ABSTRACT

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Title: Petrology and geochemistry of a suite of granulite facies rock and associated granitoids from Makrohar Granulite Belt, Central India

Thermotectonic evolution of the rocks of Central Indian Tectonic Zone (CITZ) is crucial to understand the growth of the Indian shield and its response to the supercontinental cycles of the Earth. In this study detail petrology and robust geochronological data from a suite of metaigneous (porphyritic metagranitoid, felsic orthogneiss and meta-mafic rocks) and metasedimentary rocks (metapelite and garnet-cordierite biotite rock) from the least studied Makrohar Granulite Belt (MKGB) that is situated in the NE part of the CITZ are presented and analyzed.

The porphyritic metagranitoid suite develops megacrystic K-feldspar and plagioclase phenocrysts, embedded in medium to fine-grained matrix of biotite ± amphibole + quartz + K-feldspar + plagioclase + ilmenite ± garnet with widely variable phenocryst (variably deformed) to matrix ratio. The bulk compositions of the rocks overlap with the compositions of the I-type granitoid, emplaced in a continental arc setting. Systematic geochemical trends combined with the variation in modal mineralogy suggest crystal fractionation to be the dominant process during the evolution of this arc magma. Phase equilibrium modeling in Na_2O-CaO-K_2O-FeO-MgO-Al_2O_3-SiO_2-H_2O-TiO_2 system under various physicochemical conditions suggests that both post-emplacement fractionation of a felsic magma and combined fractionation-crustal assimilation of a mafic magma at shallow depths (≤5 kbar) likely to produce the observed chemical variation in the arc granites. The in-situ U-Pb zircon age of the zircon with oscillatory zoning constrains the timing of magmatism at 1750 Ma.

Petrology and geochemical data of the felsic orthogneisses identify two rock groups: charnockitic orthogneiss (COG) and garnet orthogneiss (GOG). Geochemical fingerprints suggest that the magmatic protoliths of the gneisses are S-type granitoids, formed in a continental arc setting. In situ U-Pb zircon dates yield the time of the arc magmatism at ca. 1400-1350 Ma. This is the first report of mid-Mesoproterozoic arc magmatism in the CITZ. These arc granites were subsequently metamorphosed at granulite facies condition that culminated at ~800-850°C, 7-7.5 kbar and then followed sequentially by a steeply and mildly decompressive retrograde P-T path that can be traced upto 4 kbar and 500ºC. The geometry of the P-T paths ('clock wise') combined with secondary planar structures in the outcrop of these rocks are consistent with reworking of the Mesoproterozoic arc rocks and the adjoining metapelites and metabasic rocks in a continent-continent collisional setting. In-situ Th-U-total Pb monazite and in-situ U-Pb ages of zircon overgrowth date the deformation and metamorphism in the span of ca. 974-913 Ma.

Combined field relations, and phase equilibria modeling study on the banded psammopelites identify an early granulite facies metamorphism (garnet + plagioclase + K-feldspar + quartz + ilmenite without any feldspar and muscovite); manifested by the garnetiferous leucosomes that define a regional planar fabric formed at ~800°C, 7 kbar which is corroborated well with the P-T conditions reported from the adjoining felsic orthogneisses. The garnet-cordierite-biotite rock occurs as patches in the strike continuity of the psammopelite and develops two mineralogically exclusive domains (with and without anthophyllite). Both the domains form high variance mineral assemblage presumably results from infiltration driven metamorphism. The garnet-aluminosilicate veins that dissect the garnet-cordierite-biotite rock are interpreted by infiltration-driven metasomatism where the infiltrated fluid interacted with aluminous host rock, caused hydrofractures and deposited prismatic sillimanite, coarse vein quartz and garnet (crack-seal mechanism). Formation of fibrolite in places supports that unlike the aluminosilicate veins where Al was mobile, Al was also locally

immobile. Variation of chemical potentials of chemical species at nearly constant P-T was responsible for the stability of anthophyllite.

Field study and petrographic observations identify two groups of meta-mafic rocks among which the coarse grained ones have a magmatic mineral association of olivine + clinopyroxene + orthopyroxene + plagioclase + ilmenite + magnetite ± apatite. In the subsolidus stage diffusion controlled reactions between primary olivine and plagioclase formed the double coronae (inner corona: orthopyroxene and outer corona: amphibole + spinel). Olivine in few cases is extensively replaced and pseudomorphed by symplectic association of orthopyroxene + magnetite pointing towards a mechanism governed by oxidation. Phase equilibrium modeling of the garnetiferous meta-mafic rocks suggest that metamorphism culminated at 750-800 °C and 7-9 kbar stabilizing the peak metamorphic mineralogy of garnet + clinopyroxene + orthopyroxene + plagioclase + ilmenite + quartz. Combining the physical conditions of the formation of amphibole + biotite during retrogression the depicted metamorphic P-T path is well matched with the felsic orthogneisses and metapelites of the MKGB.

The K-feldspar megacryst in the porphyritic metagranitoid develops extensive myrmekite all along the periphery of the alkali feldspar megacryst. Myrmekite shows two different morphologies: (1) vermicular intergrowth of plagioclase (An_{38-39}) and quartz (Myr1) and (2) polygonal aggregates of coarse plagioclase (An_{45-46}) and quartz (Myr2). Petrographic features suggest that (1) myrmekite nucleates on alkali feldspar and plagioclase porphyroclast and the myrmekite front moved into the alkali-feldspar by replacing it and (2) the myrmekite and the secondary biotite that replaces plagioclase porphyroclasts and garnet form together. Whereas deformation had a decisive role in forming the polygonal aggregates in Myr2, field and microtextural features do not support any significant control of deformation during the formation of Myr1. Reaction modeling and mass balance calculation suggest that Ca and Na are added to and K is removed from the alkali-feldspar during synergic formation of the myrmekite and the secondary biotite. Interpretation of the reaction textures in different isothermal-isobaric sections of μK_2O-μCaO in the KCFASH system suggest a feedback mechanism that operated between the two reaction sites (at myrmekite and at the site of secondary biotite) during infiltration of brine rich fluid in the metagranitoid at c. 550°-600°C and 5-6 kbar). Integrating the analyses of this study with the published information following inferences are drawn:

1. MKGB experienced a protracted period of magmatism, both felsic and mafic compositions, sedimentation (protoliths of metasedimentary rocks) and deformation that can be tracked from ca.1750 Ma to 913 Ma.
2. The ca. 1750 Ma old arc magmatism in the MKGB is consistent with the view that both MKGB and Mahakoshal Supracrustal Belt, now separated by the Son Narmada South Fault formed a coherent block till 1750 Ma. A southward progression of the arc front in the Indian shield from ca. 1900 Ma to ca. 1600 Ma is envisaged during the growth of the Columbia supercontinent.
3. The ca. 1400-1350 Ma arc magmatism is presumably linked to collapse or closure of a basin (either north or south of the MKGB) in the CITZ in response to the prolonged accretionary phase of the Columbia supercontinent and preponderance of ca. 1000-950 Ma tectonometamorphic event superposed on the older continental basement in the CITZ, Chotanagpur Granite Gneiss Complex, the Eastern Ghats mobile belt and in many other parts raises the possibility that major part of the Indian Shield behaved as a coherent block during this tectonothermal event during the assembly of the Rodinia supercontinent.

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