Under microscope (4×10), the overall mineral composition is as quartz-40%, muscovite 20%, biotite-25%, plagioclase-10% and other-5% (Fig. 11). The quartz mineral grains are layered between foliation of schist.

CONCLUSIONS

The rocks of study area belong to Nawakot and Kathmandu Complexes, separated by the MT. The Lower Nawakot Group is represented by Kuncha Formation and Upper Nawakot Group by Benighat Slate; whereas the Bhimphedi Group is represented by the Raduwa Formation, Bhaisedobhan Marble, Kalitar Formation, Chisapani Quartzite, Kulikhani Formation and Markhu Formation; Phulchauki Group by Tistung Formation. The lithostratiraphy of study area lacks four lithological sequence of the Lower Nawakot Group (i.e., Fagfog Quartzite, Dandagaon Phyllite, Nourpul Formation and Dhading Dolomite) and two lithological sequences (Malekhu Limestone and Robang Formation) of the Upper Nawakot Group. The reason behind the gap in stratigraphic sequence of the Lower Nawakot Group is due to fault named Sunkoshi Fault (Stöcklin and Bhattarai, 1977). But the features of faulting are not encountered in the study area. No evidences of deformation are observed among neighbouring rock surfaces. Various microstructures of deformation are present in upper part of the Benighat Slate near the MT. Thus, it can be concluded that there might be a huge depositional gap in stratigraphic sequences between the Kuncha Formation and Benighat Slate.

Study area comprises mainly of gritty phyllites of the Kuncha Formation, calcareous graphitic slates of the Benighat Slate, mica schist and quartzites of the Raduwa Formation, marble of the Bhaisedobhan Marble; quartzites of the Kalitar Formation, Chisapani Quartzite, Kulekhani Formation and Markhu Formation; and metasandstone and metasiltstone of the Tistung Formation. The quartzite of the Markhu and Kulekhani (on strong acid) are calcareous. The strata generally dip southwards.

The MT is NW–SE trending thrust. It passes along Indrawati River and continues to southeast. The disturbed zones with mixed lithology appear in thrust zone. The exposure of rocks near the MT are highly metamorphosed than neighbouring rocks. Banded marble, banded gneiss, alteration of quartzite and gneissose schist and sporadic amphibolite are well exposed close to MT. Several anticline and syncline, microfold, boudinage, quartz vein, recrystallization of minerals and crushed rocks indicates deformational regimes.

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