

GEOLOGICAL SETTING AND OCCURRENCE OF CARBONACEOUS ROCKS

Study area lies in northernmost part of the Lesser Himalaya near the Main Central Thrust in the Kali Gandaki valley (Fig. 2). The Lesser Himalayan rocks in the area belong to the Nawakot Complex of Stöcklin (1980). In the study area, the road section south of Tatopani comprises Kunchha Formation and Fagfog Quartzite (with amphibolite). The Fagfog Quartzite is overlain by highly sheared and metamorphosed rocks of the MCT zone along the Lower MCT (Fig. 3).

The Lowermost unit of the MCT zone in the area is pelitic schist, quartzite and marble. It is followed upsection by carbonaceous schists of about 2 km thickness. The carbonaceous schists are highly sheared and internally folded. It is lead black in colour on fresh outcrops as well as in hand specimens (Fig. 4a and 4b). It has soapy lustre and gives black streak. The carbonaceous schist may be the metamorphosed equivalent of the Benighat Slate.

The schist shows rusty weathering on some surfaces due to alteration of pyrite. A few bands of calc-phyllite are observed in this unit. The uppermost unit of the MCT zone is the granitic augen gneiss, most probably equivalent to the Ulleri Augen gneiss.

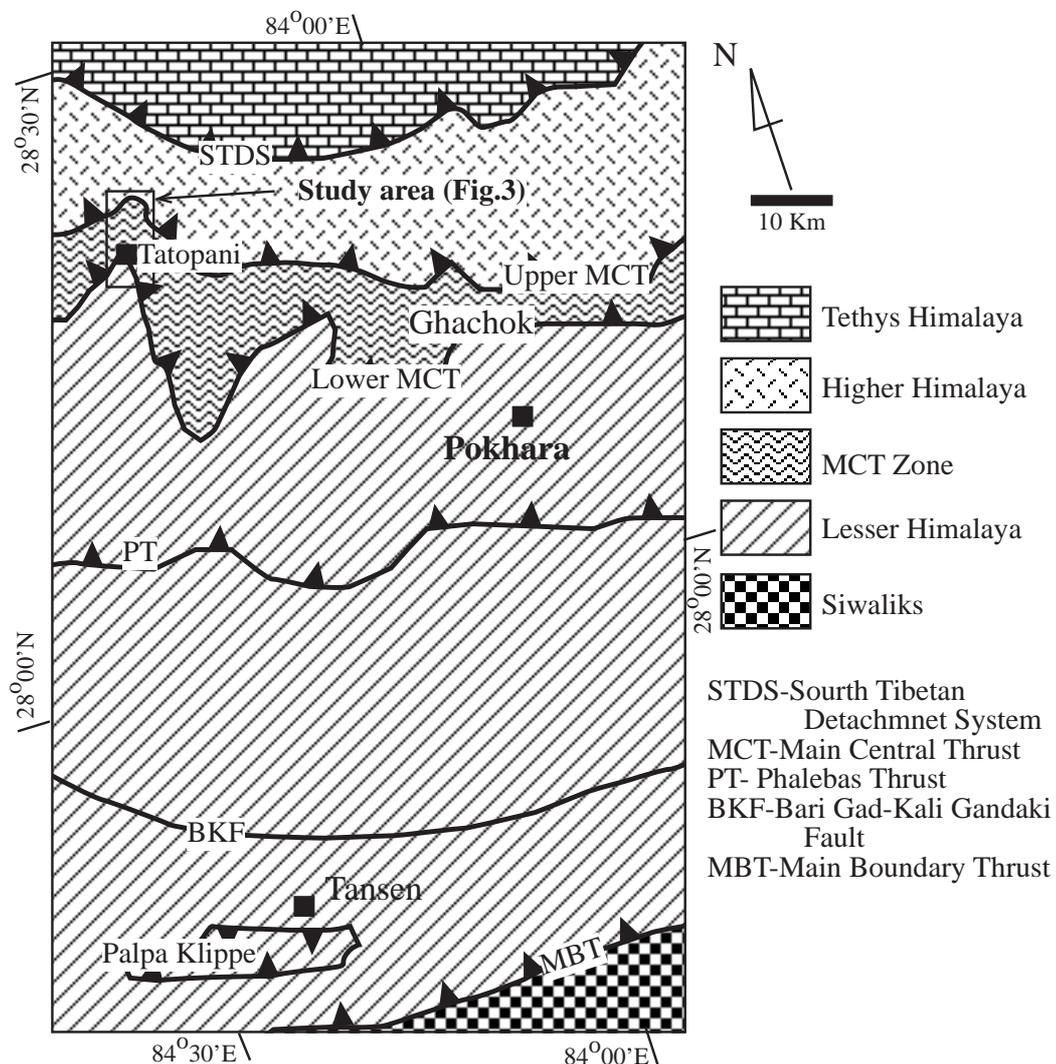


Fig. 2 Schematic tectonic map of the Pokhara-Butwal area showing the location of the study area. (Map modified from Paudel and Arita, 2000).

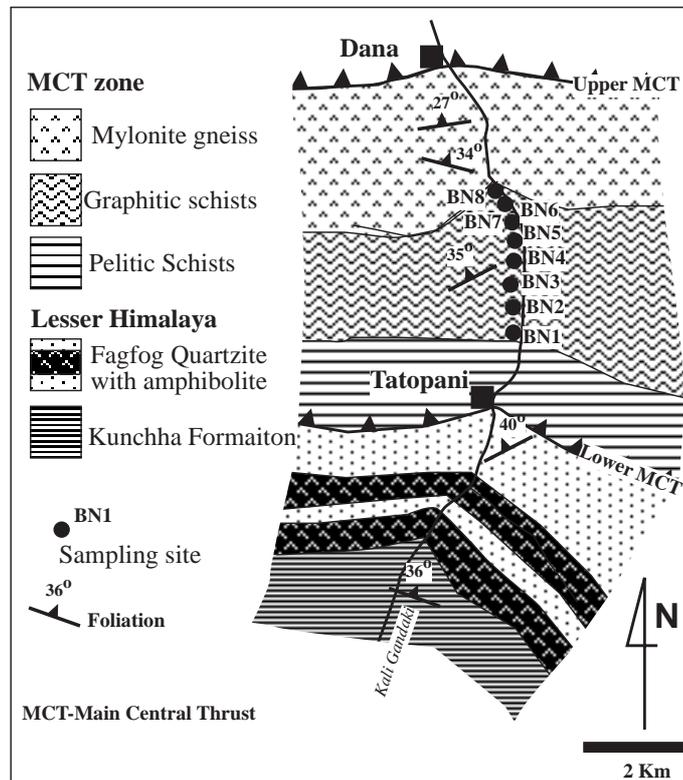


Fig. 3 Geological route map along the Kali Gandaki valley between Tatopani and Dana showing the black schists.



Fig. 4 (a) Photograph of carbonaceous schist outcrop north of Tatopani, and (b) Photograph of the carbonaceous schist in hand specimen.

STUDY METHOD

Altogether 8 samples were regularly taken along the road section from Tatopani to Dana. Samples were selectively taken from the layers which has possibility of high carbon content. Graphite analysis was carried out according to standard procedure given in Mitchell (1993). Thin-sections were prepared from all the samples and were studied under the petrological microscope mainly to know the mineralogy, grain size and texture of the rock.

Carbonaceous material was extracted from the samples (Fig. 5a) following the methods described in Griffin (1967). The bulk samples were crushed to pass a 60-mesh sieve, then boiled four minutes in 20% hydrochloric acid and washed twice with distilled water. The washed sample was again boiled five minutes in 50% hydrofluoric acid then washed four times with distilled water dried at less than 50°C.

The separated carbonaceous fractions were packed in a grooved sample holder (Fig. 5b) and studied by D8-Advance X-ray Diffractometer at the Central

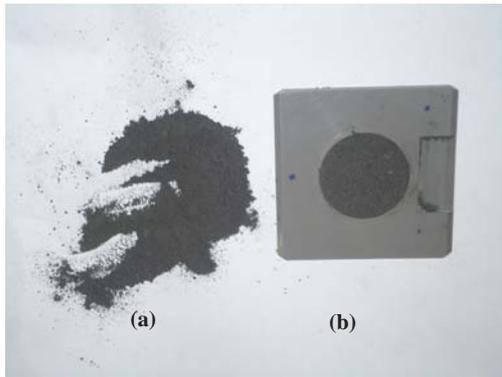


Fig. 5 (a) Carbonaceous material separated from the schist. (b) Carbonaceous material filled in grooved sample holder of X-ray diffractometer.

Department of Geology, Tribhuvan University. The Diffractometer was controlled as Cu-K α , 40 KV tube voltage, 40 mA tube current, Ni-filter, 1 mm divergence slit, 0.2 mm scatter slit and 1 mm receiving slit. The Diffractometer was run between 25° and 28°. A well-crystallized graphite gives sharp (002) peak between 26–26.5° ($d=3.43\text{--}3.36\text{\AA}$) (French 1964). The diffractograms were analysed and interpreted using the DiffracPlus softwares.

The quality of graphite was evaluated on the basis of grain size, crystallinity, and percentage of carbonaceous material.

RESULTS

Results of petrographic study

The percentage of the minerals in the samples was determined by point count method. The summary of mineralogical content is given in the Table 1.

Under the microscope, all the samples contain dominantly graphite (15-30%), quartz (25-40%) and muscovite (15-30%). Biotite is present in minor

amount (3-15%). Sample no BN1 and BN5 contain up to 10% garnet. The feldspar (albite) content ranges from 5 to 10%. The rocks are highly sheared and foliated. The foliation is defined by the parallel arrangements of graphitic materials, muscovite and elongated quartz. The graphitic material is flaky, and fine- to medium-grained (0.1 to 1 mm) (Fig. 6). Quartz show ribbon structure. Biotite is sometimes porphyroblastic. Biotite shows pale yellow to brown pleochroism. The biotite fishes contain asymmetric inclusions. Albitic plagioclase occurs as sheared porphyroclasts as well as recrystallized matrix. The albite porphyroclasts have subhedral to anhedral shape and are up to 0.5 mm in diameter.

Results of X-ray diffraction analysis

Carbonaceous materials in metasedimentary rocks recrystallize to form graphite structure with increasing diagenesis and metamorphism and reaches to the fully ordered graphite. This recrystallization is called graphitization and can be examined by the X-ray powder Diffractometer.

X-ray diffraction analysis in the present study shows that they contain well-crystallized graphite. Very sharp and prominent peaks were obtained at about 26.5° 2 θ positions in all the samples. The prominent peaks belong to graphite (Fig. 7). The graphite peaks in some samples (BN3 and BN4) samples from the lower part of the unit area relatively wide and intensity count is low (<300 count per second) (Fig. 7a). However, the graphite peaks from the upper part (BN7) are relatively narrow and the intensity count is high (>350 count per second) (Fig. 7b). As the width and intensity of the peaks is controlled by the degree of graphitization, it can be suggested that the quality and content of graphite increases upwards towards the MCT.

Table 1: Summary of mineralogy in the studied samples.

Sample No.	Mineral content in %							
	Graphite	Quartz	Feldspar	Muscovite	Chlorite	Calcite	Biotite	Garnet
BN1	20	35	5	15	x	x	15	10
BN2	25	30	5	25	x	x	3	2
BN3	20	40	10	20	x	x	10	x
BN4	25	30	10	20	x	5	10	x
BN5	15	30	x	20	x	x	10	10
BN6	15	30	10	25	15	x	5	x
BN7	25	25	10	30	10	x	x	x
BN8	15	35	10	25	15	x	x	x

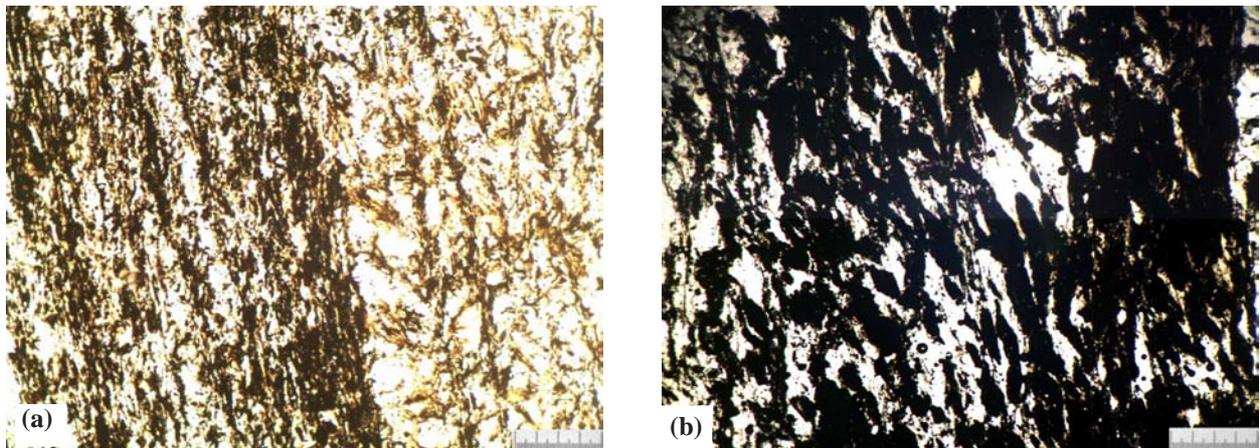


Fig. 6 Representative photomicrograph of carbonaceous schists: (a) Under plain polarized light and (b) Under crossed nicol. (Scale one small division = 0.01 mm).

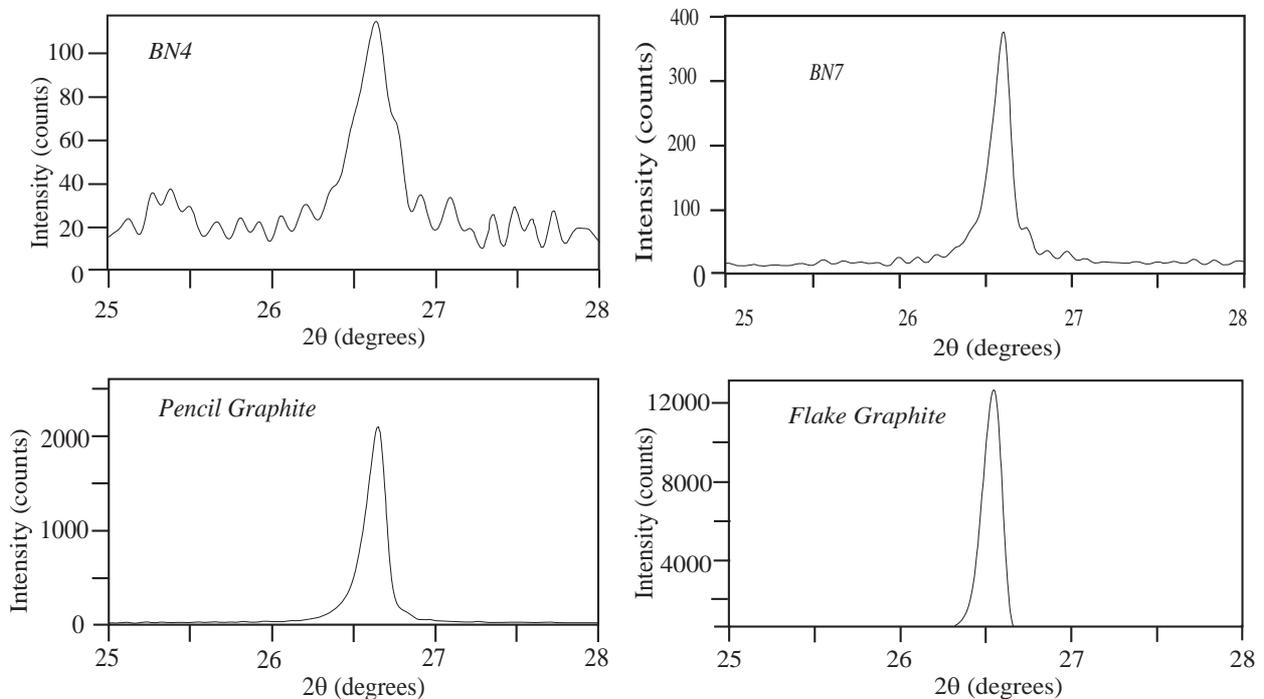


Fig.7 (a) and (b) Representative X-ray diffractogram of graphite in the carbonaceous schists. X-ray diffractograms of graphite in lead pencil (c) and flake graphite (d) are given for comparison.

DISCUSSIONS

Commercial graphite is classified as amorphous and flake (Flogg and Boyle 1987). Amorphous graphite is cryptocrystalline and grain size is $<70 \mu\text{m}$. Flake graphite is phaneritic and grain size is $>70 \mu\text{m}$. The carbonaceous schists in the present study area contain crystalline graphite as shown by well-defined peaks in X-ray diffractograms. However, the grain size of graphite varies from place to place. The graphite in the carbonaceous schist from the lower

part of the unit is fine- to very fine-grained (cryptocrystalline, $<70 \mu\text{m}$) and appears as randomly disseminated mass or scaly material under the petrological microscope. This graphite can be classified as "amorphous" graphite. Graphite in the samples from the upper part of the unit is usually coarse- to very-coarse-grained ($>70 \mu\text{m}$) and can be classified as graphite.

A review of graphite mines worldwide indicates that deposits containing graphite as low as 5% are

Table 2: Comparison of graphite in the present area with other famous graphite mines in the world. Information about the graphite in Ghachok and Walling is from Paudel (2010). Information about the other mines is from Bateman and Jenson (1990).

Place	Host rock	Graphite type	Percentage
1. Germany (Passau, Bavaria)	Micaceous schists and gneiss	Amorphous to finely crystalline	10–30%
2. South Korea (Kyonsang-Pukto)	Phyllite, Schists and marbles	Amorphous to flaky	3–4%
3. Ceylon (Sabaragmuwa Province)	Gneiss, granites	Lump in veins	>90%
4. Madagascar (Tamatave)	Schist and gneiss	Flakes	4–11%
5. Mexico (Sierra de Moradillas)	Metamorphosed coal layers	Amorphous	85–95%
6. United States (Alabama)	Mica schist	Flakes	1–5%
7. Ghachok, Kaski	Black schist	Crystalline flakes	20–30%
8. Walling, Syangja	Black slate	Amorphous	15–25%
9. Present area	Black schist	Amorphous and crystalline	15–30%

being mined commercially (Table 2). In the present area, graphite content is more than 15% in all the samples. Therefore, carbonaceous rocks of the MCT zone in Nepal may be potential sources of graphite.

CONCLUSIONS

The MCT zone in the Tatopani-FDana area of the Kali Gandaki valley comprises a very thick unit of carbonaceous schists. Petrographic study and X-ray diffraction analysis of samples from those rocks show that they contain 15 to 30% graphite. Although the grain size of graphite is variable, it is well crystalline and is appropriate for industrial purpose. As graphite is being mined commercially in rocks containing even <5% graphite worldwide, carbonaceous rocks of the MCT zone in Nepal can be regarded as a potential sources of commercial graphite.

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