3 Metamorphic Processes Associated with Orogenic Belts of India

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Rocks exposed in the cratons and fold belts bear imprint of three internal processes, viz. magmatism, metamorphism and deformation. These processes are best studied in the youngest orogen of Himalaya whose metamorphic rocks occupy hundreds or even thousands of sq km are and show a gradual increase in metamorphism from low grade (greenschist) to successively higher grades (amphibolites and granulite facies). This is because the rocks are involved in the plate tectonics and show evidence of rifting, subduction, ophiolite, island arc formation and progressive metamorphism attendant with syn- to late-tectonic granites as a result of collision of lithospheric plates. The Himalayan rocks preserve evidence of all the internal processes that occurred during its evolution by the global plate tectonics. However, the metamorphic rocks show inverted metamorphism in which higher grade rocks occur on higher, and not deeper, tectonic levels. Many explanations have been advanced for this inversion. The only plausible explanation this author thinks is post-metamorphic ductile shearing since isotherms in deep earth are never reversed. However, paleopressure and textures suggest that sillimanite zone has developed during decompression when lecucogranite was generated by partial melting of muscovite-bearing rocks.

Another area in the Indian subcontinent that shows progressive metamorphism is located to the south of Dharwar cratons (DC). The DC as whole shows a progressive metamorphism southward from greenschist through amphibolite facie to granuilte facies, with isograds running E-W, orthogonal to the regional fabric, suggesting that metamorphism outlasted deformation in these rocks. A transition zone is also found where both amphibolites and granulite facies parageneses are found. A late to post-tectonic granite, called Closepet granite of 2.5 Ga age intrudes the DC almost parallel to the regional fabric of the DC. This granite cannot also be a tectonic divide of the DC since the divide has a shear zone which trend N-S (Chitradurga SZ). This shear zone is later than 2.5 Ga old regional metamorphism. The trend of the isograds (being parallel to trench zone) does not support subduction toward W or E, A model that considers N-ward subduction of the oceanic crust whereby GB extend in E-W direction and later an E-W transpression to deform the GB which along with its basement TTG was subjected to thermal relaxation, accord beautifully with the present configuration of the schist belts and the metamorphic isograds. And this is the model of Newton (1993).

The Proterozoic fold belts cannot be considered to be the ancient analogue of the Himalaya because of (a) their relatively smaller linear extension, (b) their narrow progressive zones/facies and in some instances showing only a single extended granulite facies, (c) their occurrences between cratons or at the margin of a craton. Hence their evolution cannot be considered in terms of global plate tectonics. The fold belts have quartzite-carbonate-metapelite association with or without volcanics and are generally intruded by one or more phase of granites, to be appropriately called mobile belts. The author (Sharma, 2009) recognizes mainly six fold belts (FB) or mobile belts in the Indian shield. These are Aravalli FB, Delhi FB, Satpura FB, Singhbhum FB, Eastern Ghats mobile belt (EGMB), and the questionable Pandyan mobile belt. The last belt named so by Ramakrishnan (2003) contains Pan-African granulites with vestiges of older rocks. This belt contacts the Proterozoic granulites (or Southern Granulite Terrain, SGT) of the Dharwar craton along the Palghat-Cauveri Shear Zone (PCSZ). For the reasons given above, all the fold belts are considered ensialic in origin and are considered to have developed from Paleoproterozoic to Neoproterozoic periods when India was in the assembly of Columbia and Rodinia supercontinents. In all reconstructions of the supercontinents (see, e.g. Piper, 2000), India is shown as a single triangular block to suggest that the different crustal blocks were once united as one large continental landmass of the Indian shield; they did not come from far off places and directions to squeeze the intervening rocks into fold belts. The ensialic orogenesis is a modified plate tectonic mechanism in which the fold belts develop on continental crust with little horizontal movement, not involving entire plate separation and subsequent destruction of oceanic crust by subduction. The sporadic occurrences of granulites in some ensialic belt and their absence in others are attributed to delamination of mantle lithosphere during rifting or collision of the crustal blocks. In these high grade rocks anatexis occurred and produced granulites as refractory residue after liquid extraction in form of granitic bodies. These granulites are taken to indicate an important granulite event. In the final stage of ensialic orogenesis, reversal of movement direction of crustal blocks is considered due to the combined effect of sediment load in the rifted basin, decay of underlying plume/mantle diaper and consequent change in the vertical component of stresses (Sharma, 2009). Interestingly, the Proterozoic ensialic belts of the Indian shield have compressive stresses (convergence) mainly in two directions: N-S for Singhbhum fold belt (located between Chhhotanagpur Gneiss Complex and Singhbhum craton) , Satpura fold belt (located between Bastar-Bhandara craton and Bundelkhand craton), and E-W or nearly E-W for Aravalli-Delhi fold belts (located between Bundelkhand-Rajasthan craton and now missing Marwar craton) and Eastern Ghats Mobile belt (between Bastar-East Dharwar craton and far located East Antarctica).

The EGMB formed when India-East Antarctica collided during Rodinia assembly. Evolutionary models that invoke ocean-ocean subduction and collision cannot be applicable because it is characterized by compression, island arc of andesitic composition with no possibility of charnockitic arc, crustal thickening and progressive increase of temperature. Continental rifting appears a plausible mechanism since continental melt produced by magmatic underplating when crystallizes under extremely reduced water pressure can develop charnockite rock--a dominant component of EGMB. This model is advanced in a detail by the author and is stated below for the evolution of the EGMB. India and Antarctica continents that were joined in the supercontinent (? Columbia) began to rift by ductile extension at about 2.0 Ga. This was followed by ascent of mantle plume which caused high-temperature metamorphism (1.8 Ga) of the rifted Archean basement below and deposition of pelitic sediments (protolith of khondalites) in the rift basin above. Continued extension caused lithospheric delamination and hence allowing magma underplating and to cause UHT metamorphism of the basement-cover at 1.6 Ga. Alkaline complexes seems to have intruded along boundary fault of the rift basin. Then was the stage when extension direction changed due to combined effect of sediment load in the basin, decay of underlying plume/mantle diapir and consequent change in the vertical component of stresses. This resulted into collision of India-Antarctica crustal blocks which led to deformation (and recrystallization) of the basement-cover rocks that finally made the EGMB (Rayner Cx) fold belt. This sandwich association of India-Antarctica- EGMB-Rayner Cx remained intact in the assembly of the Rodinia supercontinent. In the subsequent Grenville orogeny (1.0 – 0.9 Ga), EGMB upthrusted the cratons of Bastar-East Dharwar in the west. Much later, this part of the shield was subject to Pan-African thermal event whose overprinting is found in the EGMB and other granulites of the Indian shield. The author does not subscribe the view that the Ongole and EGB Province were subject to granuite facies metamorphism at different times because the Godavari cuts across the Terrain boundary shear.

The Pandyan granulite bet is entirely a granulite belt and is believed to have been formed by collision of Indian plate with an African block yet to be recognized.