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Petrochronological appraisal on the timing and duration of ultrahigh-temperature metamorphism in southern India: Insights from charnockite and sapphirine bearing semipelitic granulites from the Madurai Block

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A robust temporal constraint on the timing and duration of metamorphism is paramount for correctly interpreting the geodynamic evolution of orogenic belts. The Madurai Block of the Southern Granulite Terrane, India has garnered much attention on account of regional-scale ultrahigh-temperature metamorphism. Although there has been a comprehensive characterization of the conditions of metamorphism from various rock types, the timing and especially the duration of metamorphism remain ambiguous, resulting in diverse geodynamic interpretations. Here, we investigate the charnockites and associated sapphirine-bearing semipelitic granulites from the eastern part of Madurai Block by integrating texturally controlled in-situ monazite geochronology with petrology, thermobarometry and phase-equilibria modelling. The integrated petrochronological approach provides a petrographic context for the monazite ages, which enables obtaining a detailed chronological-metamorphic evolution of the rock suites to confidently constrain the P-T-t evolution and timescale of metamorphism.

Conventional exchange thermobarometry yields peak P-T conditions of 970-950°C at 10-11kbar pressure for both rock types. Peak ultrahigh-temperatures are further confirmed by feldspar solvus thermometry (950-980°C at 10kbar) in the semipelites and P-T pseudosection (MnNCKFMASHTO) contoured for compositional and modal isopleths of major minerals phases in both the rock types. Subsequent decompression-cum-cooling has led to the formation of coronal Opx+Pl in the charnockite and symplectic Opx±Crd±Spr±Pl in the semipelite, at the P-T range of 950-820°C and 9.0-6.5kbar. This was followed by cooling to sub-solidus conditions. Based on the obtained P-T estimates, preserved reaction textures, and phase equilibria modelling, a clockwise P-T evolution with decompression-cum-cooling is inferred for both rock types.

The in-situ U-Th-Pb ages and compositional characteristics of monazite grains are strongly correlated to their textural association, providing a temporal control on the obtained P-T path. The core of the matrix monazite in the charnockite and semipelite, having low Th, Y and extreme HREE depletion, yielding weighted mean ages of 590-582 Ma, date the prograde evolution. The rim of matrix monazite in charnockite and mantle in the semipelite, having relative Th enrichment than

core, yielding weighted mean ages of 557-552 Ma, date extensive dissolution-reprecipitation from melt at the peak stage. The relatively Th and Y enriched and moderately HREE depleted rim of matrix monazite in the semipelite, yielding weighted age of 516 Ma, date initial garnet breakdown during post peak melt-crystallization. In contrast, the Th-poor and Y- and HREE-rich symplectic monazite, yielding weighted mean age of 490 Ma, date extensive garnet breakdown during final stages of melt crystallization. Our findings point to a collision initiation at ~590 Ma, where the peak conditions were attained at ~550 Ma followed by extensional collapse at ~520-490 Ma, resulting in rapid upliftment of lower crustal rocks to mid-crustal levels in sustained UHT conditions, followed by cooling to reach a stable geotherm. Our results suggest a long-lived hot orogeny in the Madurai Block, where the UHT conditions were sustained for at least 60 MYr. The UHT conditions were most likely attained in the core of a long-lived hot orogen by the combined effect of conductive heating through radioactive decay and mantle heat supply, with the former being the primary driver.