Episodic Crustal Evolution of the Southern Granulite Terrane: Implications from the Bhavani Suture Zone and the Shevaroy Granulite Block, Southern India

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Summary of the thesis

1. Introduction

Archean terrains across the globe offers important evidences for the processes operated in the early Earth. This study reports new petrological, geochemical, pressure-temperature (*P-T*), and zircon U-Pb geochronological data of the mafic rock suites from the Mettupalayam region within the Bhavani Suture Zone (BSZ) and south–western region of Shevaroy Block (SB), Southern India. Based on these results, this study attempts to evaluate the regional tectonic history of the Southern Granulite Terrane (SGT). Results from this study provide new evidence for the existence of multiple subduction and collision of magmatic arcs and continental fragments towards the Dharwar Craton during the Archean-Paleoproterozoic transition.

2. Results

2.1. Whole-rock geochemistry

Representative and fresh parts of the examined samples were selected for whole-rock geochemical analyses. The size of the samples was initially reduced in a jaw crusher, and then manually fine-powdered in an agate mortar. Major oxides were analyzed by 'lithium metaborate/tetraborate fusion ICP whole rock (Code 4B)', and minor and trace elements by 'trace element ICP/MS (Code 4B2)' techniques at Activation Laboratories of Ontario, Canada. The fused sample was diluted analyzed by Perkins Elmer Sciex ELAN 600, 6100 or 9000 ICP/MS. Three blanks and five controls (three before sample group and two after) are analyzed per group of samples. Duplicates are fused and

analyzed every 15 samples. The instrument is recalibrated every 40 samples. Detection limits of major elements are 0.01%, whereas those of REE are 0.002-0.05 ppm. Detailed analytical conditions and detection limits are summarized in http://www.actlabs.com/.

The total alkali and SiO_2 relationship can be utilized for the classification of igneous protolith. According to TAS diagram, all the samples from the Mettupalayam region and the Shevaroy Block are sub-alkaline and displayed basaltic affinity except for one dioritic gneiss (MS-15A) from Mettupalayam region and one amphibolite (SA-10B) from Shevaroy Block, showing basaltic andesite affinity. In the primitive-mantle normalized trace element plot (Sun and McDonugh, 1989), majority of the studied rocks from Mettupalayam region and Shevaroy Block show negative Nb, Ta, P, Ti anomalies, relatively high constant high field strength elements (HFSE: Zr, Hf), and enrichment of large ion lithophile elements (LILEs) such as Ba and K. However, the garnet-bearing mafic granulite (SA-10A) from the Shevaroy Block did not show Nb, Ta, P and Ti negative anomalies. In the chondrite-normalized REE plot after McDonugh and Sun (1995), amphibolites and dioritic gneiss samples from the Mettupalayam region and amphibolites, meta-ultramafics, and coarse-grained mafic granulite samples from the Shevaroy Block are characterized by enriched light rare earth elements (LREE) pattern relative to the high field strength elements (HREE), suggesting fractional crystallization. However, the garnet-bearing mafic granulite (SA-10A) from the Shevaroy Block displayed depleted LREE pattern relative to the HREEs.

2.2. Geochronology

Zircon U-Pb dating was performed by laser ablation-inductive coupled plasma-mass spectrometry (LA-ICP-MS). Detailed procedures for zircon separation and U-Pb analyses are summarized in Tsutsumi et al. (2012). Zircon grains were separated by heavy liquid (diiodo-methane) and magnetic separation from crushed rock samples, and

then purified by handpicking under a binocular microscope. Zircon grains from the studied samples and standard materials were mounted in epoxy resin disc and polished until the surface was flattened with the center of the grains exposed. The FC1 zircon ($^{206}Pb/^{238}U$=0.1859; Paces and Miller, 1993) and NIST SRM 610 standard glass were used as standard materials. Back-scattered electron and cathodoluminescence (CL) images were obtained using scanning electron microprobe - cathodoluminescence (SEM-CL) equipment, JSM-6610 (JEOL) and a CL detector (SANYU electron), installed at National Museum of Nature and Science, Japan. U-Th-Pb isotopic analyses were carried out using LA-ICP-MS (Agilent 7700x with ESI NWR213 laser ablation system) installed at the National Museum of Nature and Science, Japan. A Nd-YAG laser with a 213 nm wavelength and 5 ns pulse was used for the analysis. A 25-micron spot size and 4–5 J/cm^2 laser power was adopted in this study. He gas was used as the carrier gas instead of Ar gas to enhance a higher transport efficiency of ablated materials (e.g., Eggins et al., 1998). Common Pb corrections for the concordia diagrams and for each age were made using ^{208}Pb (Williams, 1998), on the basis of the model for common Pb compositions proposed by Stacey and Kramers (1975). The upper and lower intercepts in the concordia diagram were calculated using the Isoplot4.15/Ex software (Ludwig, 2008).

Magmatic zircons from the Mettupalayam amphibolite yielded an upper intercept age of 2600 ± 38 Ma. Zircon grains from the dioritic gneiss (Mettupalayam) displayed a similar upper intercept age of 2562 ± 34 Ma and weighted mean $^{206}Pb/^{207}Pb$ age of 2524 ± 6 Ma, indicating protolith emplacement related to Neoarchean arc magmatism. Overgrowth rims around the magmatic zircons from this amphibolite defined an upper intercept age of 2520 ± 30 Ma, possibly representing a thermal effect related to 2.52 Ga arc magmatic event.

2.3 *P–T* conditions

The garnet-bearing mafic granulites observed from the Mettupalayam region and southern margin of the SB were used to estimate the *P–T* conditions and *P–T* paths for the better insights of the evolutionary history of these regions. A peak metamorphic condition of 760–860°C/7.2–10 kbar and 860–910 °C/~9 kbar were estimated for the garnet-bearing mafic granulites from Mettupalayam region and southern part of the SB, respectively using phase equilibria modeling in the NCKFMASHTO system.

3. Discussion

Petrological studies of the rocks examined in this study suggest that these rocks underwent high-grade metamorphism and also experienced a near isothermal decompression along a clockwise *P–T* path during their retrograde evolution stage. The clockwise *P–T* paths and high-grade metamorphism are commonly associated with the process of subduction and collision during continental amalgamation. The geochemical evidence suggests a subduction-related arc magmatic tectonic setting for the mafic rocks studied in this study. Thus, geochemical and geochronological data obtained in this study further confirm the previous tectonic model that envisages multiple subduction and collision of magmatic arcs and continental fragments towards the south of the Dharwar Craton during Neoarchean-Paleoproterozoic transition. Results from this study also shed lights towards the continental crustal growth processes operated during the early Archean.