# Petrology and U-Pb SHRIMP zircon chronology of granitoids from Shyok Suture Zone, Ladakh Himalaya, India: Evidence of Early Cretaceous subvolcanic calc-alkaline granitoid magmatism

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Ladakh Himalaya is an integral part of Trans-Himalaya system, and the lithounits constituting this sector are exposed all along the vast zones of Indus and Shyok Sutures Zones of northwest Himalaya. Shyok Suture Zone (SSZ) separates the Dras island arc in the south from Karakoram-Tibet in the north (Gansser, 1977). The SSZ represents tectonized remainder of a marginal (back-arc) basin while experiencing crustal shortening and is mainly composed of volcano-sedimentary formations (Rai, 1982). Ladakh, Saltoro, and Karakoram blocks form a triple point at intersection of Karakoram Fault (KF) and Khalsar Thrust (KT) while moving from south to north in Nubra-Shyok confluence area (Weinberg, 2000). In this area Ladakh range is delineated by Khardung Formation in the north and Shyok Formation in the northeast, which separates Ladakh block from Saltoro block along Khalsar Thrust (KT), which is most often considered eastern continuation of the Main Karakoram Thrust.

Saltoro block of Nubra-Shyok confluence area is mainly comprised of vast amount of calc-alkaline granitoids of batholithic dimension exposed in and around Tirit region of Nubra valley referred herein Tirit granitoids, which are intimately associated with volcanics of Khardung Formation. In this region marginal parts of Ladakh granitoids have been found intruding the Shyok Formation whereas Tirit granitoids are intrusive into dacite and andesite of Khardung Formation. Field relationships particularly between Tirit granitoids and volcanics, Al-in-hornblende barometers, U-Pb SHRIMP zircon chronology have been carried out in order to understand intrusive nature, depth of emplacement and crystallization age of Tirit granitoid magma. Presence of mm to cm-sized dacitic and large-sized andesitic xenoliths ubiquitous in Tirit granitoids suggest strong assimilation, stopping and collapse of overlying volcanic materials while intrusion of Tirit granitoid melts at epizonal-subvolcanic emplacement level. Al-in-hornblende barometers (~1.08-2.1 Kbar) further corroborate emplacement and solidification of Tirit granitoid melt at subvolcanic level. The obtained pressures also indicate that the Tirit magma chamber has experienced a minimum overburden of *ca* 4 Km or to a maximum of *ca* 8 Km thick volcanic sequences (lithostatic pressure assuming $P_{TOTAL}= P_{LOAD}$) which are at places either partly preserved or completely removed at present erosional levels. On the other hand, tectonically separated marginal parts of Ladakh granitoids contain less frequent xenoliths of shale and metabasics of Shyok Formation, which suggest winty intrusive contact relation of granitoid melt with country-rocks. Both Ladakh and Tirit granitoids contain mafic to hybrid microgranular enclaves, which suggest mixing and mingling of mafic-felsic magmas in plutonic environment, a typical feature observed in calc-alkaline I-type granitoid complex.

Three representative granitoid samples, one each from assimilated and unassimilated parts of Tirit granitoid and one sample from Ladakh granitoid close to the contact with country-rocks, were chosen for U-Pb SHRIMP zircon chronology. Back scattered electron (BSE) and cathodo-luminescence (CL) images suggest euhedral and oscillatory zoned nature of zircons, which sometimes bear inherited zircon cores recycled from source regions. Total thirty four areas were analyzed from seventeen zircon crystals of unassimilated, free from any assimilative signature with volcanics, Tirit granitoid. Twelve zircon spots have yielded weighted mean $^{206}Pb/^{238}U$ age of crystallization 109.4±1.1 Ma (MSWD=3.5) corresponding to Early Cretaceous. It is interesting to observe that inherited cores of some zircons have provided three groups of older $^{206}Pb/^{238}U$ ages in the range of 278-393 Ma, 519-713 Ma and 1933 Ma, which suggest involvement of heterogeneous Carboniferous, Cambrian-Neoproterozoic and Paleoproterozoic crustal

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sources in the generation of Tirit granitoid. It is likely that sediments derived from ancient continental crust were mixed with juvenile crust before the onset of subduction of oceanic crust below the Asian plate. Zircons from Tirit granitoid having strong assimilative features yield weighted mean $^{206}Pb/^{238}U$ age of crystallization 105.30±0.80 Ma (MSWD=1.4). Two inherited cores of zircons from unassimilated Tirit granitoid also yield $^{206}Pb/^{238}U$ ages of 476 Ma and 952 Ma again pointing involvement of minor amount of older continental crust in the genesis of Tirit granitoids. Although there are strong evidences of intrusion and assimilation of volcanics by Tirit granitoids, zircons derived from volcanics in Tirit granitoid are absent. The obtained two ages (*ca* 110 Ma and 105 Ma) at least suggest episodic nature of Tirit granitoid magmatism during Early Cretaceous, and the dacite and andesite as early eruptive phases of Khardung volcanism must have occurred prior to 105 Ma. Earlier suggested ages (~68-74 Ma) for calc-alkaline Tirit granitoids (Weinberg et al. 2000, Upadhyay, 2008) are much younger than the present ones, and correlate well with the ages of Ladakh granitoids. Dunlap and Wysoczanski (2002) have suggested thickness of Khardung Formation about 7 Km deposited between 60.5 Ma and 67.4 Ma, which constrain minimum age of Late Cretaceous for Shyok Formation. However, we suggest minimum age of Early Cretaceous for Khardung volcanics. Zircons from Ladakh granitoids which contain xenoliths of shales and metabasics have yielded weighted mean $^{206}Pb/^{238}U$ age of crystallization 67.32±0.66 Ma (MSWD=1.3), and it is remarkable that these zircons are completely devoid of inherited cores. Based on strong field and chronological evidences we opined that the Tirit granitoids in SSZ most likely represent early pulses of Early Cretaceous calc-alkaline magmatism formed in subduction environment, which intrude the dacite and andesite (>105 Ma) layers of Khardung volcanics at subvolcanic-epizonal levels.

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