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U-Pb ages of the Nardanda Pegmatite of the Kathmandu Crystalline Nappe and augen gneisses of the Gosainkund Crystalline Nappe, central Nepal Himalaya

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ABSTRACT

A 15 km long E-W running Nardanda Pegmatite belonging to the Kathmandu Crystalline Nappe (KCN) is exposed at the northern margin of the Kathmandu Valley near the contact with the Gosainkund Crystalline Nappe (GCN), a southward extension of the Higher Himalayan Crystallines. Nardannda Pegmatite is very coarse grained and consists of quartz, potash feldspar, plagioclase, tourmaline and muscovite with accessory kyanite, garnet and beryl. Chemically it is aluminous, quartz rich, leucocratic and potassic. The coarse-grained augen gneisses of the GCN are well exposed around Gulbhanjyang, Mahesh Khola, Kalphu Khola, Sundarijal and Melamchi Bazaar areas and are composed of coarse-grained quartz, potash feldspar, plagioclase, biotite and muscovite with accessory apatite, zircon and opaque minerals. Fibrolite sillimanite and kyanite are locally present. The gneisses probably represent an old deformed body of granitic origin.

The monazite and xenotime from the Nardanda Pegmatite of the Kathmandu Crystalline Nappe and zircon from the Gulbhanjyang augen gneiss and monazites from augen gneiss from Sangle Village, extension of Sundarijal augen gneiss of the GCN were dated by U-Pb method at the Laboratory of NERC, Isotope Geosciences Centre, UK. Monazite and xenotime from the pegmatite show its crystallization during Miocene ages (25 ± 1 Ma). An Early-Ordovician (486 ± 0.5 Ma) U-Pb age is obtained on zircons from the Gulbhanjyang augen gneiss. This augen gneiss may be considered as the magmatic product of the Pan African signature (Cambro-Ordovican magmatic event), similar to the magmatic history of the "Lesser Himalayan" granite and the augen gneiss of the Higher Himalayan Crystallines. Similarly, Miocene age (26 ± 1 Ma) is obtained on monazite from the augen gneiss of Sangle Village, extension of Sundarijal augen gneiss. The monazite of this augen gneiss records the final phase of the metamorphism and the Himalayan deformation during 26 ± 0.5 Ma. The age of augen gneiss of Sundarijal is closer to the age of the Nardanda Pegmatite. The movement of the ductile MCT in the study area was stopped since 25 Ma.

Keywords: U-Pb dating, Miocene and Cambro-Ordovician magmatic events, Tertiary metamorphism, central Nepal

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INTRODUCTION

In Nepal Himalaya different acidic magmatic events occurred in the different tectonic units during the different geological episodes. Precambrian Ulleri type augen gneiss, Precambrian Ampipal alkaline gneiss, Cretaceous trachytic volcanism (Aulis Formation) occurred in the Lesser Himalaya; Cambro-Ordovician Lesser Himalayan granite, small bodies of augen gneiss and pegmatite intruded in the Lesser Himalayan Crystalline nappes; similarly, augen gneiss of the Formation III, and several metric to kilometric Cambro-Ordovician augen gneiss bodies exposed to the north of Kathmandu Valley and Oligo-Miocene Higher Himalayan and North Himalayan leucogranites and pegmatites in the Higher Himalaya are the examples of differrent acidic magmatic bodies (Le Fort and Rai 1999).

The objective of this research focuses to obtain the geochronological ages on the magmatic bodies and the peak metamorphism using by the U-Pb dating on monazite, zircon and xenotime in the pegmatite of the Kathmandu Crystalline Nappe and augen gneisses of the Gosainkund Crystalline Nappe.

GEOLOGICAL SETTING

The central Nepal crossing from south to north is geologically divided into Siwaliks, Lesser Himalayan Sequence (LHS) and Higher Himalayan Crystallines (HHC), respectively (Fig. 1). The Main Central Thrust (MCT) is a major syn-to post collisional thrust fault dividing the LHS and the HHC. The Mahabharat Thrust (MT) in central Nepal is considered as the southern prolongation of the

MCT separating the Nawakot Complex and the Kathmandu Complex (Stöcklin and Bhattarai 1977; Stöcklin 1980, Pandey et al. 1995, Johnson et al. 2001), while two nappes as the Gosainkund Crystalline Nappe (GCN), an southern extension of the HHC to the north and the Kathmandu Crystalline Nappe (KCN) to the south separating by the MCT passing to the northern margin of the Kathmandu Valley have been proposed (Rai 1998, 2001; Rai et al. 1998; Upreti and Le Fort 1999). The MT separates the LHS and the KCN to the eastern, southern and western part of the Kathmandu Valley. The Nardanad Pegmatite exposed in the northern margin of the Kathmandu Valley separates the GCN from the KCN. The LHS consists of late Precambrian to Paleozoic? sedimentary and metasedimentary rocks such as limestone, dolomite, gritstone, conglomerate, slate, phyllite, schist, metasandstone, quartzite, augen gneiss (Ulleri augen gneiss) and amphibolite. The KCN consists of metasedimentary rocks (phyllite, schist, marble, metasandstone, and quartzite) of Precambrian age and sedimentary to metasedimentary rocks (limestone, slate, metasandstone, phyllite, calc-phyllite and marble) of Paleozoic age. The GCN comprises of high grade metamorphic rocks from amphibolite to granulite facies rocks (augen gneiss, granitic gneiss, micaschist, migmatite, cal-silicate gneiss, marble and quartzite).

In this study the detailed field and mineralogical studies of the Nardanda Pegmatite and the augen gneisses exposed in the GCN are carried out.

NARDANDA PEGMATITE OF THE KATHMANDU CRYSTALLINE NAPPE

A 15 km long E-W running Nardanda Pegmatite belonging to the KCN is exposed at the northern margin of the Kathmandu Valley near the contact with the GCN, a southward extension of the Higher Himalayan Crystallines. This pegmatite extends up to Mahakhu Village, north of Mahesh Khola to the west, it follows the Kalphu Khola continuously up to Sano Tinghare Village, north-east of Banepa City crossing Budhanilkantha, Sundarijal and Sankhu villages (Fig. 2). The maximum thickness of the pegmatite exposed to the north of the Kathmandu City is about 300 m and the thickness is gradually decreased towards east and west in lenticular shape.

The pegmatite is very coarse grained in texture and consists of quartz, potash feldspar, plagioclase, tourmaline and muscovite with accessory kyanite, garnet and beryl (Fig. 3a). The tourmaline is schrol (iron rich), black in color, automorphic, prismatic in form up to 3 cm long with presence of fractures. Blue colored, automorphic beryl can be observed on the north of Sankhu Village. Garnet and kyanite are rarely present.

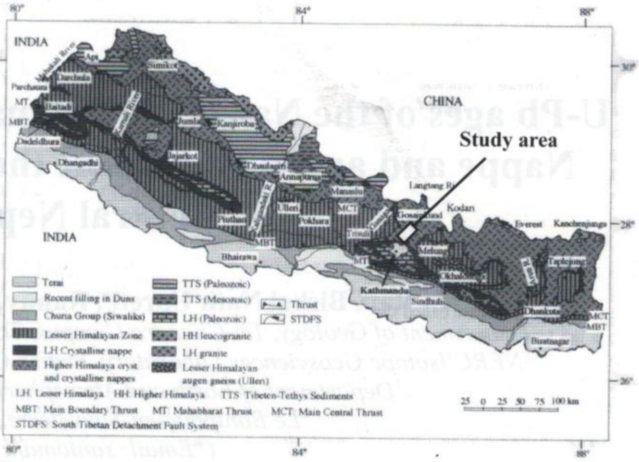


Fig. 1: Geological map of Nepal showing the study area (after Upreti and Le Fort 1999)

AUGEN GNEISSES OF THE GOSAINKUND CRYSTALLINE NAPPE

In the GCN, metric to kilometric sized augen gneiss and granitic gneiss are exposed (Hashimoto 1959; Arita et al. 1973; Stöcklin 1980; Le Fort and Rai 1999; Rai 1998, 2001). Most of the exposed gneisses form elongated lenses which lie parallel to the position of the MCT along the Mahesh Khola, Kalphu Khola, north of the Kathmandu Valley around Sundarijal Village, and close to Melamchi Bazaar, north-east of the Kathmandu Valley (Fig. 2). More or less oval shaped augen gneiss is also exposed in the central part of the GCN at Gulbhanjyang Village (Fig. 2). Most of the augen gneiss outcrop is also intruded by centimentric to metric leucogranitic veins.

The augen gneiss consists of coarse grained potassic feldspar, quartz, biotite, muscovite with tourmaline making a prominent foliation. Zircon, apatite and opaques are the accessory minerals. In some exposures, quartz-sillimanite lense is associated with the augen gneiss. The size of the augen potassic feldspar ranges from centimetric to decimetric in size (up to 10 cm long at Gulbhanjyang Village; Fig. 3b). The size of this feldspar ranges up to 18 cm in the Sundarijal Village (Arita et al. 1973). The lithological characteristics of the gneisses can be compared with the lithology of the Cambro-Ordovician augen gneisses of the Formation III or Chame orthogneiss of the Higher Himalayan Crystallines (Le Fort 1975; Pêcher 1978; Colchen et al. 1980, 1986).

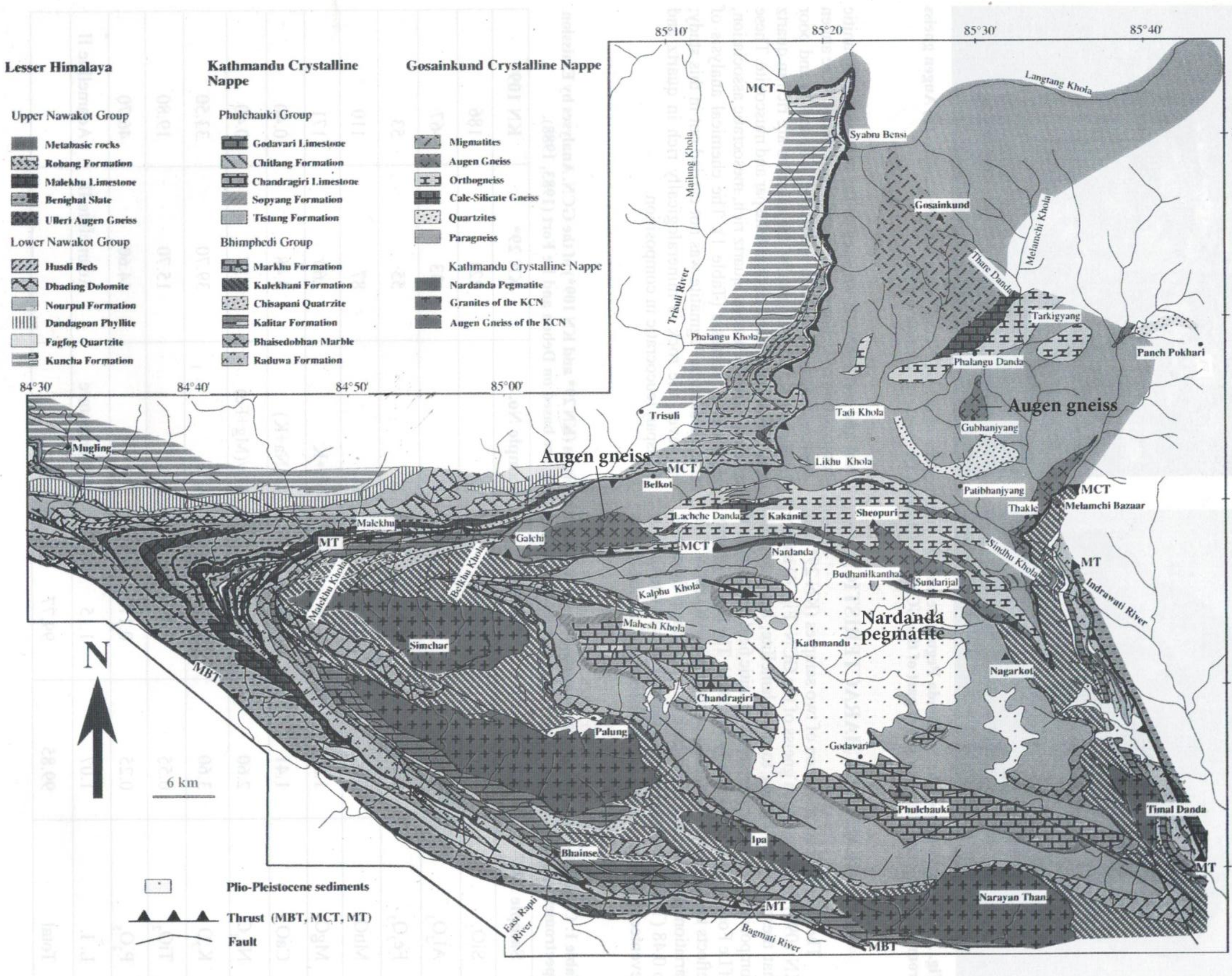
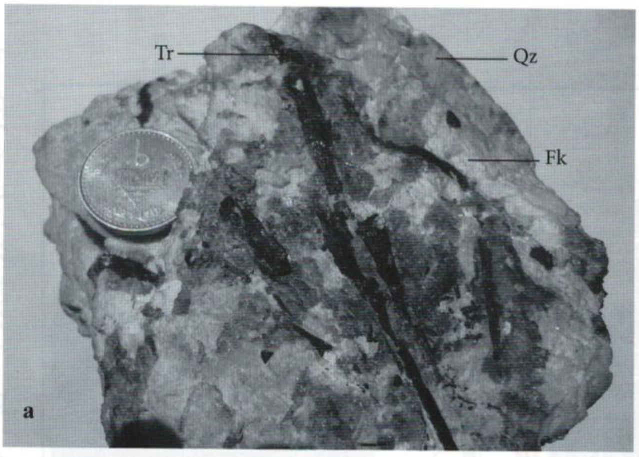


Fig. 2: Geological map of the central Nepal (after Stöcklin and Bhattarai 1977; Stöcklin 1980; Rai 1998). MBT: Main Boundary Thrust, MCT: Main Central Thrust, MT: Mahabharat Thrustv



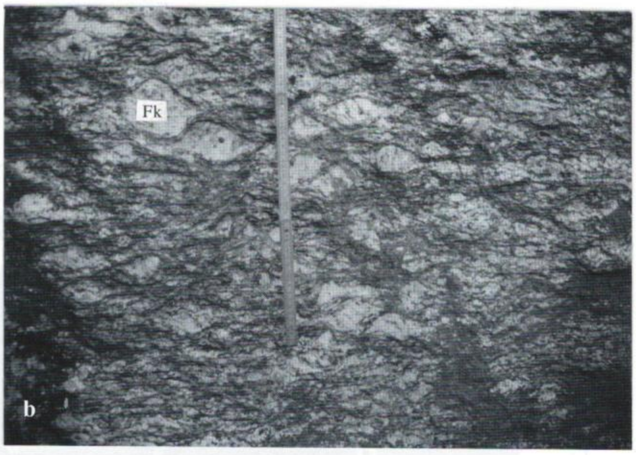


Fig. 3: Field exposures of the Nardanda Pegmatite and the augen gneiss of the GCN; (a) Nardanada Pegmatite. (b) Augen gneiss from Gulbhanjyang Village, central part of the GCN. Fk: feldspar, Qz : quartz, Tr: tourmaline

GEOCHEMICAL CHARACTERISTICS

The chemical composition of two samples (KN 29* and KN 109*) from the augen gneiss of the GCN (Fig. 4) shows that these samples belong to the adamellite; however, the composition belongs to the mainly granitic field (Q_F-P diagram of Le Fort and Rai 1999; Rai 1998, 2001). The heterogeneity reflects the important variations of the K/(Na+K) ratio. This variation of K/(Na+K) ratio in both samples ranges from 0.40 to 0.48 (Table 1) while the ratio varies from 0.14 to 0.76 in seventeen samples of the augen gneisses of the GCN (Le Fort and Rai 1999). Compared to the reference of granitic composition of Debon and Le Fort (1983, 1988), these augen gneisses appear to be rich in Fe, Mg, Ca, and Ti and poor in Na and K. Minerlogically, the samples are rich in quartz and dark minerals and poor in feldspar and muscovite. These gneisses are aluminous, quartz rich, mesocratic association, dominantly potassic (Table 1). The chemical analysis of the Nardanada Pegmatite was not carried out in this study; however, the rock is mineralogically rich in quartz and feldspar, leucocratic in composition.

Table 1: Chemical and mineralogical compositions of the augen gneisses (KN 29* and KN 109*) of the GCN. Analyses by Emission Spectrometry, CRPG, Nancy, France. The parameters and topology are based on Debon and Le Fort (1983, 1988).

Sample No.	KN 29*	KN 109*	Sample No.	KN 29*	KN 109*
SiO_2	71.64	68.21	Q	221	186
Al_2O_3	13.55	14.78	P	-33	-67
Fe_2O_3	4.03	4.83	A	55	53
MnO	0.05	0.05	B	87	110
MgO	1.20	1.66	Na+K	160	171
CaO	1.41	1.85	K/(Na+K)	0.48	0.40
Na_2O	2.60	3.17	Mg/(Mg+Fe)	0.37	0.40
K_2O	3.60	3.23	Q%	39.70	33.50
TiO_2	0.55	0.67	B%	15.70	19.80
P_2O_5	0.25	0.17	F%	44.60	46.70
L. I.	1.07	1.15	Nomenclature	Adamellite II	Adamellite II
Total	99.85	99.77			

U-Pb GEOCHRONOLOGY

Method and results

The samples were prepared in Institut Dolomieu, Grenoble, France by making grains ranging the sizes from 0.1 to 0.12 mm. Bromoform was used to obtain the fractions of the density (less than 2.9) and mythyl for the fraction of the density (greater than 2.9). Methyl was used to collect the grains of zircon, monozite and xenotime. The Franz was utilized to isolate the grains of zircon, monozite and xenotime, respectively. The grains of these minerals were dated to obtain the ages in NERC Isotope Geoscinces Centre, Notts, UK.

*Sample KN 861**

Sample KN 861* from leucocrate pegmatite of the Nardanda Pegmatite was collected along the Kathmandu-Kakani road section, boarder of the Kathmandu and Nawakot districts (Fig. 4a). During heavy mineral separation, beautiful monazite crystals with few crystals of xenotime and zircon were found. Two analyses from monazite and one analysis from xenotime were carried out showing the crystallization age of 25 ± Ma from pegmatite (Fig. 5a).

*Sample KN 29**

This sample was collected from Gulbhanjyang massif located at Golbhanjyang Village along a trekking route from Sundarijal to Gosainkund ridge (Fig. 4). During the process of heavy mineral separation, only zircon mineral was found. Monazite and xenotime were absent in this sample. The three fractions of mineral grains of zircon were analyzed which are co-linear (lightly discordant 25-50%) with a superior intercept of an age of 486 ± 9 Ma and inferior intercept, proximity of the origin with 0.0 ± 11 Ma (Fig. 5b). The discordant could be appeared due to loss of Pb during the recent Himalayan orogen.

*Sample KN 109**

Sample KN 109* from augen gneiss was collected from Sangle Village, north of Balaju, Kathmandu. This gneiss is the contineous exposure of Sundarijal massif belonging to the GCN. This gneiss is exposed to the southernmost margin of the GCN, proximity of the MCT and about 5 km NE from the Nardanda Pegmatite (KN 861*) of the KCN. During the heavy mineral separation only magmatic monazite without xenotime and zircon was found. From analyses only two ages fall above the concordia curve shown by most of the monazites with an age of 26.5 Ma by $^{207}Pb/^{325}U$ (Fig. 5c).

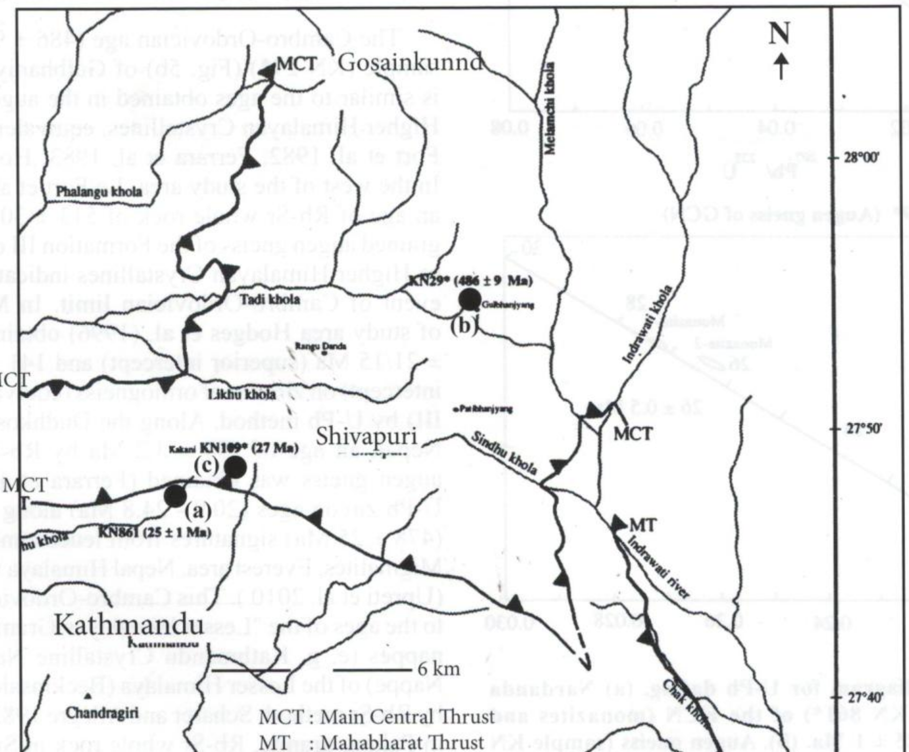


Fig. 4: Location of samples in the figure where (a) correspond to Nardanda Pegmatite (sample KN 861*) of the KCN along the Kathmandu-Kakani road section, (b) correspond to Augen gneiss (sample KN 29*) of the GCN from Gulbhanjyang Village, north of the Kathmandu Valley along the trekking route of Sundarijal-Gosainkund range and (c) correspond to Augen gneiss (sample KN 109*) from Sangle Village, north of Balaju, Kathmandu Valley.

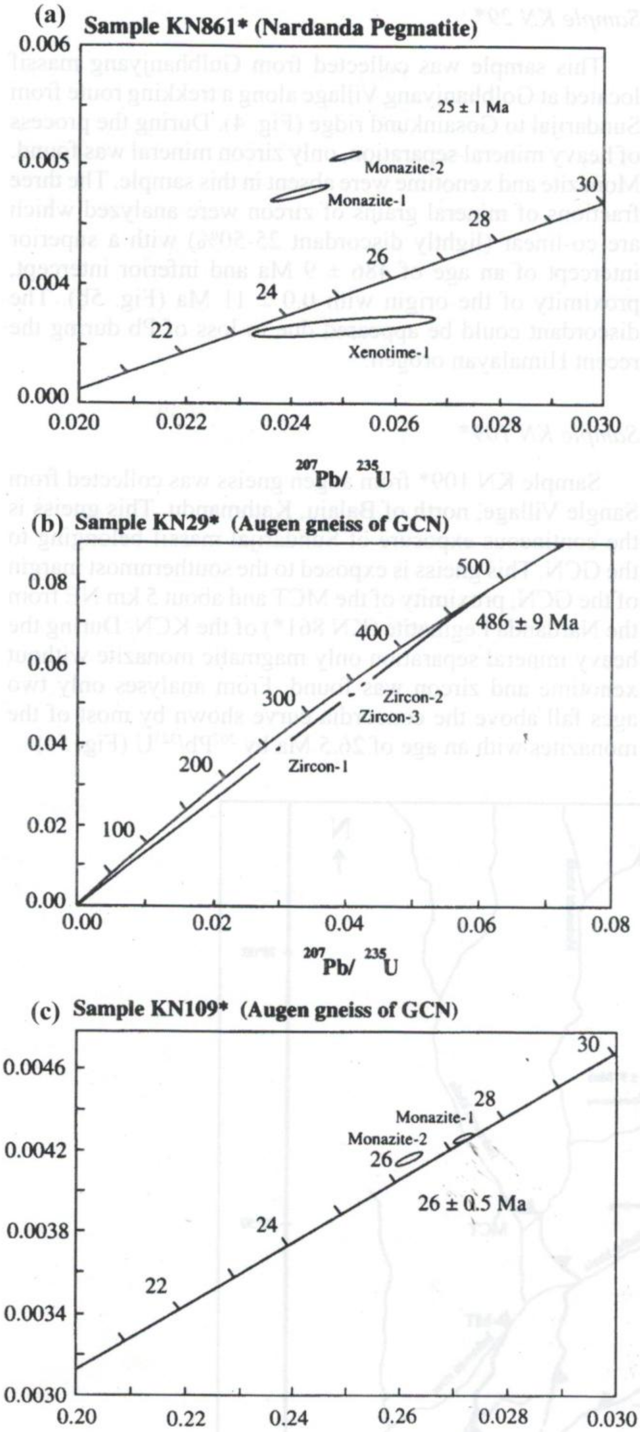


Fig. 5: Concordia diagram for U-Pb dating. (a) Nardanda Pegmatite (sample KN 861*) of the KCN (monazites and xenotime) showing 25 ± 1 Ma. (b). Augen gneiss (sample KN 29*) (zircons) of the GCN showing 486 ± 9 Ma, and (c) Augen gneiss (sample KN 109*) (monozites) of the GCN showing 26.0 ± 0.5 Ma.

DISCUSSIONS AND CONCLUSIONS

The ages of 25 ± 1 Ma (sample KN 861*) obtained in monazite and xenotime by U-Pb method show the crystallization age of the Nardanda Pegmatite (Fig. 5a). These ages are similar to the leucogranites of the Higher Himalaya obtained by the same method (U-Pb) and Th-Pb method. In Langtang area, north of study area, monazite and xenotime of paragneiss and lecogranite of the Higher Himalaya show 20.4 to 20.7 Ma (Parrish et al. 1992). Similarly, 22.0 to 24.0 Ma from monazite of leucogranites of Makalu (Schäer 1984), 20.0 ± 1.0 Ma from monazite of north of Everest (Copeland et al. 1987), 14.4 ± 0.6 Ma from same mineral of non-deformed leucogranite of Everest (Schäer et al. 1986), 25.0 Ma from same mineral at west of Manaslu (Daniel et al. 1987), 23.0 Ma on monazite at the Manaslu (Harrison et al. 1995) were obtained. Harrison et al. (1995, 1996) obtained two phases of the ages (22.9 ± 0.6 Ma; Larkya La phase) and (19.3 ± 0.3 Ma; Bimtang phase) in the crystals of monazite from Manaslu granite by Th-Pb method. In the present study, the age obtained in the Nardanda Pegmatite is comparatively older than the ages of leucogranites of the Higher Himalaya. This pegmatite is situated along the margin of the MCT, about 50 km south from the granites of northern Higher Himalaya. The younger ages of leucogranites on the northern leucogranites could correspond to the migration zones of genesis with respect to the propagation of the thrusting along the MCT.

The Cambro-Ordovician age (486 ± 9 Ma) of analyzed sample (KN 29*) (Fig. 5b) of Gulbhanjyang augen gneiss is similar to the ages obtained in the augen gneisses of the Higher Himalayan Crystallines, equivalent of the GCN (Le Fort et al. 1982; Ferrara et al. 1983; Hodges et al. 1996). In the west of the study area, Le Fort et al. (1986) obtained an age of Rb-Sr whole rock of 513 ± 30 Ma in the coarse grained augen gneiss of the Formation III of the Tibetan Slab or Higher Himalayan Crystallines indicating the magmatic event of Cambro-Ordovician limit. In Madi Khola, west of study area Hodges et al. (1996) obtained an age of 502 ± 21/15 Ma (superior intercept) and 141 ± 53 Ma (inferior intercept) on zircons of orthogneiss (equivalent of Formation III) by U-Pb method. Along the Dudhkoshi Valley, eastern Nepal, an age of 550 ± 3.2 Ma by Rb-Sr whole rock in augen gneiss was obtained (Ferrara et al. 1983). Tertiary U-Pb zircon ages (20.9 - 24.8 Ma) along with Pan African (478 ± 25 Ma) signatures from leucosomes of the Namche Migmatites, Everest area, Nepal Himalaya was recently dated (Upreti et al. 2010). This Cambro-Ordovician age is similar to the ages of the "Lesser Himalayan Granites" of crystalline nappes (e. g. Kathmandu Crystalline Nappe, Dadeldhura Nappe) of the Lesser Himalaya (Beckinsale in Mitchell 1981 by Rb-Sr method; Scharer and Allègre 1983 by U-Pb method in Palung granite, Rb-Sr whole rock in Simchar granite by Le Fort et al. 1983). The age obtained in the augen gneiss of Gulbhanjyang Village shows that the augen gneiss of the GCN consists of similar magmatic materials as compared to the magmatic materials of the Higher Himalayan Crystallines and this GCN is the bridge between the Higher Himalayan Crystallines (HHC) and the Kathmandu Crystalline Nappe (KCN).

The ages (26 ± 0.5 Ma) of the augen gneiss (sample KN 109*) of Sangle Village (extension of the augen gneiss of Sundarijal) are completely differents than the Cambro-Ordovician age (486 ± 9 Ma) (sample KN 29*) of the augen gneiss of Gulbhanjyang Village, however, both gneisses have similar petrographic and geochemical characteristics. In sample (KN 109*) from augen gneiss only monazite age was obtained while the age of zircon was not dated. The monazite from this gneiss (extension of Sundarijal gneiss, originally formed by magmatic material) can be recrystallized during the amphibolite facies metamorphism (600 - 650°C). This sample (KN 109*) of augen gneiss is located at nearly the contact between the GCN and the Nardanda Pegmatite of the KCN (about 5 km NE from the sample KN 861*) (Fig. 4). In such way monazites could be recrystallized in the augen gneiss of the Sundarijal during the emplacement of the Nardanada Pegmatite and peak metamorphism of the study area. Therefore, the younger age (26.0 ± 0.5 Ma) of the monazite of augen gneiss of Sundarijal (sample KN 109*) than the monazite age of the augen gneiss of Gulbhanjyang (486 ± 9 Ma; sample KN 29*) can be interpreted that the monazites from augen gneiss (KN 109*) record the final phase of the metamorphism (Tertiary metamorphism; 26 ± 0.5 Ma) and the Himalayan deformation recorded by the Nardanda Pegmatite. The anatexis event of the Namche Migmatites, Everest region occurred between 20.9 and 24.8 Ma (Upreti et al. 2010). These ages provide the age of the peak Tertiary metamorphism in the Everest region. Viskupic and Hodges (2001) obtained the monazite and xenotime $^{207}U/^{235}Pb$ ages (25.4 ± 0.11 and 22.11 ± 0.22 Ma) from the same area. The age (26 ± 0.5 Ma) on monazite of augen gneiss of Sundarijal is closer to the ages of the monazite and xenotime of the Nardanda Pegmatite (25 Ma). However, the age of sample KN 109* (augen gneiss) is the record of the peak metamorphism. This age is closely compared with the ages of 20.0 - 22.0 Ma, monazite of granite and paragneiss from Langtang area (Parrish et al. 1992); 20.9 Ma Ar-Ar ages from amphiboles of the MCT zone, eastern Nepal (Hubbard and Harrison 1989). These ages are younger than the age of sample KN 109* (augen gneiss of Sundarijal Village).

The Ar-Ar age on muscovite of the Nardanda Pegmatite is 12 Ma (Copeland et al. 1997). The age of 26.0-26. 5 Ma obtained in augen gneiss (KN 109*), about 5 km NE from this pegmatite can be interpreted as the record of the peak metamorphism (Tertiary metamorphism) and Himalayan deformation by monazite of augen gneiss. The Nardanda Pegmatite, like the augen gneiss (KN 109*) could be cooled since the peak metamorphism at 26.0-26.5 Ma (600-650°C) passing through the 12.0 Ma recorded by Ar-Ar closing temperature (about 300°C) of muscovite in pegmatite. These two ages (25 Ma) in pagmatite and (26. 5 Ma) in augen gneiss obtained by U-Pb method and Ar-Ar age on muscovite in pegmatite situated approximately in the same altitude having the difference in temperature of 300° C indicate the normal thermal gradient. The geochronological ages show that the movement of the ductile MCT was stopped since 25 Ma in the study area.

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