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Early Proterozoic granite of the Taplejung Window, far eastern Lesser Nepal Himalaya

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ABSTRACT

The Lesser Himalayan Sequence of the Taplejung Window in the far eastern Nepal Himalaya can be divided into Taplejung Formation, Mitlung Augen Gneiss and Linkhim Schist (from bottom to top respectively). The window is a large domal shaped anticline plunging to the east.

Two-mica granite bodies (Amarpur Granite, Kabeli Khola Granite and Tamor River Granite) have intruded the metasediments of Taplejung Formation. The granite bodies are discordant to subconcordant in relation to the country rocks. Quartz, alkali feldspar, plagioclase, muscovite, biotite and tourmaline are the main constituent minerals of the granite. Generally, the core of granite bodies is undeformed, where as the marginal part is gneissfied with S-C mylonitic texture showing the top to south sense of shear. This sense of shear is related to the movement along the Main Central Thrust (MCT). All the samples from the granitic bodies fall under the granite field in the normative quartz-alkali feldspar-plagioclase (QAP) triangular diagram. The mineral composition shows that the granite is peraluminous in nature. The Kabeli Khola Granite has yielded a 40Ar/39Ar muscovite age older than 1.6 Ga indicating its magmatic age. The granites of the study area can also be correlated with the 1.8 Ga Ulleri type augen gneiss of central Nepal.

GEOLOGICAL SETTING

The study area is located between the longitudes 87°35' and 87°48'E and latitudes 27°14' and 27°30'N (Fig. 1). In this paper, an attempt has been made to briefly describe the lithostratigraphy of the Lesser Himalayan Sequence and the granites exposed in the Taplejung Window (Fig. 1). The age, petrographic characteristics and field relation of the granites with the country rock are also discussed.

The Lesser Himalayan Sequence (LHS) exposed in the study area belongs to the tectonic window named as Tamor Khola Window (Schelling and Arita 1991, Schelling 1992) or Taplejung Window (Upreti et al. 2000, Rai et al. 2001). The window is formed by the erosion of the overlying amphibolite to granulite facies metamorphic rocks of the Higher Himalayan Crystalline (HHC) thrust sheet. The contact between the LHS of the window and the overlying crystalline rocks is marked by the Main Central Thrust. The intensity of the deformation and grade of metamor phism gradually decreases downward from the MCT displaying the typical inverted metamorphism. The window is a large domal shaped anticline deeply cut by the Tamor River exposing the deep section of the LHS. On the basis of lithology, three stratigraphic rock units of the LHS have been recognized in Taplejung Window: From bottom to top, they are: Taplejung Formation, Mitlung Augen Gneiss and Linkhim Schist (Figs. 2 and 3).

Taplejung Formation

Taplejung Formation is the lowermost unit which consists of greenish to lead grey phyllite with interbeds of grey metasandstone and quartzite (Fig. 2). This unit has been further subdivided into three different members in the southeastern part of the window on the basis of lithological characteristics (Ghimire 2001). This unit can be correlated with phyllite and quartzite of Taplejung window of Bashyal (1970), Kuncha Formation in the central Nepal (Bordet 1961, Stocklin and Bhattarai 1977, Stocklin 1980), Taplejung Group (Schelling 1992). In this formation three granitic bodies are exposed near the confluence between the Tamor River and Kabeli Khola (Gautam 2001, Koirala 2002, Upreti et al. 2002) (Figs. 2 and 3).

The crenulated phyllite of this formation is composed of quartz, chlorite, sericite while metasandstone/quartzite contains quartz, sericite and chlorite. The garnet crystals appear on the upper section of this formation.

Mitlung Augen Gneiss

Mitlung Augen Gneiss overlies the Taplejung Formation (Figs. 2 and 3). It consists of highly sheared, coarse grains of quartz, K-feldspar, plagioclase, biotite and muscovite. Augens of feldspar and quartz range in size from few mm up to 3 cm in diameter. This unit is equivalent to the Ulleri Augen Gneiss of the central Nepal (Le Fort 1975, Arita 1983),

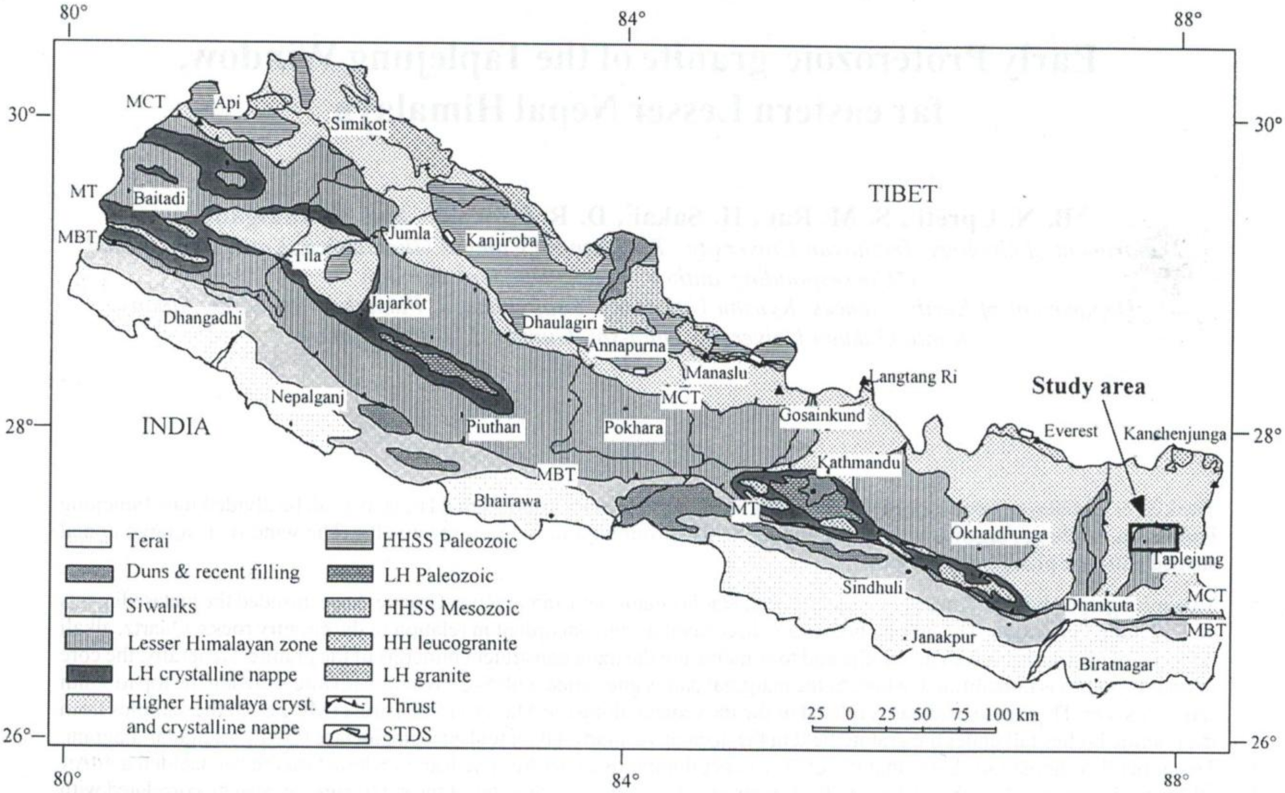

Fig. 1: Geological map of Nepal (after Upreti and Le Fort 1999) with location of the study area. HH leucogranite: Higher Himalayan leucogranite, HHSS Mesozoic: Tethyan Sedimentary Series (Mesozoic) of the Higher Himalayan, HHSS Paleozoic: Tethyan Sedimentary Series (Paleozoic) of the Higher Himalaya, LH crystalline nappe: Lesser Himalayan crystalline nappe, LH granite: "Lesser Himalayan" granite, LH Paleozoic: Sedimentary Series (Paleozoic) of the Lesser Himalayan nappes (Phulchauki Group), MBT; Main Boundary Thrust, MCT: Main Central Thrust, MT: Mahabharat Thrust, STDS: South Tibetan Detachment System.

feldspathic schist of Taplejung area (Bashyal 1970) and Sisne Khola Augen Gneiss of Tamor Khola Window (Schelling 1992). The common presence of xenoliths (metasandstone and quartzite) in the augen gneiss is a strong evidence of the magmatic origin of the gneiss.

Linkhim Schist

The uppermost unit of the LHS is the Linkhim Schist which overlies the Mitlung Augen Gneiss and separated from the Higher Himalayan Crystallines by the MCT (Figs. 2 and 3). Strongly foliated metapelitic biotite-schist with or without garnets and quartzite are the common rock types. Amphibolite is rarely present. Garnets are more common towards the top of the unit and range in size from a few mm to 1 cm in diameter. Hornblende-garnet bearing schist is also observed in the southeastern part of the window (Ghimire 2001). This unit is comparable with the biotite-musovite-quartz schist with amphibolite and garnetiferous quartz-biotite schist with chlorite from Taplejung Window (Bashyal 1970), and Khare phyllite of eastern Nepal (Schelling 1992).

Granites of the Taplejung Formation

Three separate large bodies of granites- namely Amarpur Granite, Kabeli Khola Granite and Tamor River Granite intrude the metasediments of the Taplejung window.

Amarpur Granite

This granite is well exposed around Amarpur area in the southern part of the study area (Fig. 2). It has intruded into the metasandstone and phyllite of the Taplejung Formation. The granite is an elongated body extending in E-W direction and measures 5.8 km by 2 km. The main body is undeformed and unmetamorphosed in its core showing granular texture and composed of quartz, feldspar, tourmaline, muscovite and biotite. However, along the periphery the granite exhibits strong deformation producing distinct S-C mylonitic texture and pronounced north-south mineral lineation indicating a top to south sense of shear. The mineral lineation generally trends 100 E. The xenoliths of metasandstone and phyllite are common in the peripheral part of the body.

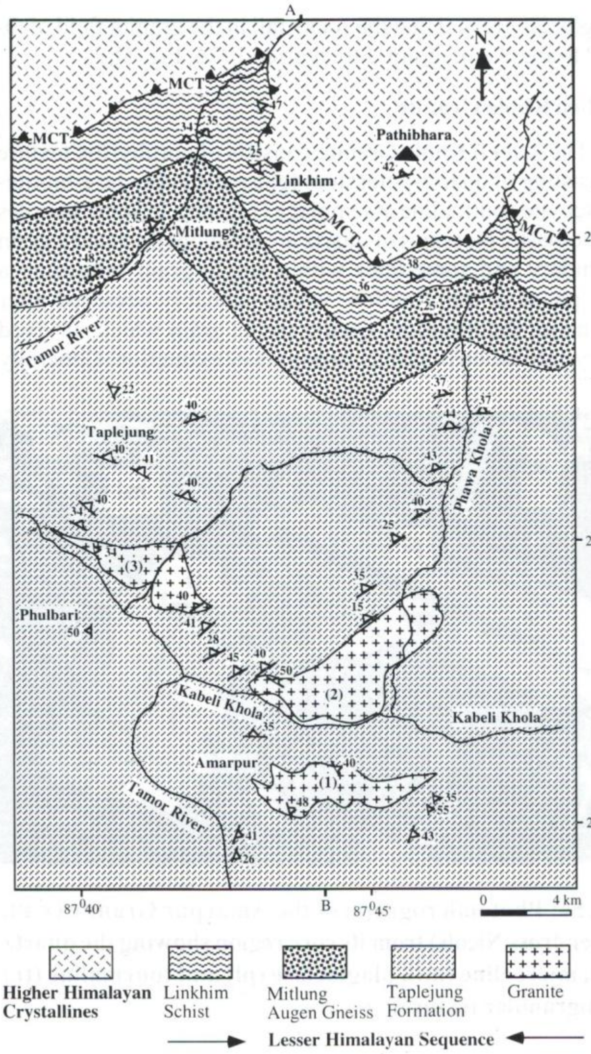

Fig. 2: Geological map of the northern part of Taplejung Window, far Eastern Nepal Himalaya. A-B represents the cross section shown in Fig. 3. MCT: Main Central Thrust, (1) Amarpur granite, (2) Kabeli Khola granite and (3) Tamor River granite.

Kabeli Khola Granite

This granite is the largest one among the three granite bodies in the area and is exposed along the Kabeli Khola and the Phawa Khola sections. It has intruded into the metasandstone and phyllite of Taplejung Formation (Fig. 2). It is an elongated body with a spoon shaped in outline and extends along an NE-SW direction. The dimension of the granite body is 7 km long and 2 km wide. The body is also relatively undeformed in the core showing granular texture. The coarse grained granite of the core area consists of quartz, feldspar, biotite, muscovite and tourmaline. Along the periphery, the granite is deformed and is represented by orthogneiss. The deformation shows S-C mylonitic texture with top to south sense of shear. The baking effect in some places is marked by up to 2 m thick hornfels. The xenoliths of phyllite and quartzite are common.

Tamor River Granite

The granite body is exposed in an area to the south of Taplejung Bazzar and extends parallel to the Tamor River. It intrudes the metasandstone and phyllite of Taplejung Formation. The body is wedge shaped in outline and extends in a ESE-WNW direction. Like other granites of the study area, the core of this granite body is also undeformed preserving granular texture and consists of quartz, feldspar, tourmaline, muscovite, and biotite. The body is deformed to orthogneiss along the periphery with the presence of S-C mylonitic texture and N-S mineral lineation indicating the south directed sense of shear. Xenoliths of metasandstone and phyllite are frequently observed in the boundary of the body (Fig. 4). The size of xenoliths varies from few cm to 11 cm. Up to 2 m thick hornfels have developed around the body.

Many other small granitic bodies are also found to intrude the metasediments of the Taplejung Formation. All these granites are highly deformed into orthogneisses. Field relations of all these granites with their country rocks are found to be similar. These granites are sub concordant to disconcordant with the foliation planes of the country rocks. No significant contact metamorphism has been observed around these granites except some hornfels of about 1 to 2 m thick in some places particularly in the surrounding of the

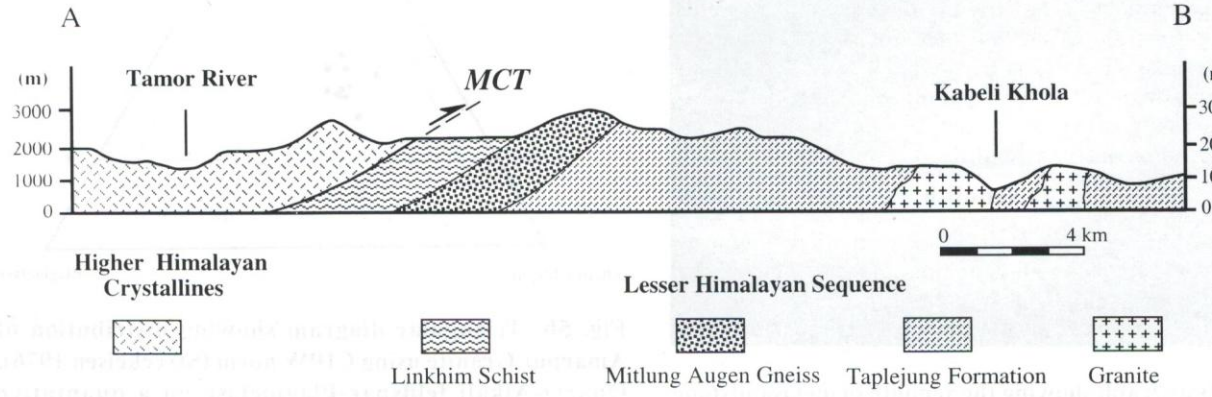

Fig. 3: Geological cross-section of the northern part of Taplejung Window. MCT: Main Central Thrust

Kabeli Khola Granite and Tamor River Granite. All these granites have same mineralogical composition from the core to margin. All these granite bodies show a general E-W trend probably resulted due to the N-S compression during the thrusting of the HHC along the MCT.

PETROGRAPHY

Samples were collected systematically from the periphery to the core from all the three granite bodies. On the basis of petrographic study, average percentage of different minerals in each sample was calculated (Table 1). Only quartz, alkali feldspar and plagioclase were taken into consideration for the recalculation of the percentage and plotting QAF triangular diagrams (Table 2).

Amarpur Granite

The Amarpur Granite consists of porphyritic and occasionally equigranular texture. It consists of quartz-potassium feldspar-plagioclase-biotite-muscovite-tourmaline assemblage (Fig. 5a). Recrystallization of some quartz grains are observed. Plagioclase and K-feldspar (microcline) range in size from 1 mm to 5 mm. Quartz shows wavy extinction as a result of deformation. Muscovite is slightly pleochroic. Pleochroic biotites are relatively smaller in size than muscovite crystals. Yellowish brown to green tourmaline crystals are highly fractured along their prismatic section.

Petrographic study (model analysis of 10 granite samples) revealed that the Amarpur Granite on an average contains quartz (30%), alkali feldspar (31%), plagioclase (17%), muscovite (7%), biotite (5%), tourmaline (7%) and the rest is phyllosilicate minerals (3%) (based on the arithmetic means of percentages of minerals in different samples) (Table 1a). The average recalculated percentages of quartz, alkali feldspar, and plagioclase feldspar are 36%, 41% and 23% respectively (Table 2a). The plotting of the average recalculated percentage of quartz, alkali feldspar, and plagioclase reveal that the rocks fall in the granite field of Q-A-P triangular diagram (Streckeisen 1976, Fig. 5b).

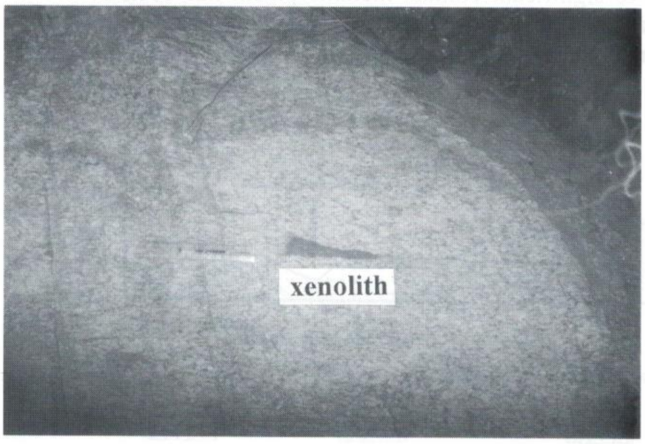

Fig. 4: Photograph showing the xenolith of metasandstone in the Tamor River Granite.

Kabeli Khola Granite

The Kabeli Khola Granite consists of porphyritic texture consisting of quartz-potassium feldspar-plagioclase-biotite-muscovite-tourmaline assemblage (Fig. 6a). In some samples granoblastic mossaics of quartz are developed around a grain boundary and sometimes within single grain indicating a late phase of deformation, which probably occurred after the major deformation. Quartz (relict grain which survived recrystallization) exhibits strong wavy extinction. Generally

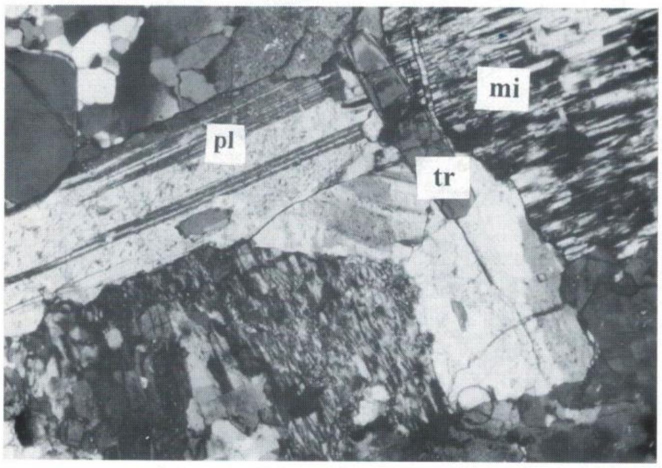

Fig. 5a: Photomicrograph of the Amarpur Granite (x 40, under cross Nicols) from its core region showing the quartz (qz), microcline (mi), plagioclase (pl) and tourmaline (tr) (equigranular texture).

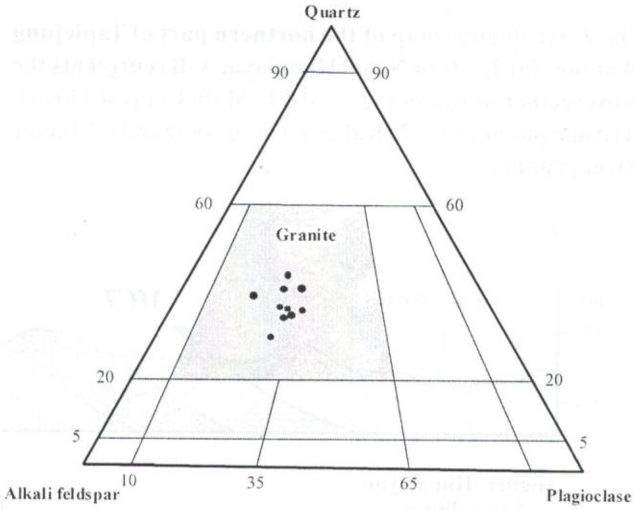

Fig. 5b: Triangular diagram showing distribution of Amarpur Granite using CIPW norm (Streckeisen 1976). Quartz-Alkali feldspar-Plagioclase on a quantative mineralogical classification of igneous rocks.

Table 1: Model analysis (from petrography) of the granite rocks of the Taplejung Formation of LHS, Taplejung Window, far eastern Nepal.

1a: Amarpur Granite

S. N.	Sample No.	Quartz %	Alkali Feldspar	Plagioclase Feldspar %	Muscovite %	Biotite %	Tourmaline %
1	DR9	23	38	18	8	4	7
2	K1	30	35	20	5	3	5
3	K2	33(8*)	33	18	7	4	4
4	K3	28	33	13	7	8	8
5	DR11	27	33	18	10	5	5
6	DR12	32(6*)	28	20	12	7	6
7	K16	30	30	15	8	4	10
8	DR15	31(6*)	23	15	7	9	8
9	X	27	32	18	4	5	5
10	Y	40(8*)	28	15	4	4	7
Average of 10 samples		30	31	17	7	5	7

* Recrystallized quartz percentage

1b: Kabeli Khola Granite

11	P1 A	26(7*)	20	12	10	5	18
12	P1 B	40(15*)	20	15	8	10	7
13	P1C	37(15*)	20	15	8	5	7
14	P2	40(20*)	20	15	8	5	5
15	P3	35(15*)	18	21	10	5	7
16	M1	28(5*)	23	18	10	5	7
17	M2	25(2*)	18	20	12	7	5
18	M3	25(5*)	23	15	8	4	7
19	M4	29(2*)	17	12	10	5	5
20	DR7	37(5*)	15	20	8	8	10
Average of 10 samples		32	19	16	9	6	8

*Recrystallized quartz percentage

subhedral crystals of plagioclase and microcline are highly deformed and altered. The muscovite is slightly pleochroic. The crystals of tourmaline are highly fractured, subhedral to euhedral in shape and yellowish to bluish green in color.

On an average (10 samples), the rock contains quartz (32%), alkali feldspar (19%), plagioclase (16%), muscovite (9%), tourmaline (8%), biotite (7%) and phyllosilicate minerals (9%) (Table 1b). The average recalculated percentage of quartz, alkali feldspar and plagioclase are 39%, 33% and 28% respectively (Table 2b). The triangular plot of normative quartz-alkali feldspar-plagioclase (QAP diagram) shows that the rocks fall within the field of granite (Fig. 6b).

Tamor River Granite

The major constituents of Tamor River Granite are quartz, microcline, plagioclase, biotite, muscovite and tourmaline mostly showing porphyritic texture. Quartz grains are recrystallized along the boundary. Generally subhedral crystals of plagioclase and microcline are highly deformed and altered (Fig. 7a). Their size ranges from 1 mm to 8 mm. The muscovites, like in other granites of the area show slight pleochroism. Biotite crystals are relatively smaller in size than the muscovite crystals. The large crystals of tourmaline are highly fractured and they are subhedral to euhedral in shape with brown to blue or blueish green in color.

1c: Tamor River Granite

S. N.	Sample No.	Quartz %	Alkali Feldspar	Plagioclase Feldspar %	Muscovite %	Biotite %	Tourmaline %
21	P7	40(20*)	30	15	5	3	5
22	P8	36(12*)	24	18	9	5	5
23	P9	30(10*)	35	10	7	5	10
24	P10(A)	22(0*)	30	15	10	9	5
25	P10(B)	28(0*)	33	13	7	8	8
26	P12	28(0*)	25	15	5	12	5
27	P13(A)	43(8*)	15	17	10	5	5
28	M14	25(0*)	33	18	10	7	5
29	M15	43(13*)	23	15	7	3	6
30	M16	38(5*)	24	18	5	5	5
Average of 10 samples		33	27	15	8	6	6

*Recrystallized quartz percentage

Table 2: Recalculated to 100% of Quartz (Q), Alkali feldspar (A) and Plagioclase (P).

2a: Amarpur Granite

S. N.	Sample No.	Quartz %	Alkali Feldspar %	Plagioclase %
1	DR9	29	48	23
2	K1	35	41	24
3	K2	33	43	24
4	K3	38	45	17
5	DR11	35	42	23
6	DR12	35	38	27
7	K16	40	40	20
8	DR15	40	36	24
9	X	35	42	23
10	Y	43	37	20
Average of 10 samples		36	41	23

2b: Kabeli Khola Granite

11	P1 A	37	39	24
12	P1 B	41	33	26
13	P1C	38	35	27
14	P2	36	36	28
15	P3	33	33	34
16	M1	35	35	30
17	M2	38	29	33
18	M3	34	35	31
19	M4	48	30	22
20	DR7	47	24	29
Average of 10 samples		39	33	28

2c: Tamor River Granite

S. N.	Sample No.	Quartz %	Alkali Feldspar %	Plagioclase %
21	P7	31	46	23
22	P8	36	36	28
23	P9	31	54	15
24	P10(A)	33	45	22
25	P10(B)	38	45	17
26	P12	41	37	22
27	P13(A)	52	22	26
28	M14	33	43	24
29	M15	44	34	22
30	M16	44	32	24
Average of 10 samples		38	39	23

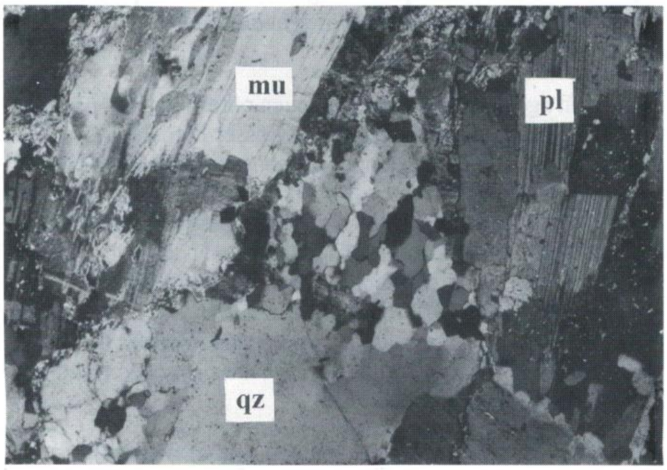

Fig. 6a: Photomicrograph of the Kabeli Khola Granite (x 40, under cross Nicols) showing the quartz, microcline, plagioclase and muscovite. Note the alignment of the mineral grains along a particular direction and the granoblastic mossaics of quartz at the centre of the photograph.

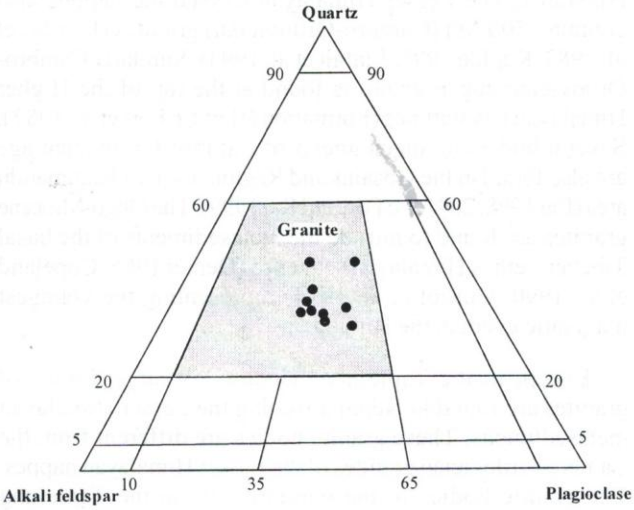

Fig. 6b: Triangular diagram showing distribution of the Kabeli Khola Granite using CIPW norm (Streckeisen 1976). Quartz-Alkali feldspar-Plagioclase on a quantative mineralogical classification of igneous rocks.

On an average (10 samples), the granite contains quartz (33%), alkali feldspar (27%), plagioclase (15%), muscovite (8%), biotite (6%), tourmaline (6%) and phyllosilicates (5%) (Table 1c). The average recalculated percentage of quartz, alkali feldspar and plagioclase are 38%, 39% and 23% respectively (Table 2c). The rocks fall in the field of granite on the Q-A-P triangular diagram (Fig. 7b).

Petrographcially, all the samples of the three granite bodies show larger percentage of muscovite than biotite. When this result is plotted on the A-B or Characteristic Minerals Diagram of Debon and Le Fort 1988, the granites fall under the two mica-granite type and belong to the peraluminous domain (Fig. 8 and Table 1a, 1b and 1c).

CORRELATION AND AGE OF GRANITES AND MITLUNG AUGEN GNEISS

The Lesser Himalayan terrain of Nepal has experienced several magmatic episodes at different geological times. The Pre-Cambrian Ulleri Augen Gneiss (Pecher 1978), the Pre-Cambrian Ampipal Alkaline Gneiss (Lassere 1977), the Cretaceous volcanic rocks, the Aulis Formation (Sakai 1983) represent the main magmatic episodes in the Lesser

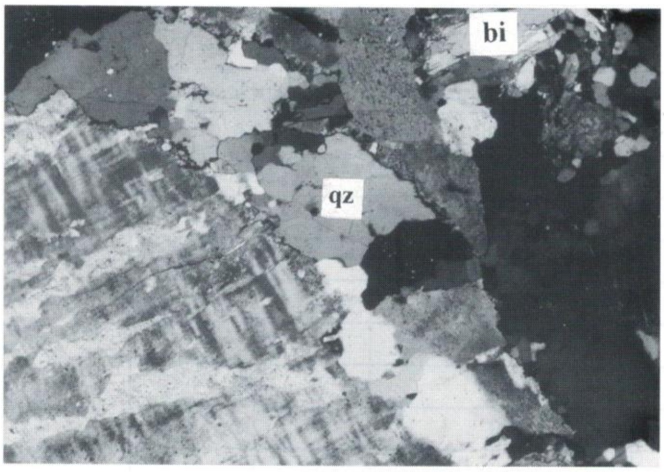

Fig. 7a: Photomicrograph of the Tamor River Granite (x 40, under cross Nicols) showing the quartz, plagioclase and muscovite. Deformed plagioclase at the left corner of the photograph.

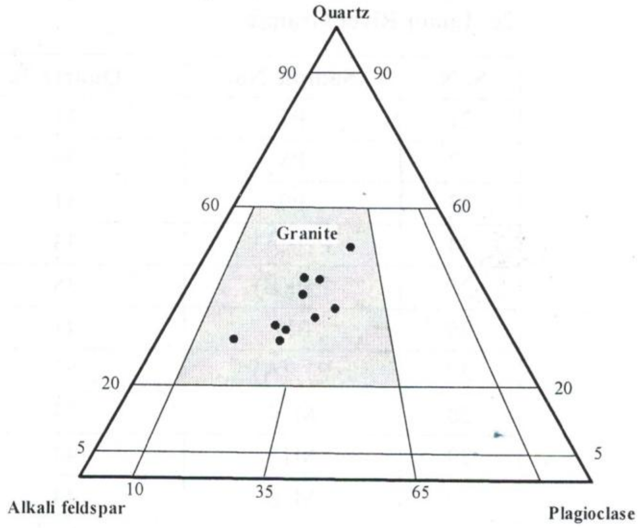

Fig. 7b: Triangular diagram showing distribution of the Tamor River Granite using CIPW norm (Streckeisen 1976). Quartz-Alkali feldspar-Plagioclase on a quantative mineralogical classification of igneous rocks.

Himalaya. The Lesser Himalayan Crystalline nappes also contain ~500 Ma (Cambro-Ordovician) granites (Le Fort et al. 1983, Kaphle 1991, Einfalt et al. 1993). Similarly Cambro-Ordovician augen gneiss is found at the top of the Higher Himalayan Crystallines (Formation III of Le Fort et al. 1982). Several bodies of augen gneiss of Cambro-Ordovician age are also found in the Gosainkund Region north of Kathmandu area (Rai 1998, 2001; Le Fort and Rai 1999). The Oligo-Miocene granites are found to intrude the metasediments of the basal Tibetan-Tethys Himalayan sequence (Deniel 1985, Copeland et al. 1990, Guillot et al. 1994) representing the youngest magmatic event in the Himalaya.

Except in the Taplejung window, no large bodies of granites are found in Nepal intruding the Lesser Himalayan metasediments. These granite bodies are different from the Cambro-Ordovician granites of the Lesser Himalayan nappes. The granite bodies in the window intrude the Taplejung Formation which lie stratigraphically below the Mitlung Augen Gneiss. Based on the field relation and petrography, the Mitlung Augen Gneiss can be correlated with the Ulleri Augen Gneiss of central Nepal (Le Fort 1975). In the present study area, the granites of the window and Mitlung Augen Gneiss have similar mineralogical composition. The xenoliths of phyllite and metasandstone are found in both granites and Mitlung Augen Gneiss showing the evidence of magmatic origin of both the rocks.

In Lesser Himalaya of central Nepal, Rb-Sr analyses of 12 rock samples of Ulleri Augen Gneiss have yielded an age of around 2 Ga (Vidal et al. 1987). Tourmaline bearing pegmatite veinlets intruding the Kuncha Formation of the Lesser Himalaya yielded a muscovite age of 1744 ± 84 Ma by Rb-Sr method (Deniel 1985). Another similar age of 1867 to 1878 Ma was obtained on zircons from the Kuncha Formation in Langtang (Parrish and Hodges 1996). Amritpur granite from the Lesser Himalayan rocks of Kumaun, India yielded 1880 ± 40 Ma (Varadarajan 1978). Similarly, Rb-Sr whole rock isochron age (1678±44 Ma) has been obtained from Lingtse Augen Gneiss, Darjeeling, Sikkim Lesser Himalaya (Paul et al. 1996). The zircon of Rampur metabasalts of the Larji-Kullu-Rampur window in the Lesser Himalaya, India yielded an evaporation age of 1800 ± 16 Ma interpreting as the minimum evaporation age of magmatism (Miller et al. 2000). The Bomdila Gneiss of Arunachal Pradesh, India shows Rb-Sr whole rock age of 1827 to 1914 Ma (Zeitler et al. 1989). The U-Pb Zircon ages of the Ulleri type augen gneisses (granitic gneiss) in far western Nepal Lesser Himalaya was found to be 1.8 Ga (DeCelles et al. 2000).

The $^{40}Ar/^{39}Ar$ muscovite plateau age of a sample from the Kabeli Khola granite exposed at the Kabeli Khola was found to be 1.5 Ga (Upreti et al. 2002). Further analyses of the rocks yielded 1.5-1.6 Ga $^{40}Ar/^{39}Ar$ age spectrum of muscovite from Kabeli Khola granite indicating the pattern of degassing of Ar gas, at 960-1300 C (about 88% 39K). This result indicates that the granitic rocks have undergone weak metamorphism and the magmatic age must be older than 1.6 Ga (Takigami et al. 2002).

CONCLUSIONS

Taplejung Formation, Mitlung Augen Gneiss and Linkhim Schist are the three main stratigraphic units of the Lesser Himalayan Sequence in Taplejung Window of far eastern Nepal Himalaya. Amarpur Granite, Kabeli Khola Granite and Tamor River Granite are major acidic igneous bodies intruding into the metasediments of Taplejung Formation.

The petrographical studies and Q-A-P triangular diagram of granites show that the rocks are of granitic composition and peraluminous in nature. The marginal part of granites is

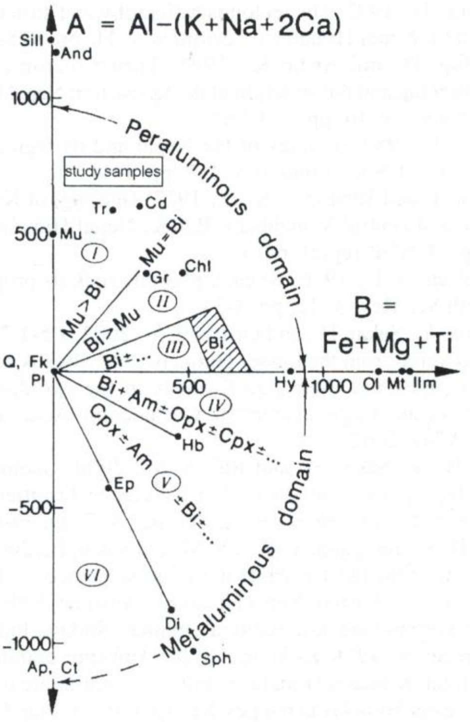

Fig. 8: 'A-B' or 'characteristics minerals' diagram (Debon and Le Fort 1983). A is a classical "alumina index" and B is directly proportional to the weight content of dark minerals in common granitic rocks (La Roche 1964). There are six sectors, numbered from I to VI, corresponding to a specific mineralogical composition. I, II, III represent the sectors of peraluminous rocks with, respectively: I muscovite (Mu) > biotite (bi) by volume representing the studied samples; II biotite > muscovite; III biotite (usually alone); IV, V, VI represent the sectors of metaluminous rocks with, respectively, IV biotite + amphibole (am) ± pyroxene (Opx, Cpx); V clinopyroxene (Cpx) ± amphibole ±biotite; VI unusual rocks (e. g. carbonatites).

gneissified with S-C mylonitic texture. This texture indicates a top to south sense of shear related to the MCT movement. The 40Ar/39Ar muscovite plateau age of the Kabeli Khola Granite suggests that the magmatic age of the granite is older than 1.6 Ga. Thus, these granites can be correlated with the Ulleri type augen gneiss of central and western Nepal Lesser Himalaya. Both the granites and the Mitlung Augen Gneiss show similar mineralogical composition. The xenoliths of phyllite and metasandstone are found in both granites and Mitlung Augen Gneiss showing the evidence of magmatic origin for both.

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REFERENCES

Arita, K., 1983, Origin of the inverted metamorphism of the Lower Himalayas, central Nepal. Tectonophysics, v. 95, pp. 43-60.

Bashyal, R. P., 1970, Geology of Taplejung area. Technical report, HMG of Nepal, Kathmandu (unpublished).

Bordet, P., 1961, Recherches geologiques dans l'Himalaya du Nepal, region du Makalu. Paris, Ed. Centre Natl. Rech. Sci. 275 p.

Copeland, P., Harrison, T. M. and Le Fort, P., 1990, Age and cooling of the Manaslu granite: implications for Himalayan tectonics. Jour. Vol. Geoth. Res. Special Pub., v. 44, pp. 33-50.

Debon, F. and Le Fort, P., 1988, A cationic classification of common plutonic rocks and their magmatic associations: principles, methods, applications. Bull. Mineral, v. 111, pp. 493-510.

DeCelles, P. G., Gehrels, G. E., Quade, J., LaReau, B. and Spurlin, M., 2000, Tectonic implication of U-Pb Zircon ages of the Himalayan Orogenic Belt in Nepal. Science, v. 288, pp. 497-499.

Deniel, C., 1985, Apport des isotopes du Sr, du Nd et du Pb a la connaissance de l'origin des leucogranites himalayens. Exemple du Manaslu (Himalaya, Nepal). Ph. D. Thesis, University of Clemont-Ferrand, France, 114 p.

Einfalt, H. C., Hohendorf, A. and Kaphle, K. P., 1993, Rb-Sr whole rock age determination of Dadeldhura granite, Far-Western Nepal. Schweiz. Mineral. Petrogr. Mitt., v. 73, pp. 97-106.

Gautam, T., 2001, Geological mapping and Engineering Geological study in the northern part of the Taplejung Window, Eastern Nepal Himalaya. M. Sc. Thesis, Tribhuvan University, 91 p.

Ghimire, S., 2001, Geological mapping in the Taplejung Window, Panchthar district, Eastern Nepal Himalaya with special emphasis on the metamorphism and tectonics. M. Sc. Thesis, Tribhuvan University, 88 p.

Guillot, S., Hodges, K.V., Le Fort, P. and Pecher, A., 1994, New constraints on the age of the Manaslu leucogranite: evidence for Oligocene-Miocene tectonic denudation in the central Himalaya. Geology, v. 22, pp. 559-562.

Kaphle, K. P., 1991, Geochemistry of Dadeldhura granite and its mineral potential. Jour. Nepal Geol. Soc., v. 7, pp. 21-38.

Koirala, D. R., 2002, Geology of Taplejung area, far eastern Nepal Himalaya with special emphasis on the petrography of the granitic pluton. M. Sc. Thesis, Tribhuvan University, 80 p.

La Roche, H., 1964, Sur l'expression graphique des relations entre la composition chimique et la composition minéralogique quantitative des roches cristallines. Presentation d'un diagramme destivé à étude chimico-minéralogique des massifs granitiques et grano-dioritiques. Application aux Vosges cristallins. Sci. Terre, v. 9, pp. 293-337.

Lasserre, J. L., 1977, Amphibolites and alkaline gneisses in the Midland formation of Nepal. Petrography, geochemistry, geodynamic involvements. In: Ecologie and geologie de l'Himalaya. Colloque International n0 268 Himalaya, Paris, Centre. Natl. Rech. Sci. vol. Sci. de la Terre, pp. 213-236.

Le Fort, P., 1975, Himalaya: The collided range. Present knowledge of the continental arc. Am. J. Sci., v. 275A, pp. 1-44.

Le Fort, P. and Rai, S. M., 1999, Pre-Tertiary magmatism of the Nepal Himalaya: recycling of continental crust. Jour. Asian Earth Sci., v. 17, pp. 607-628.

Le Fort, P., Pecher, A. and Vidal, P., 1982, Les gneiss oeilles de la Dalle du Tibet: un episode magmatique acide au Paleozoique inferieur en Himalaya du Nepal. 9eme Reun. Sci. de la Terre, Paris, Soc., Geol., France, edit., 69 p.

Le Fort, P., Debon, F. and Sonet, J., 1983, The lower Paleozoic "Lesser Himalayan" granite belt: emphasis on the Simchar pluton of central Nepal. In: "Granites of Himalayas, Karakorum and Hindu-Kush,". F. A. Shams (ed.), Inst. Geol. Punjab Univ., Lahore, Pakistan, pp. 235-255.

Miller, C., Klotzli, U., Frank, W., Thoni, M. and Grasemann, B., 2000, Proterozoic crustal evolution in the NW Himalaya (India) as recorded by circa 1.80 Ga and 1.84 Ga granitic magmatism. Precambrian Research, v. 103, pp. 191-206.

Parrish, R. R. and Hodges, K. V., 1996, Isotopic constraints on the age and provinance of the Lesser and Greater Himalayan sequence, Nepal Himalaya. GSA Bull, v. 108, pp. 904-911.

Paul, D. K., McNaughton, N. J., Chattopadhyay, S., and Ray, K.K., 1996, Geochronology and geochemistry of the Lingtse gneiss, Darjeeling, Sikkim Himalaya. Jour. Geol. Soc. India, v. 48, pp. 497-506.

Pecher, A., 1978, Deformations and metamorphisme associes a une zone de cisaillement:Exemple du grand chevauchement central Himalayen (MCT). These d'Etat., Univ. Grenoble, France, 354 p.

Rai, S. M., 1998, Les nappes de Katmandou et du Gosainkund, Himalaya du Nepal central (etude cartographique, structurale, metamorphisme et radiochronologique). Ph. D. Thesis. Joseph Fourier University, Grenoble, France, 244 p.

Rai, S. M., 2001, Geology, geochemistry and radiochronology of the Kathmandu and Gosainkund nappes, central Nepal Himalaya. Jour. Nepal Geol. Soc. Special Pub., v. 25, pp. 135-155.

Rai, S. M., Upreti, B. N. and Sakai, H., 2001, Geology, structure and metamorphism of the Taplejung Window and frontal belt, Eastern Nepal. Jour. Nepal Geol Soc., v. 24, pp. 26-28.

Sakai, H., 1983, Geology of Tansen Group of the Lesser Himalaya in Nepal. Fac. Sci. Kyushu University, Japan, XXV, pp. 27-74.

Schelling, D., 1992, The tectonostratigraphy and structure of the Eastern Nepal Himalaya. Tectonics, v. 11, pp. 925-943.

Schelling, D. and Arita, K., 1991, Thrust tectonics, crustal shortening and the structure of the far-eastern Nepal Himalaya. Tectonics, v. 10, pp. 851-862.

Stocklin, J., 1980, Geology of the Nepal and its regional frame. Jour. Geol. Soc., London, v. 137, pp. 1-34.

Stocklin, J. and Bhattarai, K. D., 1977, Geology of Kathmandu area and central Mahabharat Range, Nepal Himalaya. HMG Nepal/UNDP report, 64 p.

Streckeisen, A. L., 1976, To each plutonic rock its proper name. Earth Sci. Rev., v. 12, pp. 1-34.

Takigami, Y., Sakai, H., and Orihashi, Y., 2002, 1.5-1.7 Ga rocks discovered from the Lesser Himalaya and Siwalik belt; 40Ar/39Ar ages and their significances in the evolution of the Himalayan Orogen. Geochim. Cosmochim. Acta., v. 66, No. S1, A762, 2002.

Upreti, B. N., Sakai, H. and Rai, S. M., 2000, Geology of the Taplejung area (abstract). Earth Science Frontiers (China University of Earth Sciences, Beijing), v. 7, pp. 39-40.

Upreti, B. N., Takigami, Y., Rai, S. M. and Sakai, H., 2002, 1.5 Ga granite from the Lesser Himalayan Sequence of Taplejung Window, far Eastern Nepal Himalaya. Abstract, 17th Himalay-Karakorum-Tibet International seminar, Sikkim, India.

Varadarajan, S., 1978, K-Ar ages of the Amritpur granite, district Nainital, Kumaun Himalaya, and its stratigraphic position in the Lesser Himalayan nappes, Kumaun, India. Jour. Geol. Soc. India, v. 19, pp. 380-382.

Vidal, P., Le Fort, P. and Pecher, A., 1987, Les gneiss oeilles d'Ulleri: un episode magmatique Precambrien dans le Moyen Pays du Nepal Central. Abstract, Seminaire Himalaya-Karakorum-Tibet, Nancy, France, pp. 13-15.

Zeitler, P. K., Sutter, J. F., Williams, I. S., Zartman, R. and Tahirkheli, R. A. K., 1989, Geochronology and temperature history of the Nanga Parbat-Haramosh massif, Pakistan. Geol. Soc. Am. Spec. Pap., v. 232, pp. 1-22.