Precambrian Granitic Magmatism in the NE Himalaya: Implications for Ancient Tectonics

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The Paleoproterozoic Bomdila granites (metamorphosed to orthogneisses) are developed close to the Main Central Thrust in the amphibolite-grade metasedimentary rocks in Arunachal Pradesh, northeast Lesser Himalaya. On the basis of field and petrographical observations, two principle types of granites have been distinguished: porphyritic biotite-muscovite (two-mica) granites and tourmaline-bearing leucogranites. Both types are subalkaline, strongly peraluminous (A/CNK > 1.1) and have >70% SiO_2, Na_2O+K_2O = 5.5–8.5%, and K_2O/Na_2O = 0.8–2.9. The Bomdila orthogneisses are enriched in incompatible elements such as Rb, Ba, K and Th, and depleted in high field strength elements (HFSE) like Zr, Hf, Ta, Y and Nb. The enrichment of the Bomdila samples in the incompatible elements and their depletion in HFSE strongly supports their postulated crustal source. Both the granite suites are characterized by high incompatible elements/HFSE ratios, which is similar to many intra-crustally derived granites. Tourmaline granites are clearly distinguished by their low Sr and Ba contents compared with the two-mica granites and are generally depleted in Sc, Y and Nb. The discriminant Rb vs. (Nb+Y) diagram shows that the tourmaline granite generally lies within the syn-collision field (as do other Himalayan leucogranites), whereas the two-mica granites straddle the field boundary between collision granite and volcanic-arc granite. Extensive studies on Himalayan leucogranites by Harris and others (1986) suggest that the granites that form in the syn-collision zones are generally peraluminous leucogranites and may be derived from the hydrated bases of continental thrust sheets. Primitive-mantle normalized spidergrams for the Bomdila rocks, like most crustal granitoids, show negative Ti, Sr and Nb anomalies, reflecting the influence of some accessory phases such as rutile as a residual phase in high-pressure melting during the event that formed juvenile sialic crust (Gill, 1981).

In contrast with other Himalayan leucogranites that are generally characterized by unusually low REE contents, the Bomdila rocks show higher concentrations of all REEs than published averages from other such leucogranites (Vidal and others, 1982; Scaillet and others, 1990). The two-mica granites show higher REE concentrations (up to 294 ppm) than the tourmaline granites (sum = 67 ppm). The REE contents of two suites indicate light REE (LREE) enrichment over heavy REE (HREE) and have variable LREE/HREE ratios [$(La/Yb)_N$ = 3–23]. The patterns show steeply inclined LREEs with flatter and little-fractionated HREEs resulting in overall concave patterns. The REE abundances of the Bomdila granites coincide with typically crustally derived granites (i.e. La = 20–100X chondritic, Yb = 0.5–8X chondritic, Holtz, 1989) and show consistent fractionation patterns within the LREE group [$(La/Sm)_N$ = 3–5]. Negative Eu anomalies are pronounced in both the suites and reveal a very narrow range of difference (Eu/Eu* = 0.35–4) indicating that plagioclase fractionation has been essential in their petrogenesis.

Although experimental studies suggest that leucogranites can be generated by a variety of processes, both the major and trace element characteristics of the Bomdila leucogranites are better explained by varying degrees of partial melting and fractionation. An overlap in the wide concentration ranges of oxides, such as SiO_2, CaO, MgO, $Fe_2O_3^t$ and Sr of the two-mica and tourmaline granite suites, with no discernable differentiation trends on a Harker variation diagram, precludes the derivation of one suite from the other by differentiation following emplacement. This, in turn, suggests that both suites may have been derived from different sources. In order to determine the phase-equilibria conditions of the Bomdila granites, the samples were projected onto the Q-Ab-Or phase diagram which also contains 2 and 5 kbar minima and eutectics of the haplogranite system with varying aH_2O in the melt (Holtz and others, 1991). It can be noticed in the diagram that the two-mica granites do not cluster about a minimum-melt composition characteristic of water-saturated haplogranite phase relations (Tuttle and Bowen, 1958). Instead, they form a spread of compositions with a trend defined by variable quartz/orthoclase and orthoclase/albite ratios. Experimental work by Johannes and Holtz (1990) has demonstrated that quartz/orthoclase ratios increase as pressure decreases in water-undersaturated melts. Further studies indicate that orthoclase/albite ratios of granite minimum-melt compositions are greatly increased at decreased water activities (Ebadi and Johannes, 1991). Experimental studies on crystallization of leucogranite magmas (Scaillet and others, 1995) suggest that two-mica granites and tourmaline granites can be generated at low (between 5 and 7.5 wt %) and high (>7 wt. %) initial water contents, respectively. Therefore, the Bomdila two-mica granites with quartz-rich compositions and plotting at decreased pressures (< 5 kbars) and low water activities in the diagram, suggest their derivation from an alumina-saturated source under water-undersaturated condition at temperatures >800^{0}C. In contrast the tourmaline-granite samples cluster around a composition corresponding to minimum melt at ~3 kbar, aH_2O ≈ 0.5. These values are consistent with thermobarometric studies of the many well-studied leucogranites from the Himalaya such as Manaslu (Guillot and others, 1991), Langtang (Inger and Harris, 1993), etc.

From the above discussion, it can be convincingly argued that the two suites of the peraluminous Bomdila orthogneiss were predominantly formed by partial melting and fractional crystallization (in the case of two-mica granites) of pelitic rocks from the upper crust. Presence of metasedimentary enclaves (pelitic schists) in the two-mica granites and the crystallization of magmatic tourmaline in tourmaline granites are also consistent with a metasedimentary source (Bernard and others, 1985). An attempt is made in this paper to explore the possible source rocks for these granites. In this perspective, the mica schists with which the granites are associated offer potential source lithologies. A striking similarity between the composition of proposed source lithology and the average Bomdila orthogneiss is clearly evident in the diagram, supporting the assumption that metasedimentary rock (similar to the micaschists) exposed along with granites are the most likely source for the Bomdila orthogneisses.

These studies show that the granites formed in a syn-collisional tectonic environment, suggesting that collision of two continental blocks might have occurred during the Proterozoic period along this linear belt, similar to the already established Paleozoic Lesser Himalayan granitoid belt (Le Fort and others, 1986) related to Pan-African orogeny. This further implies an episode of significant Proterozoic orogenic events in the Lesser Himalaya. Subsequent tectonics exposed these granites to weathering and provided detritus to the newly formed large Proterozoic sedimentary basins in the Lesser Himalaya.

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