Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SCG06-P01 Room:Convention Hall Time:May 25 15:30-16:30

Mineral equilibrium modeling of incipient charnockite and adjacent garnet-biotite gneiss from southern India

ENDO, Takahiro[1*], TSUNOGAE, Toshiaki[1], M. Santosh[2]

[1]Univ. Tsukuba, [2]Kochi Univ.

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 CO2-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 800C at 4.5 kbar to 850C at 8.5 kbar, which is broadly consistent with the results from the conventional geothermobarometry (810-880C 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 >900C), 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 H2O (M(H2O)) modeling demonstrated that Opx-free assemblage in Grt-Bt gneiss is stable at M(H2O) = 0.3 to 1.5 mol.%, and orthopyroxene occurs as a stable mineral at M(H2O) <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 CO2-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.

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Metamorphic reaction to describe local-scale difference in mineral assemblage stable under different conditions

YAMASAKI, Yukiko[1*], IKEDA, Takeshi[1], MOTOYOSHI, Yoichi[2], HIROI, Yoshikuni[3], PRAME, Bernard N.[4]

[1]Earth and Planet. Sci., Kyushu Univ., [2]National Institute of Polar Research, [3]Graduate School of Sciences, Chiba Univ., [4]Geological Survey of Sri Lanka

Mineral assemblage of metamorphic rocks varies according to temperature, pressure and fluid composition. In regional metamorphic belts, we have a common understanding that the difference of mineral assemblage stems from the difference of temperature and pressure. In contrast, it is not so uncommon that the mineral assemblage varies in local scale (several decimeters). It is unlikely that temperature and pressure differ in these scales. Fluid composition, instead, could vary in local scale. Local variation of fluid composition could explain the change of the mineral assemblages that are mutually described by any dehydration reactions. Few researches have estimated the relevant reaction based on the difference of mineral composition and occurrence between the adjacent rocks. This study clarified the reactions to produce orthopyroxene in arrested charnockites from central Sri Lanka based on compositional difference of hornblende and biotite between charnockites and surrounding gneisses.

Biotite in charnokites is enriched in Fe+Mg and depleted in Ti as compared with that in the host gneisses. This compositional difference is expressed as the following substitution with a site vacancy, [ ],

[ ]Ti = $(\mathrm{Fe+Mg})_2$

The charnockites contain hornblende that is rich in K, Fe+Mg and Si, and poor in Na, Ti and Al relative to those in the surrounding gneisses, which is described by the substitution,

$[\ ]_{0.5}\mathrm{Na}^{M4}\mathrm{Ti}^{M1-3}\mathrm{Al}_{0.5} = \mathrm{K}_{0.5}(\mathrm{Fe+Mg})^{M4}(\mathrm{Fe+Mg})^{M1-3}\mathrm{Si}_{0.5}$

Using these substitutions, the reactions responsible for the formation of orthopyroxene can be estimated as,

Ti-rich biotite + quartz = Ti-poor biotite + orthopyroxene + ilmenite + alkali feldspar + H_2O (1)

Ti-rich holnblende + quartz = Ti-poor hornblende + orthopyroxene + ilmenite + anorthite + albite + alkali feldspar + H_2O (2)

Each reaction contains either biotite or hornblende. Changes of the modal abundance of biotite and hornblende reflect the amount of orthopyroxene produced by reaction (1) and (2), respectively. The amounts of orthopyroxene in the estimated reactions well agree with the modal abundance of orthopyroxene in charnockites. These reactions are dehydration reactions, indicating that the mineral assemblage observed in the charnockites is stable under conditions of CO_2-rich fluid. We conclude that the difference of mineral assemblage between charnockites and gneisses can be ascribed to the difference of fluid composition.

Keywords: charnockite, hornblende-biotite gneiss, Sri Lanka, metamorphic reaction

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Mid to late Archean TTG magmatism in the eastern Madagascar; a view from whole rock geochemistry and U-Pb geochronology

ICHIKI, Takashi[1*], Yasuhito Osanai[2], Masahiro Ishikawa[1], Nobuhiko Nakano[2], Tatsuro Adachi[2]

[1]Graduate School of Environment and Information Sciences, Yokohama Nat. Univ., [2]Earth Sci., Kyushu Univ.

Madagascar occupies a key position in the East African Orogen for understanding the continental growth and the tectonics of collision between East Gondwanaland and West Gondwanaland. Especially in the eastern Madagascar is composed of mid Archean domain (Masora) in the east and late Archean domain (Antananarivo) in the west.

The magma genesis and timing of magmatism were studied by whole-rock chemical analysis and LA-ICP-MS U-Pb zircon age dating of granitoids in these domains.

Masora domain is divided into two parts, north and south region, defined by metamorphic grade. The rocks from the north region are only weakly deformed. The north region mainly consists of trondhjemites with subordinate amounts of metapelities including meta-BIFs, and late granitoids with mafic-ultramafic rocks. Trondhjemites in the northern Masora domain are characterized by high SiO2 (67.80-70.98 wt.%), high Al2O3 (15.86-18.44 wt.%), and high Na2O (5.35-5.98 wt.%), low TiO2 (0.27-0.40 wt.%), Mg# (31-35), CaO (1.90-2.24 wt.%), K2O (1.64-2.65 wt.%). Antananarivo domain is divided into two parts, north and south region, defined by lithology. The south region mainly consists of Hbl-Bt gneisses with subordinate amounts of Grt-Opx granuilites, amphibolites, quartzites and metapsammites including meta-BIFs. Whole rock chemical analyses for the major and trace elements demonstrate that Hbl-Bt gneisses in the southern Antananarivo domain are of igneous origin and chemically comparable with CIPW normative tonalities. Hbl-Bt gneisses are characterized by high SiO2 (71.00-73.16 wt.%), high Al2O3 (15.89-16.33 wt.%), and high Na2O (4.41-4.67 wt.%), low TiO2 (0.18-0.23 wt.%), Mg# (38-43), CaO (3.40-3.82 wt.%), low K2O (1.04-1.71 wt.%). All of these granitoids (trondhjemites and Hbl-Bt gneiesses) show pronounced negative Nb, Ti, P anomalies on the primitive mantle-normalized spidergram. These characteristics are comparable to Archean TTG (tonalite-trondhjemite-granodiorite) (e.g. Martin et al., 2005).

A xenocrystic zircon in a trondhjemite sample collected from the northern part of the Masora domain gives a single grain concordat age of mid Archean (ca. 3.2 Ga). Hbl-Bt gneiss sample in the southern part of the Antananarivo domain shows slightly scattered and discordant late Archean age (ca. 2.7 Ga). This new age is slightly older than reported oldest ages of Antananarivo domain (ca. 2.5 Ga; Kroner et al., 2000).

These results show that the area between mid Archean (Masora) and late Archean (Antananarivo) domains is underlain by ca. 2.7Ga tonalitic rocks. Similar magmatic age is reported from the southern India. Late Archean magmatic age of the charnockite and meta-granite (ca. 2.65-2.53) were reported from the Salem Block in the southern India (Clark et al., 2009; Sato et al., 2011), where located between the mid to late Archean Dharwar Craton (e.g. Peucat et al., 1993) to the north and late Archean Madurai Block (Plavsa et al., 2012) to the south. Hence we speculate that Madagascar and India records progressive outward continental growth by accretion of mid-to-late Archean (ca. 2.7-2.6 Ga) crust and the late Archean (ca. 2.5 Ga) crust to ca. 3.2Ga Dharwar nuclei crust. Although Tucker et al. (2011) suggested the ’Greater Dharwar Craton’ model to explain the juxtaposition of Madagascar with India from the late Archean (ca. 2.5 Ga), we suggest more stepwise crustal growth in the Archean era.

Keywords: Madagascar, Achean TTG, geochronology, geochemistry