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Preliminary 2-D thermal modeling of Proterozoic granulite: a case study of structurally controlled exhumation

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Deep continental crustal rocks undergone granulite-grade of metamorphism are exposed at the orogenic belts. Mesoproterozoic Eastern Ghats Granulite belt is one such polymetamorphosed and polydeformed terrain. The unique character of this belt is the occurrence of ultrahigh temperature metamorphosed granulites on a regional-scale where the peak metamorphism is estimated to be in excess of 1000 ^{o}C at ~8-10 kbars. The reason(s) for such extreme thermal conditions at the deeper parts of the Proterozoic orogen and an appropriate geotectonic setting for such extreme high heat flow are still eluding the geoscientists. Moreover, the exhumation processes and rates of exhumation are one of the least studied areas for the deep interiors of such extremely hot orogen.

Proper structural and petrological assessments, particularly exhaustive analysis of pressure-temperature-deformation-time evolutionary history of Eastern Ghats Granulite belt pave the path to look for exhumation histories. This belt is known to be anisotropic and domainal in terms of isotopic signatures and tectonothermal histories. The domain 2 of this orogenic belt presents the best-studied section showing an overall anticlockwise P-T path evolution with three to four deformation and metamorphic events in an overall possible accretionary orogenic set-up. Regional-scale structural studies along the Vishakhapatnam-Araku transect of domain 2 show imprints of superposed deformation at high angle producing domal structures. Three such large-scale domes are arranged from south-east (Madudavada mega-sheath) to north-west (Anantagiri dome and domal structure near Araku).

The present study is based on the occurrence of aluminous granulite with sapphirine-spinel-aluminous orthopyroxene-cordierite-sillimanite-garnet-biotite-quartz-feldspar near the boundary of the "Maduravada mega-sheath". Fe-Mg compositional profiles of porphyroblastic garnet adjacent to orthopyroxene, and that with adjacent retrograde biotite (fluorine-Ti-Mg-rich) show development of zoning only in the latter case. Geothermometric calculations indicate formation of biotite at ~875 ^{o}C during the early cooling, followed by the formation of compositional zoning in adjacent porphyroblastic garnet. In an earlier study, we estimated an anomalously fast cooling rate from this zoning profile of garnet *i.e.*, 12 to 25 ^{o}C/Ky, which is several order higher than the normal thermal relaxation rates reported from younger orogenic belts. In the present study, we have tried to formulate a preliminary two-dimensional numerical thermal model using rapid upheaval of deep crust in a compressional tectonic setting through a domal structure having near-vertical foliation planes. The model calculation is based on an initial thermal condition similar to that of known old continental crust having a steady-state geotherm on 100 km wide area with depth of 35 km. An already perturbed geotherm of 900 ^{o}C at the lowermost part is then folded up in an antiformal parabolic shape, more or less in the fashion of a diapiric upheaval. The 2-D conductive cooling is then assumed and cooling rates have been calculated at different places from the boundary of the upheaved portions, i.e., 0 to 1.25 km at a depth of 5 km from the surface. We use a finite volume method with an implicit time integration to solve the thermal conduction equation with a radiogenic heat source decaying with the depth. The initial cooling rates of ~10-20 ^{o}C/Ky is estimated to be achieved near the boundary with non-linear subsequent decay, similar to the recorded cooling rate from the Fe-Mg zoning profile in the studied rock. The thermomechanical consequence of such deep crustal flow process in presence of partial melt in the overall perspective of the Proterozoic orogen is being checked, in addition to the plausibility of such high degree of thermal relaxation rate.

Keywords: Deep crustal UHT granulites, Anomalously high thermal relaxation rate, 2-D thermal model and crustal flow