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Variable source rock composition and restite assemblage entrainment as major drivers for compositional diversity in granitoids: A case study from the Madurai Block of the Southern Granulite Terrane, India

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Compositionally diverse granitoids constitute a dominant proportion of the rock ensemble in many Precambrian high-grade terranes. Their formation is related to crustal anatexis, fractionation of mantle-derived mafic melt, or a combination of both. These end-member processes have important bearing on the geodynamic scenario for their emplacement and are crucial to crustal evolution, driving either crustal growth or reworking. However, their broad compositional range often obscures the distinction between these processes. This is evident in the mid-Neoproterozoic granitoids of the Madurai Block, where their origin is debated between fractional crystallization of basaltic precursors in an arc and crustal melting in an early rift. Here, we integrate zircon U-Pb geochronology, major and trace element chemistry, and petrological and geochemical modelling to investigate their genesis and primary factors affecting their compositional diversity.

The zircon U-Pb geochronology yield crystallization ages of ca. 850–770 Ma and metamorphic overprinting at ca. 550–530 Ma. Geochemically, they exhibit compositions akin to both, subduction related calc-alkaline granitoids and anorogenic A-type granitoids, with zircon Hf isotopic signatures indicating crustal reworking. The scarcity of voluminous mafic-intermediate microgranular enclaves within the charnockites and absence of contemporaneous mafic intrusions suggest that these charnockites are unlikely to be derived from admixed mantle-derived mafic melts. Instead, they may have been generated by partial melting of the lower crust.

We performed forward geochemical modelling for crustal anatexis, considering two distinct melting scenarios common in granite petrogenesis: melt segregation from the system (Purely Melt Loss (PML) events) and Restite Assemblage Entrainment (RAE) in the magma. We used two end-member average lower crust composition (mafic and intermediate) as the starting material and performed calculations along two isobaric heating paths (IBH: @9 and @11 Kbar) within a temperature range of 600 to 1050 °C. Trace element partitioning was done using appropriate partition coefficients of the elements, melt composition, and residual mineralogy. The melt extracts for the PML scenario is able to explain part of the compositional diversity, while incorporating a nominal degree of RAE (5wt%) reproduces the full range, without necessitating contributions from mantle or subducted slab derived melts.