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Geochemistry, zircon U-Pb geochronology and Lu-Hf isotope of granitoids and microgranular enclaves from Ladakh batholith, Indian Himalaya: Evidence of synchronous mixing-fractionation and chemical re-equilibration

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Felsic magmatic pulses in the north of Indus-Tsangpo Suture Zone (ITSZ) of northwest Indian Himalaya referred herein Ladakh granitoids (LG) and associated mafic to hybrid microgranular enclaves (ME) constitute the bulk of Ladakh batholith [1], which is an integral part of Trans-Himalayan gigantic batholiths. LG and ME have been subjected to phase petrology, geochemical, zircon U-Pb-Lu- Hf isotopic investigations in order to infer petrogenetic and geodynamic processes in the evolution of Ladakh batholith and the timing of India-Asia collision.

LG are calc-alkaline largely metaluminous (I-type) to a few peraluminous (S- type), magnetite (oxidized) to ilmenite (reduced) series granites whereas ME belong to highly metaluminous and magnetite series granites [2, 3]. Biotite compositions from LG suggest metaluminous to peraluminous nature of host magmas. Al-in-hornblende barometers (P= 3.35 kbars in western, P=2.99 kbar in central and P=2.17 in eastern) suggest differential unroofing of LG magma chamber(s). ME are rounded to elongated (2D outcrops), mesocratic to melanocratic in nature commonly showing sharp and occasionally crenulated margins along with viscous fingering features with host LG. Field features, microstructures and near-linear geochemical variations for TiO_2, CaO, $Fe_2O_3^t$, MgO against SiO_2 of ME have been attributed to synchronous magma mixing and fractionation of mafic-felsic magmas whereas noted data scatter for Al_2O_3, alkalies, MnO, P_2O_5, Rb and Ba appear resulted from differential degrees of chemical diffusion and mineral sorting during magma mixing and fractionation events. Identical trace and REE patterns of ME and LG can be attributed to partial chemical re-equilibration during post-entrapment cooling and mingling of ME magma globules into partly crystalline LG, rather than derivation from similar sources.

Representative fifteen samples (N=8 from LG, N=6 from ME) were selected and treated for *in situ* zircon U-Pb and Lu-Hf isotopic investigation. U-Pb zircon chronological data underline coeval nature of LG and ME magmas in Kargil-Batalik-Achinathang (LG= 45, 51, 54 Ma, ME= 48.5 Ma), Leh-Karu (LG=50 & 61 Ma, ME= 50 Ma) and Upshi-Himiya (LG=50 & 58 Ma, ME= 58 Ma) regions corresponding to western, central and eastern parts of Ladakh batholith. Most Lu-Hf isotopic data of LG and ME have shown positive $\varepsilon_{Hf}(t)$ values and young Hf model ages (200-980 Ma) comparable well to those observed for Gangadese batholith [4], which strongly suggest involvement of juvenile magma source in their genesis and mixing between felsic and mafic magmas. However, LG (ca 50 Ma) in eastern part of batholith exhibits heterogeneous Hf isotopic ratios and negative $\varepsilon_{Hf}(t)$ values suggesting partial contribution of ancient continental crust in the evolution of granitoids that would have been possible only after the collision of continents. Therefore, ca 50 Ma can be considered minimum age of the India-Asia collision. Based on field relation, geochemical and isotopic evidences this has been concluded that Ladakh batholith is product of multistage magma mixing of multiple pulses of mantle- and crustal-derived magmas concomitant fractional differentiation, mingling and diffusion mechanism.

Reference:

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