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Petrology and mineral equilibrium modeling of incipient charnockite from the Trivandrum Granulite Block, southern India: implications for granulite formation in a Gondwana fragment

T. Endo (1), T. Tsunogae (2), and M. Santosh (3)

(1) Collage of Geosciences, University of Tsukuba, Ibaraki, 305-8572, Japan, (2) Faculty of Life and Environmental Sciences, University of Tsukuba, Ibaraki, 305-8572, Japan (tsunogae@geol.tsukuba.ac.jp), (3) Division of Interdisciplinary Science, Faculty of Science, Kochi University, Kochi 780-8520, Japan

The Southern Granulite Terrane (SGT) in India is known for its classic exposures of regionally metamorphosed granulite-facies rocks formed during the collisional orogeny related to the amalgamation of Gondwana supercontinent. The SGT is composed of a collage of Proterozoic crustal blocks dissected by large Late Neoproterozoic shear/suture zones. The Trivandrum Granulite Block (TGB) is comprises dominantly metasedimentary sequence with khondalites, leptynites and charnockites with subordinate quartzite, mafic granulite, calc-silicate rocks, and meta-ultramafic rocks. The TGB is known as one of the classic examples for the spectacular development of 'incipient charnockites' within orthopyroxene-free felsic gneisses as exposed in several quarry sections in the states of Kerala and Tamil Nadu. The charnockite-forming process in the TGB is considered to have been triggered by the infiltration of CO_2-rich anhydrous fluids along structural pathways within upper amphibolite facies gneisses, resulting in the lowering of water activity and stabilization of orthopyroxene through the breakdown of biotite. However, no quantitative study on the stability of charnockitic mineral assemblage using mineral equilibrium modeling approach has been done so far. In this study, we report a new occurrence of incipient charnockite from Mavadi in the TGB and discuss the petrogenesis of granulite formation in an arrested stage on the basis of petrography, geothermobarometry, and mineral equilibrium modeling.

In Mavadi, patches and lenses of charnockite (Kfs + Qtz + Pl + Bt + Grt + Opx + Ilm + Mag) of about 30 to 120 cm in length occur within Opx-free Grt-Bt gneiss (Kfs + Qtz + Pl + Bt + Grt + Ilm) host rocks. The application of mineral equilibrium modeling on charnockite assemblage in NCKFMASHTO system to constrain the conditions of charnockitization defines a $P-T$ range of 800˚C at 4.5 kbar to 850˚C at 8.5 kbar, which is broadly consistent with the results from the conventional geothermobarometry (810-880˚C at 7.7-8.0 kbar) on these rocks. The $P-T$ conditions are lower than the inferred peak metamorphic conditions from the ultrahigh-temperature granulites of the study area (T >900˚C), which might suggest heterogeneity in peak $P-T$ conditions within this crustal block in relation to local buffering of metamorphic temperature by Opx-Bt-Kfs-Qtz assemblage. The result of T versus mole H_2O (M(H_2O)) modeling demonstrated that Opx-free assemblage in Grt-Bt gneiss is stable at M(H_2O) = 0.3 to 1.5 mol.%, and orthopyroxene occurs as a stable mineral at M(H_2O) <0.3 mol.%, which is consistent with the petrogenetic model of incipient charnockite related to the lowering of water activity and stabilization of orthopyroxene through breakdown of biotite by dehydration caused by the infiltration of CO_2-rich fluid from external sources. We also propose a possible alternative process to form charnockite from Grt-Bt gneiss through slight variations in bulk-rock chemistry (particularly K- and Fe-rich portion of Grt-Bt gneiss) that can enhance the stability of orthopyroxene rather than that of biotite.