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PETROCHEMISTRY AND PETROGENESIS OF GRANITOIDS IN RELATION TO HIMALAYAN OROGENY– A CASE STUDY OF GRANITOIDS OF KUMAUN LESSER HIMALAYA

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ABSTRACT

The granitoids of Kumaun Lesser Himalaya i.e.Almora, Mukteshwar, Champawat, Koidal,Amritpur and Dudatoli are emplaced in NW-SE direction in low to high grade metamorphic rocks of Almora and Ramgarh Crystallines. The granitoids of the area are product of collision of Indian and Asian plates during 65 to 50 Ma, which caused strong deformation and metamorphism in phases. These granitoids bear imprints of this orogenic movement and leucogranites are the result of orogenic related crustal melting. These granitoids are the pre-collision and syn to post-collision magmatic types. Binary and ternary plots indicate a granite – adamellite composition for most of the granitoids and variation in major oxide in relation to SiO_2 content indicates that different varieties are co-magmatic in character and are related to one another by fractional crystallization. The younger granitoids are K-rich while older granitoids are Na-rich and are S-type with per-aluminous and calc-alkaline nature. The calc- alkaline trends with granodiorite-adamellite composition indicate that they are emplaced successivily during the major orogenic episodes from subduction to post- collision stages and have a dominantly crustal origin.

Major oxides and trace element patterns show a close similarity with the syn-collision to post collision emplacement patterns. The REE patterns show fractionation with LREE enrichment and HREE depletion with Eu negative anomaly.

Key Words: Granite, Kumaun Himalaya, Uttaranchal.

INTRODUCTION

The collision of Indian plate with the Asian plate during 65-50 Ma has resulted in a strong phase of deformation and metamorphism. The rocks south of Central Crystalline Group show strong south vergent thrusting which has brought deeper level rocks to higher level, over low grade rocks so that metamorphic grade increase with structural heights. The Himalayan evolution is closely connected with the development of the present day Andaman – Nicobar-Indonesian island arc –subduction system in the southeast and the Makran range-Omen trench in the southwest. The eastern and western ends of the Himalaya are marked by complexly deformed zones of strike slip movement and ophiolite emplacement.

The various hypotheses on Himalayan orogeny can be grouped into two categories i. e.vertical movement and block faulting along deep faults/ fracture which served as conduit for the granite magma, the other view postulated the horizontal compression of marine sediments, the compression resulting from northward drift of the Indian subcontinent and colliding with the Eurasian plate.

This paper mainly deals with petrochemical behaviour and petrogenesis of heterogeneous granitoids of Champawat, Almora, and Nainital districts of Kumaun Himalaya. An attempt has been made to classify the granitoid suite according to its genesis and tectonic environment.

The granitoids of Kumaun Himalaya are classified into two categories, i. e. (1) Pre-Himalayan and (2) Syn-to post-Himalayan orogeny. The pre-collision granitoids are of two types; one of them bears imprints of all the phases of deformations. e.g.. Dudatoli granitoid, the other type such as Champawat, Ramgarh and Amritpur granitoids have an age of 1800 Ma y to 500 Ma y but do not bear conspicuous imprints of deformation. These granitoids are concordantly emplaced within the metasedimentary units of Almora/Ramgarh Group. These are classified as biotite granite, grey granite, porphyritic granite, muscovite granite, aplites and leucogranite. These granitoids have xenoliths of the country rocks.

The earlier works on these granitoids are very sketchy. Mishra and Sharma (1972) and Sharma and Awasthi (1980) have proposed heterogeneous crustal anatexis for the evolution of these granitoids. Kharkwal (1951) described its intrusive nature and suggested it be of magmatic origin. Pitcher (1982) opined that these plutons have the characteristic of S-type granite. The litho tectonic succession of the area is given in Table 1.

The above mentioned granitoids are medium grained consisting dominantly of quartz, feldspar and mafic minerals. Quartz grains are anhedral and highly sutured, show deformation lamellae and undulose extinction. The feldspar/ plagioclase are twinned on combined albite and carlsbad law. Zoning is often visible. Sericitisation is common. Few orthoclase grains occur as porphyroblast and might represent the influx of potash during metamorphism. The biotite shows strong light brown to dark brown pleochroism. The grain boundaries are often wavy due to deformation. The dominant texture is hypidiomorphic granular and schistose The younger granitoids are leucocratic and are practically devoid of ferromagnesian minerals.

PETROCHEMISTRY AND PETROGENESIS

To classify the granitoids, various binary and terniary diagrams were used which indicate the granite-adamellite composition for most of the granitoids (fig.1). The variation diagrams of major oxide contents of various granitoids have been studied with refrence to abundance of silica (SiO_2). It is evident that different varieties are co-magmatic in character and are related to one another by fractional crystallization. The compositional similarities among different pulses indicate either lack of any crystal fractional or change in magma composition by crustal mixing between different pulses. The different granite types show normative albite and orthoclase higher than the normative anorthite. Normative corundum is in the range of 0.52 to 11.26% and well compare with the per-almunious nature of granite. Most of the granitoids in

Table 1

Garhwal Group : Quartzite, slate, limestone and volcanics
——**North Almora Thrust/Fault**—
Almora Group : Low and medium grade metasedimentaries with granitoids
——**South Almora Thrust**—
Ramgarh Group : Low grade metasedimentaries with granitoids
——**Ramgarh Thrust**——
Bhimtal Formation : Quartzite with volcanics
—**Main Boundary Thrust**—
Siwalik Group : Sandstone and shale

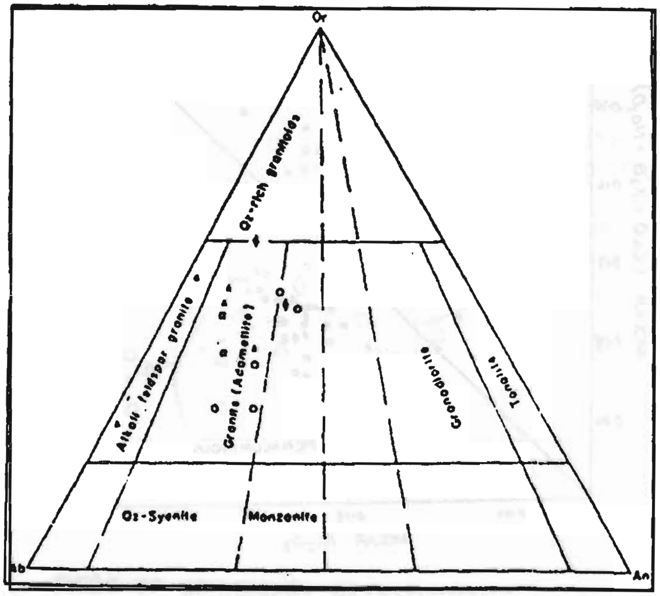


Fig. 1. Normative Or - Ab-An plot of Almora Granitods, Biotite granite (B.G.) = Circle; Porphyritic granite (P.G.) = Square; Leucogranite (L.G.) = Triangle and Gneiss (S.G.) = Diamond

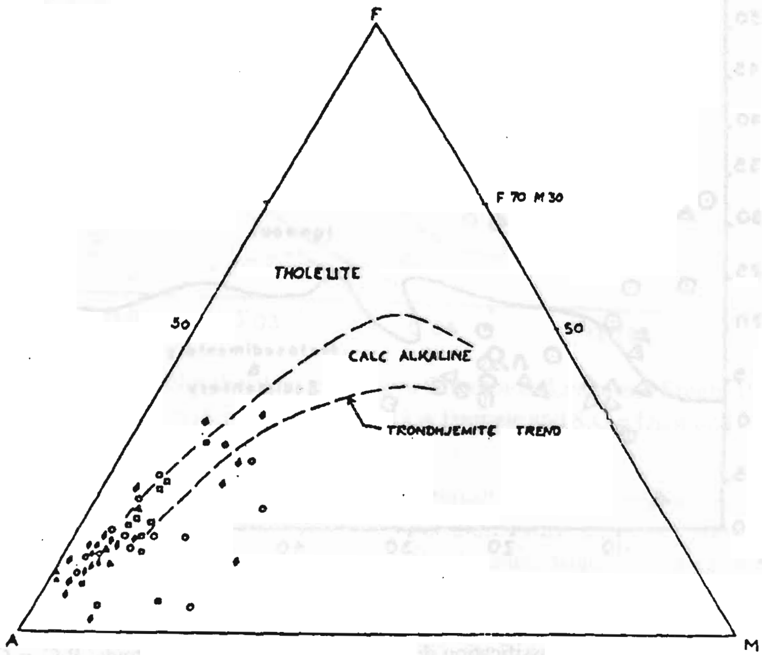


Fig. 2. AFM Diagram of Almora Granitoids; B.G. = Circle, P.G. = Square L.G. = Triangle and S.G. = Diamond

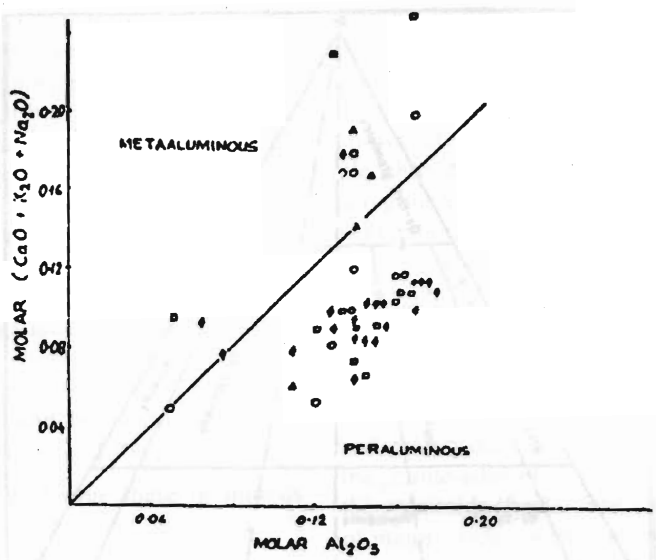


Fig. 3. Molar (Al_2O_3) vs molar ($CaO+K_2O+Na_2O$) plot of Almora Granitoids; B.G = Circle P.G. = Square, L.G. = Triangle and S.G. = Diamond

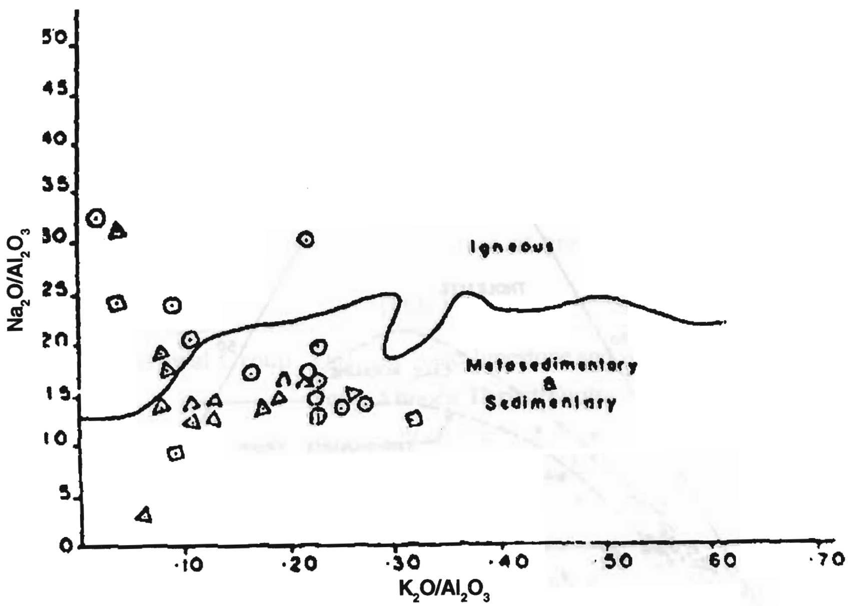


Fig. 4. Na_2O/Al_2O_3 vs K_2O/Al_2O_3 classification diagram of Mukteshwar Granitoids; B.G. = Circle, P.G = Square, L.G. = Triangle and S.G. = Diamond

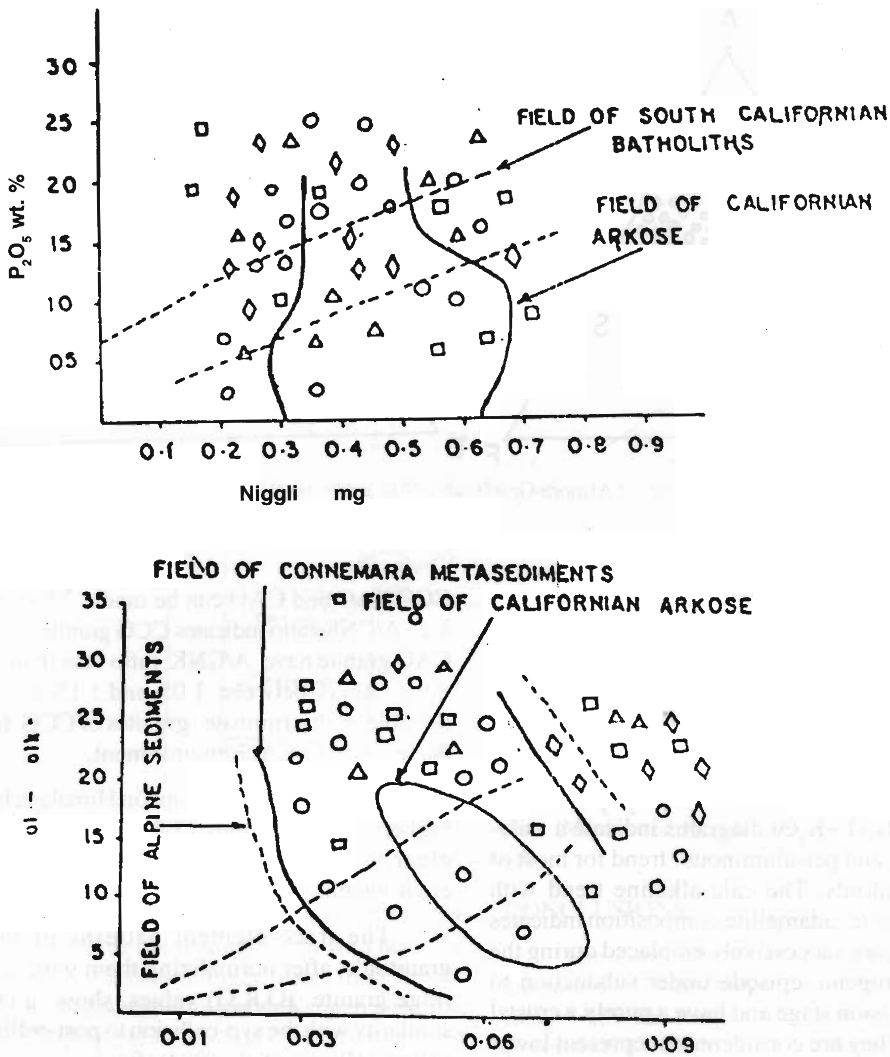


Fig. 5. Plots of Niggli values of Almora Granitoids (Leake and Singh, 1986);
B.G. = Circle, P.G = Square, L.G. = Triangle and S.G = Diamond

AFM and molar (Al_2O_3) / (CaO+ Na_2O+ K_2O) diagrams (figs. 2,3) falls in calc- alkaline field with per-aluminous character. On the basis of various binary and ternary diagrams viz. molar (Al_2O_3) vs molar (CaO+ Na_2O + K_2O), Na_2O/Al_2O_3, fig. 4 (Garell and Mackenzie, 1971), Na_2O vs K_2O, SiO_2(%) vs Al(Na + Ca/2) Chappel and White,1974). It can be inferred that these granitoids are S-type with per-aluminous and calc- alkaline nature. The Niggli values diagram of Mg vs P_2O_5, fig. 5 (Leake and Singh, 1986) and ACF diagrams, fig. 6 indicate that they are formed by Al-rich clay and shale (parent material). The variation diagrams indicate scattered and irregular patterns with restricted range of composition.

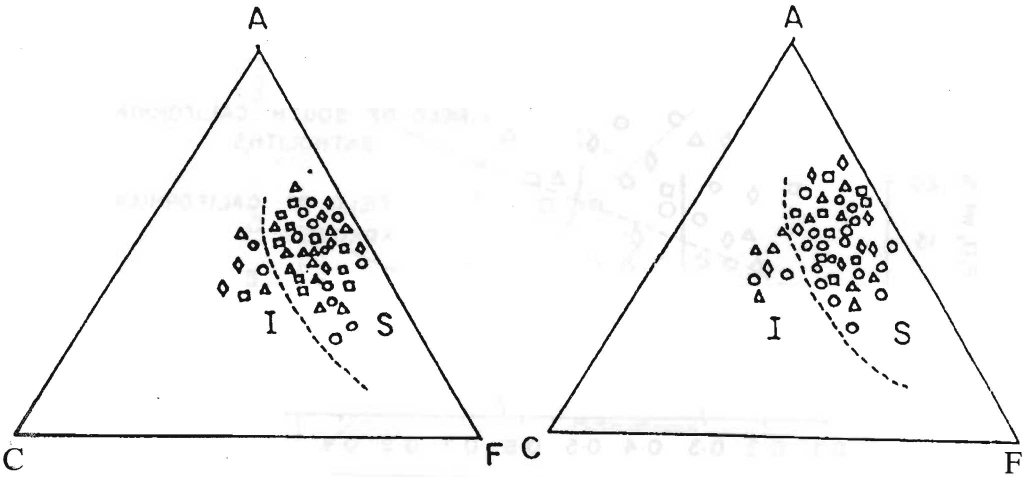


Fig. 6. ACF Classification diagram of Almora Granitoids; B.G. = Circle, P.G. = Square, L.G. = Triangle and S.G. = Diamond

Variation and these relationship clearly indicate that these different varieties of granitoids have a geochemical coherence among them and are cogenetic in character and are related to one another by crustal fractionation, which further indicates S-type granite for these granitoids.

The AFM and molar (Al_2O_3) vs molar ($CaO+Na_2O+K_2O$) diagrams indicate a calc-alkaline and per-aluminous trend for most of the granitoids. The calc-alkaline trend with granodiorite- adamellite composition indicates that they are successively emplaced during the major orogenic episode under subduction to post collision stage and have a purely a crustal origin. They are considered to represent lower crustal magma derived by dehydration melting of metasedim-ents, probably promoted by intrusion of mantle derived magma.

In order to ascertain the geotectonic environment of these granites, the discriminant diagrams (fig. 7) of Maniar and Piccoli (1989) were used. Most of the samples of granite suites fall in orogenic granite field . The orogenic field in these diagrams comprises continental collision (CCG), island arc (IAG) and continental arc (CAG) granites. On the basis of A/CNK ratio, the difference between CCG, IAG and CAG can be made. More than 1.15 A/CNK ratio indicates CCG granites, IAG-CAG granite have A/CNK ratio less than 1.0, if the ratio is between 1.05 and 1.15 it is not possible to discriminate granites of CCG from those of IAG-CAG environment.

The granitoids of Kumaon Himalaya have higher A/CNK values (1.07 to 2.25) which clearly indicate a continental collision environment.

The trace element patterns of these granitoids, after normalizing them with ocean ridge granite (O.R.G) values, show a close similarity with the syn-collision to post-collision patterns (Pierce *et al.*, 1984) (fig. 8).

The rare earth element (REE) condrite normalized patterns (fig. 9) of different rock types show fractionated patterns with enriched LREE and depleted HREE. The granitoids shows a moderate enrichment (REE up to 222.95 ppm). The rock shows fractionated patterns. The Ce_N v Yb_N value ranges from 1.74 to 36.97. The granite rocks shows heterogenous REE distribution patterns and have fractionated patterns with light REE enrichment (characteristic of calc-alkaline rocks in general).

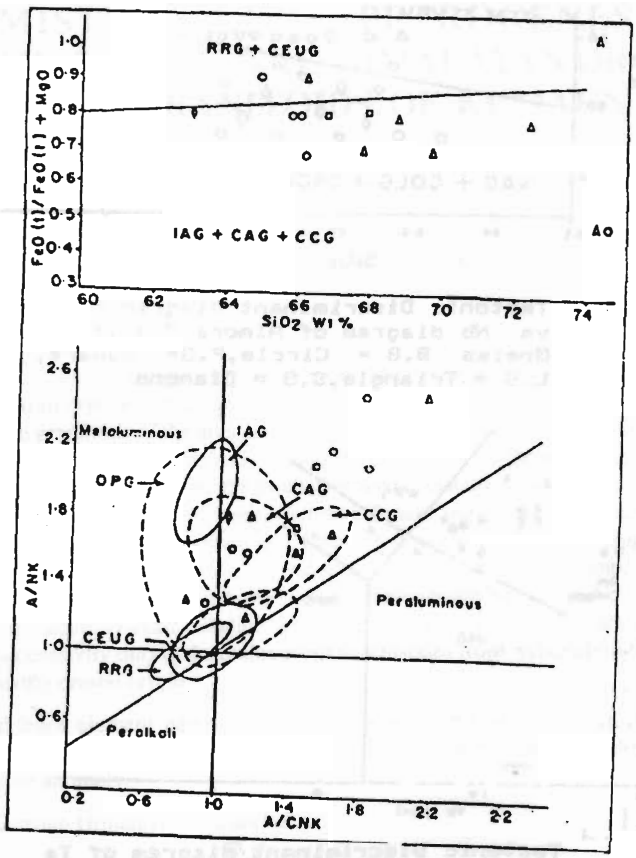
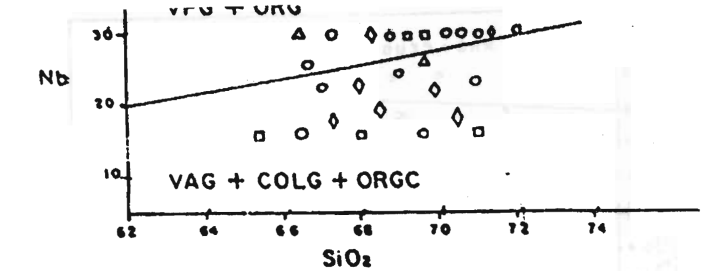


Fig. 7. Tectonic Discriminant diagram of Almora Granitoids (Maniar and Piccoli, 1989); B.G. = Circle, P.G. = Square, L.G. = Triangle and S.G. = Diamond

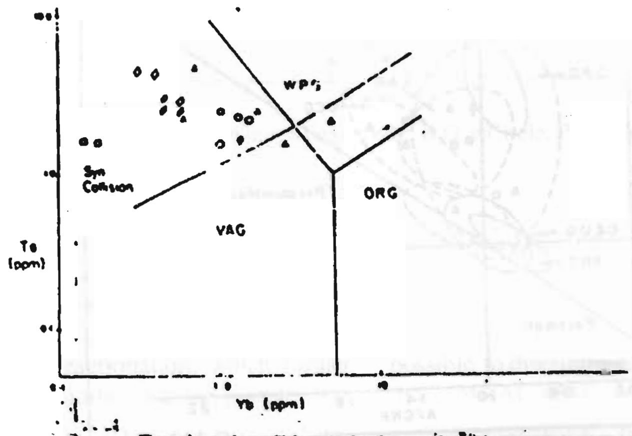
The extent of this fractionation is extremely variable. Most of the samples shows a negative Eu anamoly, however, Eu increases from biotite granite to leucogranite through augen gneisses, which probably indicates involvement of plagioclase in fractionation with younger pulses. The leucogranite have lower LREE and higher HREE abundance, which can be attributed to a small amount of either monazite or allanite crystallization and the presence of cumulus garnet, which requesters HREE. The size of Eu anomaly in the leucogranite can be attributed to the relative importance of allanite or monazite since monazite will reduce the size of the anamoly, as it does not remove Eu, wheras allanite will increase it.

CONCLUSIONS

The concordantly emplaced granitoids are emplaced in the Proterozoic metasedimentaries of Almora, Ramgarh groups and Bhimtal Formation along or close to Main Boundary Thrust. The different varieties of granitoids intrusions have wide variation in mineral composition. The dominant biotite granite phase has a granodiorite-adamellite composition. These granitoids are the product of crustal mixing and partial melting of basic component at deep crustal level, but field, petrographic and geochemical parameter of CCG do not support it to be derived from partial melting of deep crustal level. Barker (1979) do not support the above-mentioned view of deep



Tectonic Discriminant diagram of SiO_2 vs Nb diagram of Almora Granite / Gneiss B.G = Circle, P.G = Square, L.G = Triangle, S.G = Diamond



Tectonic Discriminant diagram of Ta vs Yb diagram of Almora Granite / Gneiss B.G = Circle, P.G = Square, L.G = Triangle, S.G = Diamond

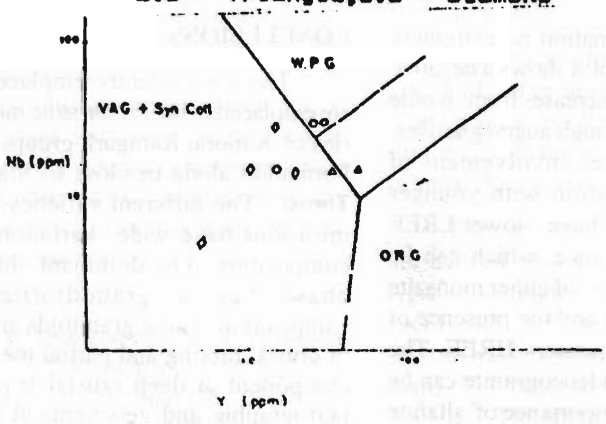


Fig. 8. Tectonic discriminant diagram of Y vs Nb (Pierce *et al.*, 1984); B.G. = Circle, P.G. = Square, L.G. = Triangle and S.G. = Diamond

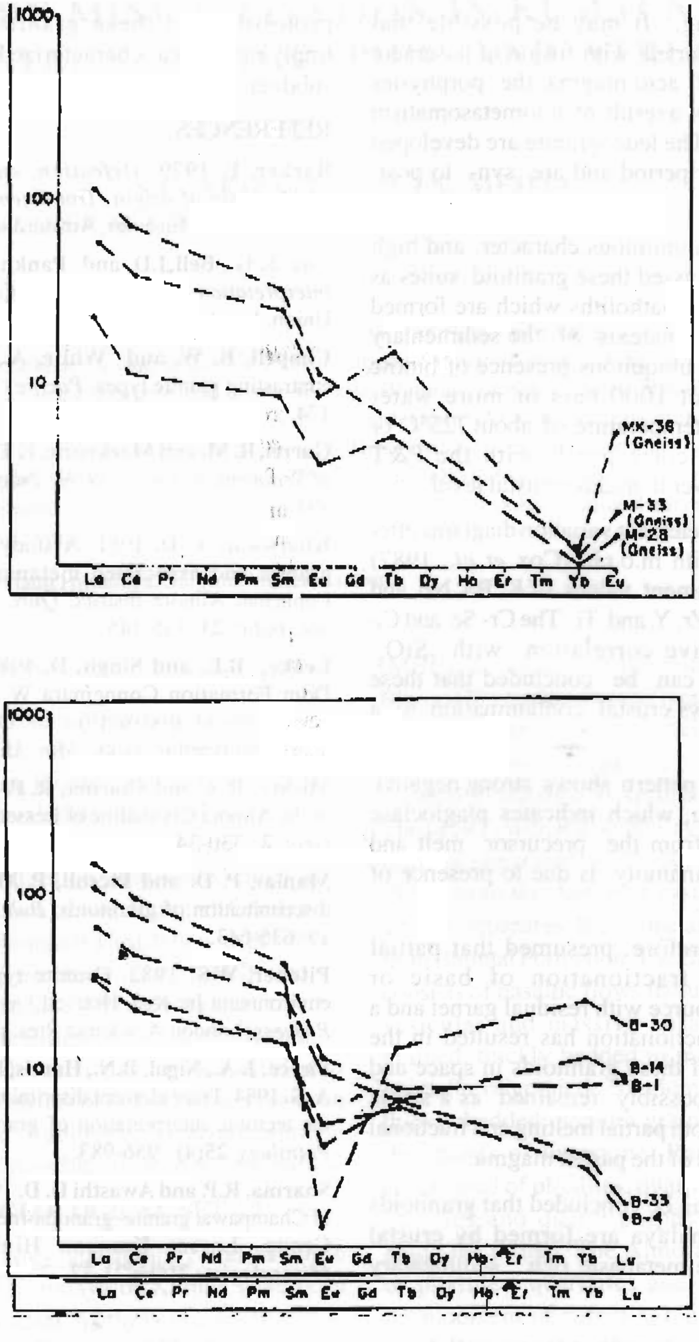


Fig. 9. REE Chondrite normalised pattern of Almora granitoids.

crustal melting. It may be possible that development started with fusion of basement and eruption of acid magma, the porphyries were formed as a result of autometasomatism of sediments. The leucogranite are developed at a much later period and are syn- to post-tectonic.

The per-aluminious character and high A/CNK ratio classed these granitoid suites as S-type granitic batholiths which are formed by the crustal anatexis of the sedimentary protoliths. The ubiquitous presence of biotite indicates about 1000 bars or more water pressure and a temperature of about 725°C or lower which corresponds with the P&T condtion of lower to middle crustal level.

The trace element variation diagrams after normalizing with m.o.r.b. (Cox *et al.*, 1987) indicate enrichment values of K, Ba, Nb and depletion of P, Zr, Y, and Ti. The Cr- Sc and Co has a negative correlation with SiO_2. Therefore, it can be concluded that these granitoids shows crustal contamination to a greater extent.

The REE pattern shows strong negative anamoly of Eu, which indicates plagioclase fractionation from the precursor melt and positive Yb anamoly is due to presence of residual garnet.

It is, therefore, presumed that partial melting and fractionation of basic or intermediate source with residual garnet and a plagioclase fractionation has resulted in the development of these granitoids in space and time. Garnet possibly remained as a stable phase during both partial melting and fractional crystallizations of the parent magma.

Thus it can be concluded that granitoids of Lesser Himalaya are formed by crustal anatexis of the metabasic rich sedimentary protoliths and these granitoids probably implying an area characterized by collision to subduction tectonics.

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