Long-lived (>90 Myr) granulite-facies metamorphism in the Trivandrum Block, southern India.

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The Southern Granulite Terrane in India is composed of various Archean to Neoproterozoic continental blocks, magmatic arcs, and supracrustal units amalgamated through complex subduction-accretion-collision event and high-grade metamorphism during the Latest Neoproterozoic to Cambrian Gondwana amalgamation. The Trivandrum Block corresponds to a unit in the southern part of the terrane with abundant metasediments and orthogneisses. The pressure-temperature (*P-T*) evolution of the high-grade metamorphism and its time scale are important for unraveling metamorphic processes during the collisional event. The *P-T* evolution recorded in various lithologies in the Trivandrum Block has been argued in numerous previous studies, and it is a subject of ongoing debate. The peak metamorphic ages reported in previous studies from the Trivandrum Block also show a wide range of ca. 600-510 Ma. It is therefore still not known whether the Trivandrum Block underwent single metamorphism with *P-T* variations within the block, or it experienced two discrete metamorphic events at 800-900 ˚C and >950 ˚C. In this study, we present new petrological, geothermobarometric, and geochronological data from khondalites, charnockites, bleached charnockites in the western part of the Trivandrum Block and discuss pressure-temperature-time (*P–T–t*) evolution of the block for unraveling the duration and heat source of high-grade metamorphism.

Phase equilibria modeling of the khondalite from Elavinmoodu quarry located in the western part of the Trivandrum Block indicates peak *P-T* condition of 920-1030 ˚C and 6.0-7.6 kbar, suggesting UHT metamorphism. Prograde and retrograde *P-T* conditions of ~750 ˚C/~7 kbar and ~750 ˚C/~4 kbar, respectively, were also obtained, based on which a clockwise *P-T* path with geotherm-parallel slow cooling is inferred. Consistent *P-T* conditions are obtained from khondalite exposed at Kakkod quarry where incipient charnockite patches within khondalite and foliation-parallel bleached layers within massive charnockite are preserved. Phase equilibria modeling of the incipient charnockite and the bleached rock indicate metamorphic *P-T* conditions of 820-950 ˚C/ 5-10 kbar and 800-1000 ˚C/~6 kbar, respectively. These data suggest that the bleaching of charnockite occurred during high-grade (or UHT) metamorphism, possibly because of fluid flow around the peak metamorphism.

Zircon and monazite U-Pb geochronology for a khondalite sample from Elavinmoodu quarry suggests that prograde, peak, and retrograde metamorphisms took place at around 582±17 Ma, 555.1±8.1 Ma, and 527.3±8.0 to 501.9±8.5 Ma, respectively. Later infiltration of hydrous fluid and hydration of garnet to form biotite occurred at around 489±12 Ma. Our results suggest that high-grade metamorphism continued at least 90 Myr, from 582 Ma to 489 Ma, suggesting a long-lived thermal event possibly related to the input of radiogenic heat from the crust and/or magmatic heat from syn- to post-tectonic intrusions.

The results of this study suggest single metamorphic event along a clockwise *P-T* path. The duration of

high-grade metamorphism (>90 Myr) is nearly consistent with that of metasediments from the Wanni Complex (>50 Myr; Hirayama et al., 2018), but it is shorter than that of long-lived high-grade metamorphism of the Highland Complex (~180 Myr; He et al., 2018). Although previous studies suggested that the supracrustal units of the Trivandrum Block could be a continuation of the Highland Complex (e.g., Dharmapriya et al., 2016; Takamura et al., 2018), the high-grade metamorphism of the Highland Complex might have started earlier than that of the Trivandrum Block possibly due to complex and multi-stage collisional processes related to the amalgamation of Gondwana Supercontinent.

Keywords: Trivandrum Block, P–T–t evolution, Ultrahigh-temperature metamorphism, Phase equilibria modeling, U–Pb geochronology

