Advective Heat Transfer in Gondwana Crust: The Role of Magmas

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This presentation focuses on the ultra-high temperature metamorphic assemblages from the Gondwana crustal fragments and seeks the source of heat and volatiles. The paper argues that adiabatic heat input from magmatic sources could have served as an important vector for the ultra-high temperatures and CO2-rich volatiles.

The crustal fragments of East Gondwana including India, Sri Lanka and East Antarctica record the imprints of high- and ultra-high temperature (UHT) events. Mineral assemblages and reaction textures including sapphirine+quartz, osumulite+garnet, orthopyroxene+sillimanite+quartz, Mg-bearing pigeonite and coarse mesoperthites have been described from various granulite facies segments in the Gondwana crustal fragments indicating equilibration temperatures up to 1120oC at pressures in the range of 6-10 kbar (Harley and Motoyoshi, 2000; Osanai et al., 1999, 2000; Sengupta et al., 1999, Harley, 1998; Raith et al., 1997; Sheraton et al., 1980, among others). Stable isotope thermometry on calcite-graphite pairs in calc-silicate rocks and marbles from these terrains also indicate high metamorphic temperatures (Satish-Kumar, 1999). While the ultra-high temperature metamorphic assemblages described from the Napier Complex in East Antarctica have been dated as Archaean (ca. 2500 Ma), those in the Eastern Ghats Belt of Peninsular India occur within Grenvillian (ca. 1000 Ma) metamorphic belt. The sapphirine-bearing assemblages and high temperature metacarbonates in southern India and Sri Lanka, on the other hand, occur within Pan-African (ca. 540 Ma) terrains. Thus, it is evident that parts of the Gondwana crust have been subjected to multiple ultra-high temperature events during their course of evolution from Archean to Proterozoic times, subsequent incorporation into various supercontinental configurations, and final amalgamation within the Gondwanaland assembly.

The exhumation history of these ultra-high temperature terrains, as inferred from mineral reactions, phase equilibria and pressure-temperature-time paths, is diverse in different terrains. The Archean granulites of Napier Complex in East Antarctica record unequivocal evidence for isobaric cooling along a counter-clock wise P-T path. Those in the Eastern Ghats Granulite Belt show evidence for early isobaric cooling followed by late isothermal decompression. The Pan-African ultra-high temperature segments in southern India and Sri Lanka show characteristic steep isothermal decompression paths along a clock-wise trajectory. Thus, we identify comparable mineral assemblages, reaction textures and ultra-high temperature records from lithologies formed at different periods of the Earth's history and in contrasting tectonic settings. Therefore, we argue that a single and unified model of continental collision or lithospheric delamination following crustal thickening (cf. Harley, 1998) may not be sufficient to invoke the extreme temperatures attained during the UHT metamorphic events. The same applies to models invoking steep geotherms for the Archean since they fail to account for the younger UHT assemblages. Also, many of the UHT assemblages are characteristically anhydrous, requiring low water activities to stabilize. This means that alternate source of heat and anhydrous fluids have to be sought for.

We focus attention on the feature that many of the UHT terrains are either interlayered or closely associated with ultramafic, mafic and other related suites of magmatic rocks. We propose that the adiabatic heat input from magmas could have played an important role in the generation of both regional UHT assemblages as in Napier Complex, and isolated UHT occurrences as in the Eastern Ghats Granulite Belt, Madurai Block of southern India and Highland Complex of Sri Lanka. The advective heat transfer from magmatic sources could have been fundamental in crustal metamorphism leading to high- and ultrahigh-temperature assemblages. This model would also explain the source of anhydrous fluids involved in many of the UHT assemblages since the mafic and ultramafic magmas might have served as conduits for the transfer of CO2-rich fluids.