The Indian Granulites

Granulites have been in the limelight during the last two decades. There are several reasons behind this prominence. They are considered to be good analogues of middle to lower crustal rocks, they are amenable to reasonably good pressure-temperature estimates, they straddle the boundary between metamorphism and melting.

The Indian subcontinent displays profuse development of granulites especially in the South Indian cratonic areas and in the Eastern Ghats belt. The Eastern Ghats granulites did not receive much attention until about a decade ago. This can be turned to an advantage. For, the tools of granulite research have since been honed further and several recent findings have compelled us to look at some issues differently.

In the last decade a number of detailed studies aimed at illuminating the evolution of the Eastern Ghats granulites were published. Barring a few investigations based on remote sensing and structure, the overwhelming proportion of these studies was petrological. Indeed, the last few years have witnessed a spate of papers focussed on the petrology of these granulites. The common refrain in these papers is phase equilibria, more explicitly, geothermobarometry and metamorphic reactions. A stimulus for both, especially the latter, is the presence of osumilite – (its decomposition products), sapphirine- and spinel-bearing assemblages. Many of these assemblages are now known, both from experimental phase equilibria studies and geothermobarometry, to have equilibrated at high temperatures and fairly high pressures ($\sim$ 950°C, 9 kbar). These petrological investigations have provided us with a platform from which complementary studies such as geochronological determinations can be launched. Combining these results with those from structural and geochemical studies, a synthesis can be attempted.

The papers comprising this special section on Indian granulites, present a set of petrological investigations which employ currently popular approaches and methods, which should serve several purposes. First, they show the state of the art. Second, they point out the gaps, and third, they may help articulate significant higher order questions that should be asked.

Lal's paper calibrates sixtythree mineral equilibria in the MgO-Al_2O_3-SiO_2 system on the basis of calorimetric data and results from experimental phase equilibria studies. This will be useful for understanding the significance of Mg-Al rich granulites. **Motoyoshi** and **Pal** and **Bose** deal with pressure-temperature evolution of a suite of granulites from adjacent areas. Both set of authors report evidence of cooling followed by decompression. **Mohan** *et al* emphasize decompression and appear to be inclined towards a clockwise path, while **Pal** and **Bose** infer a counterclockwise path. This underscores the need to consider temporal relations and to check the possibility of multistage evolution. **Mohan** *et al* envision crustal thickening, this is compatible with the finding, as in **Bhattacharya's** paper, that the earliest deformation was compressional. **Bhowmik** investigated a suite of granulites from the Borra Carbonate Granulite Complex and has reconstructed the tectonic-cum-petrological scenario. He recognizes five episodes of deformation and petrological reworking associated with them. **Bhattacharya** documents structural evidence for three major episodes of folding in the Eastern Ghats granulite terrane which can serve as punctuation marks in the tectonic-cum-petrological evolution of these rocks. He argues in favour of an early compressional regime. Such detailed analysis of the deformation history should be carried out in many more areas in the Eastern Ghats Belt; on the one hand they help establishing temporal relations, on the other, they provide the information required for correct interpretation of geochronological data. An interesting conclusion of **Bhattacharya's** work is that the juxtaposition of the Eastern Ghats Belt against the Singhbhum Iron Ore Craton was by oblique collision, suggesting a transpressional regime.

Taking advantage of the editorial prerogative, I should like to make the following comments. First, in multiply deformed rocks the nature of the pressure-temperature-time paths should be deduced after due consideration of temporal relations. The pitfalls of neglecting different phases of deformation and metamorphism and clubbing them together are many. For example, lower temperatures registered during later phases, if uncritically grouped together with higher

Proc. Indian Acad. Sci. (Earth Planet. Sci.), **106**, No. 3, September 1997, pp. 63–64

temperatures attained in earlier phases, will lead to the incorrect inference—cooling.

Second, in the total picture of evolution of granulite terranes, partial melting and its consequences should receive more attention. Partial melts buffer temperatures, facilitate uplift, influence mineral equilibria and cause geochemical differentiation. If melting progresses to a stage where diapiric rise is triggered, the pressure-temperature-time paths will be perturbed.

In view of the high temperatures (900°–1000°C) recorded in the Eastern Ghats and some other granulite terranes, it is now necessary to examine the possibility, petrologically and geochemically, whether the granitic-granodioritic to dioritic rocks present in granulite terranes were derived by partial melting of crustal rocks such as amphibolites. Many workers have styled these rocks charnockites-enderbites because of the presence of orthopyroxene. Recent experiments have conclusively demonstrated that melts of granodioritic to dioritic composition can be derived by 20–40% melting of basic rocks in the neighbourhood of 1000°C and 8 kbar.

In this connection, the nexus between khondalites and leptynites, which are so closely associated in the Eastern Ghats granulite terrane, should be explored further. Some recent work indicates that the granitoid gneisses broadly referred to as leptynites were derived by dehydration melting of micas, and the protoliths varied from metapelitic to metapsammitic in composition. The pre-metamorphic compositions of khondalites and the modifications effected by partial-melting are queries relevant to the evolution of the Eastern Ghats granulites. Of special interest is the origin of the Mg-Al-rich metasedimentary granulites: do they represent protoliths of unusual composition or are they residues from dry melting at high temperatures?

Third, insights into the evolution of the Eastern Ghats granulites can be gained by forward modelling. Indian workers have not explored this field, but it is full of promise. Some unpublished work by us, based on an analytical solution applied to transient thermal regimes in granulite metamorphism initiated by homogeneous shortening, shows the profound effects of post-burial conditions on the exhumation scenarios of granulite terranes, and the control of exhumation rates on the style of reworking during multiple orogenies. It is high time that we looked beyond issues like clockwise versus counterclockwise P-T-t paths and attempted to interpret the evolution of granulite terranes in terms of velocities of burial and exhumation, of transient thermal regimes, and of duration of orogenies.

We hope that the tomorrows of granulite research will take care of these gaps and yield a fuller comprehension of the evolution of the Eastern Ghats granulites.

S K Sen
Guest Editor