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Metamorphism in Chaukhutia Area and possible linkages of Almora Nappe with the Higher Himalayan Metamorphics

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Abstract

The Almora Group is considered an equivalent of the Munsiari Formation of the Higher Himalaya and metamorphics comprising Almora Nappe, classified as the Almora Group have been largely believed to be low grade metamorphics. One of the grounds for distinguishing the Munsiari Formation from the Vaikrita Group is the lower grade metamorphism of the former. We present findings that the grade of metamorphism in the Almora Group is far higher than presumed by earlier workers and comparable to the Vaikrita Group but perhaps a direct correlation of the Almora Group of rocks either with the Munsiari Group-- as believed by many or with the Vaikrita Group does not appear reasonable.

Introduction

The Lesser Himalayan Nappes, including the Almora Nappe, are the detached patches of a once continuous thrust sheet equivalent to the Main Central Thrust of Higher Himalaya, which moved southwards from the Higher Himalaya to cover almost the whole of the Lesser Himalaya sometimes during the early Eocene. Later, erosion of the uplifting Himalaya led to the present detached disposition of Lesser Himalayan nappes and klippes in Uttarakhand and elsewhere in the Himalaya. Although the broad tectonic scenario is largely agreed upon by the geologists but many finer but crucial details of correlation of the Lesser Himalayan nappes with their root zone are still debated. Heim and Gansser(1939) and Gansser (1964) identified nappes of the Lesser Himalaya as tectonically transported from the Higher Himalaya. The Almora Nappe was correlated with the Munsiari Formation by Valdiya (1980) and he also distinguished the underlying Munsiari Formation from the Overlying Vaikrita Group by the Main Central(=Vaikrita) Thrust in the Higher Himalaya. Valdiya (1980) and Valdiya and Goel (1983) suggested upper amphibolite facies conditions for the Vaikrita Group and low grade metamorphism --greenschist facies conditions for the Munsiari Formation with very local attainment of epidote amphibolite facies conditions. Valdiya and Goel (1983) inferred peak metamorphic temperatures around 450°C and pressures around 4kbar for the Munsiari Formation rocks.

The area of interest is located in the Almora district of Uttarakhand comprising a part (East longitudes 79°15'56" to 79°27'49" and North latitudes 29°45'19" and 30°00' 00") of the Almora Nappe that extends Far East into Nepal. The paper addresses metamorphic conditions of part of the Almora Nappe and discusses latter's correlation with its possible root zone in the

Higher Himalaya.

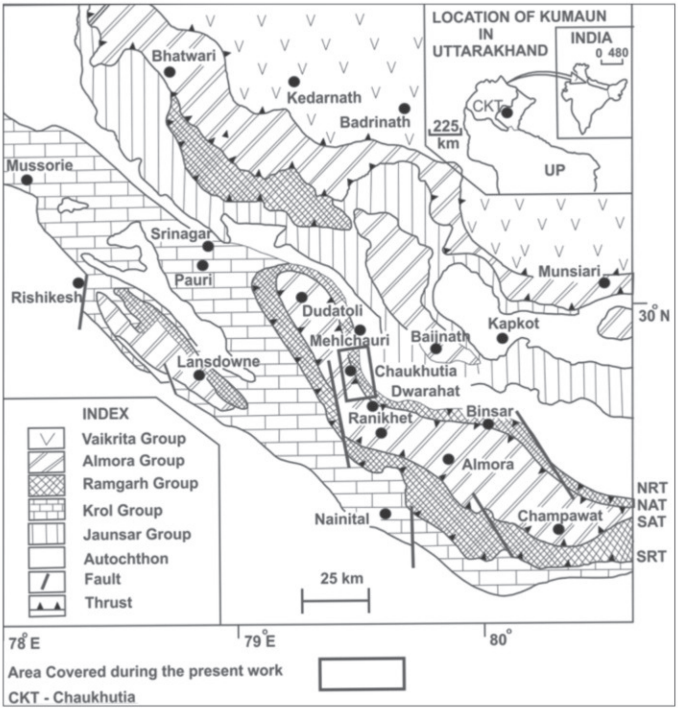

Fig.1 Generalized geological map of part of the Kumaun Himalaya (modified after Joshi, 1999)

Structural Set Up and Lithology

Almora Nappe is the name given to the composite nappe comprising the lower Ramgarh Nappe and the tectonically overlying Almora Nappe (Heim and Gansser, 1939, Gansser, 1964, Valdiya, 1980). The composite Almora Nappe is tectonically delimited from the underlying low grade metasedimentaries of the Lesser Himalaya by the Ramgarh Thrust with its northern exposure known as the North Ramgarh Thrust (NRT) and its southern exposure termed as the South Ramgarh Thrust (SRT) (Joshi, 1999). The top most part of this tectonic ensemble is the Almora Nappe senu stricto constituted by the Almora Group of rocks tectonically overlying the Ramgarh Group of rocks with the North Almora Thrust (NAT) in the North and the South Almora thrust (SAT) in the south as the two exposures of the Almora Thrust (Joshi, 1999). Most of the Ramgarh Group and the lower most part of the Almora Group of rocks are sheared with the degree of shearing decreasing up section, and this sheared ensemble responsible for bringing the Almora Nappe from the Higher Himalaya to its present location has been collectively termed as the Basal Shear Zone of the Almora Nappe by Joshi (1999). The focus of present study are the metamorphics of the Almora Group comprising parts of the Almora Nappe immediately lying south of the North Almora Thrust in the Chaukhutia area.

Bedding (S_o) marked by the lithological colour banding trends E-W to WNW-ESE with southerly dips between 10-35degrees.Four generations of folds identified by Joshi (1999) and

Joshi and Tiwari (2000, 2009) for the Almora area are also common in the Chaukhutia area. These are the isoclinal F_1 folds the tight F_2 folds, (both F_1 and F_2 plunging NE), the open F_3 folds (with sub vertical axial planes in other parts of the nappe but not observed in the area) and the F_4 folds (plunging ~15° southeast) generally occurring as broad open warps.

The metamorphic rocks belong to Saryu Formation of the Almora Group (of Valdiya, 1980) are exposed between Bhatkote and Chauna village in the Chaukhutia-Naugaon sector. The rock types are schists, gneisses and quartzites. The brownish grey and whitish grey schists are fine to coarse grained comprising quartz, muscovite, biotite and garnet. These schists are interlayered with dirty white and brownish-grey hard and compact fine to medium grained quartzites. Quartz and mica can be identified in hand specimens. The schists grade into whitish-grey and dirty white gneisses, some of which are weakly foliated, comprise medium grained minerals while others are composed of medium to coarse-grained minerals. Quartz, feldspar, mica and garnet can be identified with unaided eye.

Petrography

Major mineral constituents of schists are quartz, micas (both muscovite and biotite), chlorites, garnets, kyanites and plagioclase feldspars and the minor minerals include zoisite, sphene and magnetite. Tourmaline and zircon are also present in minor amount. Retrograded chlorite as well as sericite is present. Two generations of quartz, mica, biotite and chlorite are present. The dominant foliation is defined by the larger second generation micas which are at places cross cut by a third generation of small mica flakes. However, three types of garnets have been identified in the schists of the Saryu Formation. The first generation garnets are relict garnets that at places are stretched parallel to the foliation and contain quartz, magnetite and tourmaline inclusions. Garnet-I is pre-kinematic to the major deformation associated with the regional metamorphism affecting the area. Garnet –II are helicitic garnets containing quartz, magnetite and rare plagioclase inclusions. These garnets are syn-kinematic to the major deformation accompanying regional metamorphism. The euhedral inclusion free Garnet-III is post-kinematic to the major deformation. Garnet-III also commonly occurs as overgrowth on the syntectonic garnet cores (Fig.2).

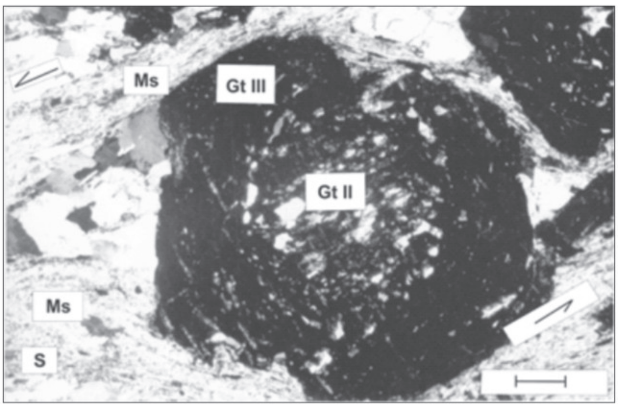

Fig.2 Synkinematic Garnet -I core with helicitic trails and the idioblastic Garnet -II rim

Saryu Formation garnets are characterized by synkinematic cores with either helicitic or snowball inclusion trails or inclusion free idioblastic garnet rim. The helicitic trails developed in response to the deformation concomitant with the regional metamorphism probably during the F1 and F2 folding. The last stage of garnet growth responsible for the fresh euhedral garnets or euhedral overgrowths on the existing garnets outlasted formation of S2 (F2) during the D_2-deformation.

Medium grained kyanites are associated with biotite, muscovite and quartz in the thin sections. Two generations of kyanite, viz. kyanite-I and kyanite-II occurring at different orientations are seen. Owing to its small modal content the kyanites could not be identified in field and have also been missed by all the earlier workers (Lal, 1959, 1969; Mishra, 1971). Plagioclase feldspars are common with the An content reaching ~ 11%.

Minerals Assemblages

1. Muscovite-biotite-plagioclase-K-feldspar-quartz
2. Muscovite-chlorite-biotite-plagioclase-quartz-tourmaline-magnetite.
3. muscovite-biotite-kyanite-garnet-plagioclase-quartz-magnetite-tourmaline
4. Muscovite-biotite-kyanite-garnet-plagioclase-quartz±carbonates-magnetite-tourmaline.
5. Muscovite-biotite-kyanite-garnet-plagioclase-quartz±zoisite-sphene-zircon.

Medium to coarse-grained gneisses of the Saryu Formation comprise quartz, muscovite, biotite, kyanite, sillimanite and K-feldspar. Garnet is present in some gneisses but is not common. Two varieties of quartz are observed in the gneisses and the older quartz invariably shows a reaction boundary whenever it is in contact with muscovite suggesting the reaction Muscovite+ quartz = K-feldspar+sillimanite+H_2O (Fig.3) Four types of muscovite and three types of biotite have been distinguished in these gneisses

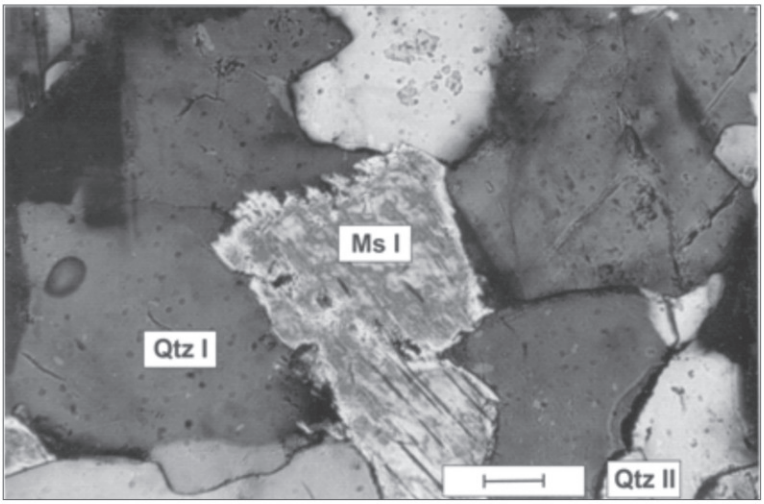

Fig. 3 Reaction boundary between muscovite-I and quartz-I suggesting the reaction Muscovite+ quartz = K-feldspar+sillimanite+H_2O

Similar to the schists two types of garnets are also observed in gneisses of the Saryu Formation of the Almora Group. Medium grained kyanite grains associated with quartz, muscovite and plagioclase also persist in the gneisses. However, randomly oriented sillimanite needles occur in association with K-feldspar, plagioclase and quartz. Plagioclases are also similar to the schists albeit with higher An content.

Mineral Assemblages

1. Muscovite-biotite-garnet-kyanite-sillimanite-plagioclase-K-feldspar-quartz.
2. Kyanite-sillimanite-garnet-biotite-muscovite-plagioclase-K-feldspar ± myrmekite ± tourmaline.
3. Sillimanite-K-feldspar-biotite-muscovite-plagioclase-quartz ± apatite.

METAMORPHIC ZONES

Four metamorphic zones have been demarcated in the area on the basis of discontinuous mineral reactions identified by petrographic studies. These are the biotite zone, garnet zone, kyanite zone and the sillimanite zone. The biotite zone encompasses phyllites, phyllitic schists, mica-schists and quartzites near the southwestern end of the area. Biotite zone is followed by the garnet zone and the garnet zone is repeated thrice along the Chaukhutia – Naugaon transect (Fig. 4). The biotite zone and the garnet zone collectively belong to the green schist facies of regional metamorphism. The biotite zone and the garnet zone are mylonitized in the proximity of the North Almora Thrust (Fig. 4). Kyanite zone comprises kyanite-garnet-mica schists that are not affected by mylonitization. The mineral assemblages of this zone are products of regional metamorphism representing kyanite – zone of amphibolites facies. The kyanite zone is repeated twice in the area (see Fig. 4). The sillimanite zone covers the sillimanite – garnet gneisses that have totally escaped the shearing related to the North Almora Thrust. On the basis of the mineral assemblages the sillimanite zone has been placed in the upper amphibolites facies of regional metamorphism. The reaction isograds between the various zones have been identified on the basis of the following reactions:

Zone –I: Biotite - Zone

……………………Garnet – Biotite Isograd …………………

Chlorite + muscovite + quartz = garnet + biotite + H_2O …………..(1)

(Thompson and Norton, 1968)

Zone –II: Garnet - Zone

……………………. Kyanite – Biotite Isograd ……………….

Almandine garnet + chlorite = kyanite + annite (biotite) ………………(2)

(Spear and Selverstone, 1983)

Zone –III: Kyanite – Zone

……………………Sillimanite – K-feldspar Isograd…………………

Muscovite + albite+ quartz = K-feldspar + sillimanite + melt ……………….(3)

(Thompson and Tracy, 1979)

Zone –IV: Sillimanite - Zone

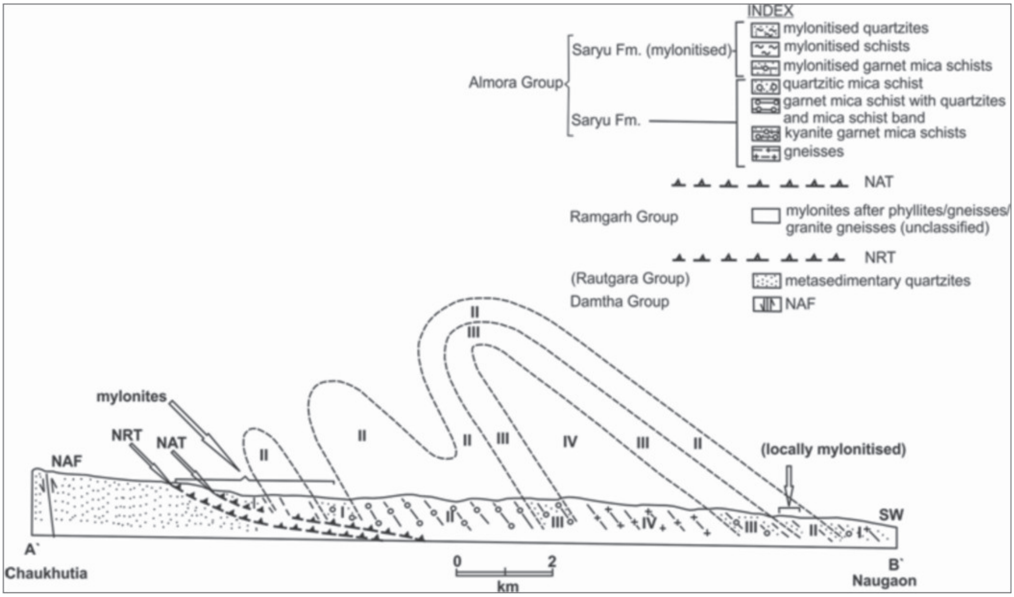

Fig. 4 Geological section showing the interpreted disposition of metamorphic zones deduced from the field and petrographic studies

The repetition of metamorphic zones observed along the geological section (Fig. 4) raises serious questions about the inverted metamorphism for this part of the Almora Nappe vis a vis the inverted metamorphic sequence of the Higher Himalaya---the root zone of the nappe. Most of the earlier workers (viz. Vannay and Grassemann, 1998; Vannay et al., 1999 and many others) have interpreted inverted metamorphism in almost all the sectors of Lesser- and Greater Himalaya. However, in the present area it is clear that the reaction isograds are folded and the limited apparent Inverted Metamorphic Sequence at the base of Almora Nappe is a consequence of a post metamorphic regional folding.

Physical Conditions of Metamorphism

On the basis of petrographic observations and metamorphic reactions a petrogenetic grid has been prepared for the area (Fig. 5). The broad P-T path the rocks have followed has been deduced on the basis of metamorphic reaction identified petrographically and is shown by arrows in the diagram. At lower grades the reactions (1) and (2) viz. the reactions responsible for the formation of garnet-biotite and kyanite-biotite (annite) assemblages have been crossed to the higher temperature side but as kyanite -plagioclase is still a stable association obviously the assemblages are on the lower pressure side of the reaction (4). The gneisses in the area have formed by the reaction (3) viz. muscovite + albite+ quartz = K-feldspar + sillimanite + melt. The petrographic evidence for this reaction is present in the unstable muscovite-plagioclase assemblage (Fig. 3) and in the occurrence of randomly oriented sillimanite needles within the K-feldspar. The regressive path of the arrow has been drawn on the basis of development of the last generation fresh tiny muscovite flakes when the aluminosilicate and K-feldspar have reacted with the water still present in the system and the reaction (3) proceeded backwards. Joshi and Tiwari (2009) have suggested peak metamorphic conditions in excess of 700°C at slightly less than 8kbar on the basis of detailed geothermobarometric calculations and petrographic studies form the adjacent eastern part of the Almora Nappe in the Chhara- Someshwar transect.

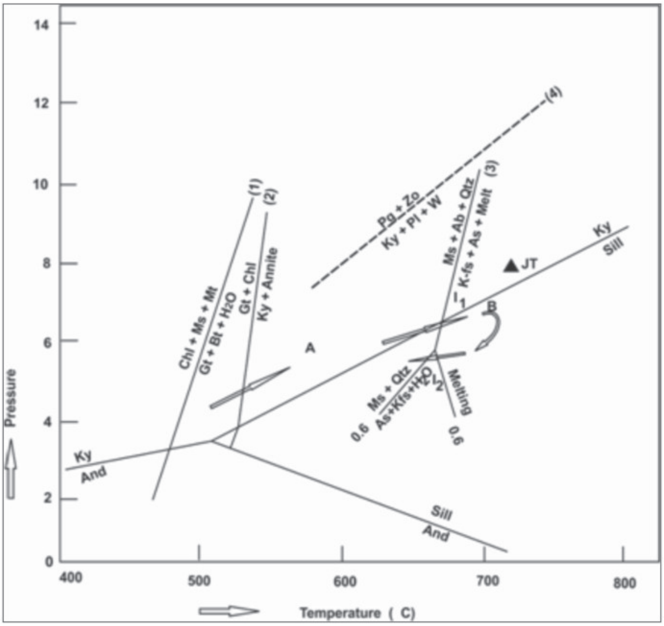

Fig. 5 P-t path for the metamorphic rocks of the Chaukhutia area deuced by petrographhic studies. The filled in triangle JT shows the peak metamorphic cionditions deduced by detailed geothermobarometry by Joshi and Tiwari(2009) form the adjacent Chhara-Someshwar transect.

Discussion and Conclusions

Central Crystallines (=Higher Himalayan Metamorphics, HHC) are largely accepted by most of the workers as the root zone of crystalline thrust sheets scattered all over the Lesser Himalayan sedimentaries with a thrust at their base which is equivalent to the Main Central Thrust (Fuchs, 1975,1981;Valdiya, 1976, 1978,Joshi and Gairola, 1980, Srikantia, 1988). Valdiya (1980) correlated the Almora Group rocks largely comprising the Almora Nappe with the Munsiari Formation of the Higher Himalaya. However, Valdiya and Goel (1983) suggested largely greenschist facies conditions for the Munsiari Formation only locally reaching epidote amphibolite facies conditions. On the basis of the mineral assemblages they concluded that the Munsiari Formation indicates comparatively lower P-T conditions, with temperatures reaching ~ 450° C at pressures around 4 kbar. However, the presence of kyanite and sillimanite in the rocks of the Chaukhutia area along with the almandine garnets clearly shows that the rocks comprising this part of the Almora Nappe have been subjected to much higher pressure- temperature conditions than those suggested for the Munsiari Formation. In contradistinction to the P-T estimates by Valdiya and Goel the present work suggests far higher temperatures of around 700°C around at least 6.5kbar pressures on the basis of petrographic observations and deduced mineralogical reactions. Joshi and Tiwari (2009) also calculated temperatures in excess of 700°C at pressures around 8kbar from the adjacent Almora area which are close to the physical conditions of metamorphism deduced for the present area (Fig. 5). Thus it is clear that the upper amphibolite facies Almora Group of rocks comprising Almora Nappe cannot be equated with the green schist facies metamorphics of the Munsiari Formation of the Higher Himalaya on the basis of the grade of metamorphism. Moreover, the repetition of the metamorphic isograds in the metamorphics of the Almora Group of rocks poses further problems for equating it with the Higher Himalayan metamorphics characterized by Inverted Metamorphic Sequence. In view of these two serious problems it appears very difficult to correlate the Almora Group of rocks with any of the exposed sequences of the Higher Himalaya.

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