Petrology and Geothermobarometry of Grt-Cpx and Mg-Al-rich Rocks from the Gondwana Suture in Southern India: Implications for High-pressure and Ultrahigh-temperature Metamorphism

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Introduction

The Palghat-Cauvery Shear/Suture Zone (PCSZ) in southern India represents a system of dominantly E-W trending shear zones that separate the Archean Dharwar Craton to the north and Neoproterozoic granulite blocks to the south. Available geochronological data on high-grade metamorphic rocks from this region have confirmed the widespread effect of a *ca*. 550-530 Ma thermal event related to the collisional amalgamation of the Gondwana supercontinent (e.g., Collins et al., 2007a, Santosh et al., 2009). Recent petrological investigations of high-grade metamorphic rocks of the PCSZ around Namakkal district identified prograde high-pressure (HP, P >12 kbar) metamorphism and peak ultrahigh-temperature (UHT) metamorphic history of this region (e.g., Shimpo et al., 2006; Nishimiya et al., 2010), which has been correlated to deep subduction prior to the collision and exhumation of the orogen during Neoproterozoic to Cambrian (Santosh et al., 2009). The PCSZ is therefore regarded as the trace of the Gondwana suture zone that continues westwards to the Betsimisaraka suture in Madagascar (Collins and Windley, 2002), and eastwards into Sri Lanka and probably into Antarctica. However, *P-T* paths related to tectonic settings of this region are still under debate as both clockwise (e.g., Shimpo et al., 2006) and counterclockwise (e.g., Sajeev et al., 2009) *P-T* paths have been reported from this region. Further detailed petrological and mineralogical investigations on various rocks are therefore necessary to reveal the tectonic history of the PCSZ. In this study, we report new petrological data of Grt-Cpx rocks (mafic granulites) from Mahadevi in the eastern extension of Namakkal district within the PCSZ, and present new evidence of HP and UHT metamorphism. Mg-Al-rich rocks from Vellapatti and Nathamedu in the district are also discussed for construction of *P-T* path.

Petrology and metamorphic conditions

Grt-Cpx mafic granulite is a major rock type in Mahadevi within the central domain of the PCSZ. These rocks contain coarse-grained (up to 1.5 cm) garnet (Alm_{31-53} Pyr_{31-44} Sps_{0-1} Grs_{14-23}) and clinopyroxene (X_{Mg} = 0.71-0.86) with minor pargasite, plagioclase (An_{35-41}), orthopyroxene, and rutile. Garnet and clinopyroxene are both subidioblastic and contain few inclusions of clinopyroxene (in garnet) and plagioclase. Orthopyroxene occur only as Opx + Pl symplectite between garnet and clinopyroxene (Fig. 1). This texture probably suggests the progress of decompressional reaction: Grt + Cpx + Qtz => Opx + Pl (1). Similar reaction textures have been reported from Paramati (Nishimiya et al., 2008), Sittampundi (Sajeev et al., 2009; Santosh et al., 2010), and Perundurai (Santosh et al., 2010) in the

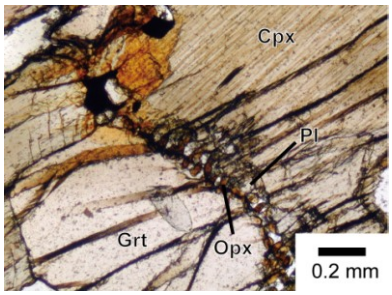

Fig. 1. Opx + Pl symplectite between garnet and clinopyroxene.

PCSZ. The prograde mineral assemblage of the rocks is therefore inferred to be Grt + Cpx + Qtz, although quartz was probably totally consumed by the progress of reaction (1). The metamorphic temperature and pressure computed using plagioclase-rich sample yield 890-900°C and 13.8-14.2 kbar using Grt-Cpx-Pl-Qtz geothermobarometers. The *P-T* condition is consistent with the stability of Grt + Cpx + Qtz assemblage (*P* >14 kbar at 900°C; Green and Ringwood, 1967).

Mg-Al-rich rocks from Vellapatti contain phlogopite, sapphirine, spinel, cordierite, sillimanite/kyanite, and rutile. Coarse-grained and idioblastic phlogopite is the most dominant mineral in the rock. Spinel (X_{Mg} = 0.88-0.89) and sapphirine (X_{Mg} = 0.97-0.98) are subidioblastic and texturally in equilibrium. Application of Spr-Spl geothermometers yielded a high-temperature range of 880-1040°C which probably corresponds to near-peak condition. Intergrowth of fan-like aggregates of fine-grained (0.05-0.13 mm) sillimanite and subidioblastic coarse-grained (0.05-2.5 mm) sillimanite are often surrounded by symplectic aggregates of Spr + Crd in Al-rich domains of the rocks. The major rock type in Nathamedu comprises quartzo-feldspathic gneiss (Qtz + Pl + Sil/Ky), Phl-Crn-Spr rock, and Opx-Sil-Ged gneiss. The Opx-Sil-Ged gneiss contains gedrite (X_{Mg} =0.61-0.68), orthopyroxene (X_{Mg} = 0.68-0.70, Al = 0.17-0.18 pfu), garnet (Alm_{46-49} Pyr_{44} Sps_2 Grs_{4-7}), sapphirine (X_{Mg} = 0.78-0.82), sillimanite, plagioclase (An_{30-31}), quartz, and biotite (X_{Mg} = 0.75-0.76). Orthopyroxene, sillimanite, and quartz in the matrix are subidioblastic and texturally in equilibrium, although they are separated by aggregates of plagioclase. Metamorphic temperature and pressure were calculated to be 905-945°C, ~12 kbar using Grt-Opx geothermobarometers applied to poikiloblastic garnet and matrix orthopyroxene in Opx-Sil-Ged gneiss.

Discussion

Our new petrological and geothermobarometric data of Grt-Cpx and Mg-Al-rich rocks from the PCSZ suggest prograde metamorphic conditions of *T* = 890-900°C and *P* = 13.8-14.2 kbar (Grt-Cpx rock) or *T* = 880-1040°C and *P* ~ 12 kbar (Mg-Al-rich rock). The HP stage was probably followed by peak UHT event as inferred from the occurrence of Opx + Sil + Qtz assemblage in Nathamedu and the calculated temperature range. Opx + Pl symplectite between garnet and clinopyroxene in mafic granulites from Mahadevi and Spr + Crd symplectite around sillimanite in Mg-Al-rich rocks from Vellapatti are consistent with decompressional event from HP stage to peak UHT stage. Such HP-UHT metamorphic history possibly along a clockwise *P-T* path has been reported from several localities in the PCSZ (e.g., Shimpo et al., 2006; Collins et al., 2007b; Clark et al., 2009; Nishimiya et al., 2010; Santosh et al., 2010). Our results therefore confirmed that the PCSZ underwent regional HP metamorphism followed by UHT event probably associated with the accretionary history of the PCSZ related to the Pacific-type orogeny and final collisional assembly of the Gondwana supercontinent in the Late Neoproterozoic-Cambrian (Santosh et al., 2009).

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References

Clark, C., Collins, A.S., Santosh, M., Taylor, R., Wade, B.P., 2009, The P-T-t architecture of a Gondwanan suture: REE, U-Pb and Ti-in-zircon thermometric constraints from the Palghat Cauvery shear system, South India: Precambrian Research, 174, 129-144.

Collins, A.S., Windley, B.F., 2002, The tectonic evolution of central and northern Madagascar and its place in the final assembly of Gondwana: Journal of Geology, 110, 325-340.

Collins, A.S., Santosh, M., Braun, I., Clark, C., 2007a, Age and sedimentary provenance of the Southern Granulites, South India: U-Th-Pb SHRIMP secondary ion mass spectrometry: Precambrian Research, 155, 125–138.

Collins, A.S., Clark, C., Sajeev, K., Santosh, M., Kelsey, D.E., Hand, M., 2007b, Passage through India: The Mozambique ocean suture, high-pressure granulites and the Palghat-Cauvery Shear System: Terra Nova, 19, 141-147.

Green, T.H., Ringdwood, A.E., 1967, An experimental investigation of the gabbro to eclogite transformation and its petrological applications; Geochimica et Cosmochimica Acta, 31, 767-833.

Nishimiya, Y., Tsunogae, T., Santosh, M., 2008, Petrology and fluid inclusions of garnet-clinopyroxene rocks from Paramati in the Palghat-Cauvery Shear Zone System, southern India: Journal of Mineralogical and Petrological Sciences, 103, 354-360.

Nishimiya, Y., Tsunogae, T., Santosh, M., 2010, Sapphirine + quartz corona around magnesian (XMg ~0.58) staurolite from the Palghat-Cauvery Suture Zone, southern India: Evidence for high-pressure and ultrahigh-temperature metamorphism within the Gondwana suture: Lithos, 114, 490-502.

Sajeev, K., Windley, B.F., Connolly, J.A.D. Kon, Y., 2009, Retrogressed eclogite (20 kbar, 1020ºC) from the Neoproterozoic Palghat-Cauvery suture zone, southern India: Precambrian Research, 171, 23-36.

Santosh, M., Sajeev, K., Li, J.H., 2006, Extreme crustal metamorphism during Columbia supercontinent assembly: Evidence from North China Craton: Gondwana Research, 10, 256-266.

Santosh, M., Maruyama, S., and Sato, K., 2009, Anatomy of a Cambrian suture in Gondwana: Pacific-type orogeny in southern India?: Gondwana Research, 16, 321-341.

Santosh, M., Tsunogae, T., Shimizu, H., Dubessy, J., 2010, Fluid characteristics of retrogressed eclogites and mafic granulites from the Cambrian Gondwana suture zone in southern India: Contributions to Mineralogy and Petrology, 159, 349-369.

Shimpo, M., Tsunogae, T. and Santosh, M., 2006, First report of garnet-corundum rocks from Southern India: implications for prograde high-pressure (eclogite-facies?) metamorphism: Earth and Planetary Science Letters, 242, 111-129.