ABSTRACT

The nature of metamorphism and tectonic styles in the Mesoarchaean and across the Archaean-Proterozoic transition has been investigated using integrated petrographic, mineral chemical, metamorphic evolutionary history, conventional geothermobarometry, garnet-monazite and monazite-xenotime trace element thermometry, phase equilibria modelling studies and coupled monazite electron probe micro-analyzer (EPMA) and sensitive high-resolution ion microprobe (SHRIMP) U-Pb dating results, applied to a variety of protolith compositions from the Holenarsipur Greenstone Belt, the largest exposed section of the Mesoarchaean Sargur supracrustal sequences (protolith age between c.3.3 and c.3.2 Ga) in the Western Dharwar Craton, South India. These rocks, which range in composition from pelitic schist, metamorphosed calc-magnesian sediments, ferruginous and aluminous quartzite and metabasalts have recorded two major tectonothermal events in the Mesoarchaean and Archaean-Proterozoic boundary that led to the growth of the Dharwar Craton.

The older Mesoarchean event (named the M_1 metamorphic cycle) between 3.14 and 3.11 Ga (SHRIMP monazite ages) along a clockwise metamorphic P-T path of evolution has been recorded from a low strain domain of the HGB. The path reveals a two-stage prograde segment with an initial phase of heating accompanying burial (dP/dT gradient ~ 30 bar/°C) and a later phase of steep burial (ΔP ~ 1.1 kbar, dP/dT gradient ~110 bar/°C), peak thermal state at 7.5 kbar, 640 °C and a post-peak, nearly isothermal decompression to (P ~ 6.3 kbar). It has been suggested that the Mesoarchaean metamorphism is part of a widespread tectonothermal event in the Western Dharwar Craton (WDC) that marked a shift in tectonic style from initial sagduction to later horizontal plate motions.

For the younger tectonothermal event, which is the most pervasive in the HGB and elsewhere in the WDC, three overprinting metamorphic cycles ($M_2 \rightarrow M_3 \rightarrow M_4$ in sequence) of contrasting thermal history and with a variability of metamorphic P-T paths have been recognised. The M_2 cycle, the oldest of the three events represents a characteristic LP-HT metamorphism along a CCW metamorphic P-T path, peak metamorphism at 4-5 kbar, 515-595°C and high thermobaric ratios (~1050-1525°C/GPa) at M_2 peak. The intermediate M_3 metamorphic cycle records prograde burial of partially cooled M_2 rocks to middle-lower crustal depths, peak metamorphism at P~7.5-10.2 kbar, T~630-655°C, and corresponding intermediate thermobaric ratios (T/P~620-875°C/GPa) and a retrograde stage, marked by combined exhumation and cooling to P~5.3-6.4 kbar, T~530-575°C. The resultant P-T path of evolution shows a variability of CW paths from classical hairpin type to two stage prograde heating segments. During the terminal M_4 metamorphism (T Max ~630-640°C at ~8.9-10.3 kbar and with lower T/P ratios at ~610-720ºC/GPa), the partially exhumed M_3 crust is reburied to lower crustal depths along an intermediate thermal gradient as during the M_3 metamorphic cycle.

While there is no direct age information for the M_2 cycle available at this stage, published geochronological data seem to suggest that the M_2 metamorphism along a warmer thermal gradient is linked with the latest Neoarchaean thermal perturbation event between 2.64 and 2.51 Ga in the WDC. SHRIMP U-Pb monazite dating constrains the timing of the M_3 metamorphism at c.2.49 Ga. On the basis of metamorphic and geochronological constraints established in this study and published metamorphic and geochronological data, the craton-scale north-south variation in metamorphic grade from greenschist facies in the north, amphibolite facies in the middle and granulite facies in the south is attributed to combined M_2 - M_3 metamorphic cycles at the dawn of the Proterozoic period.

A three-stage tectonic evolution of the HGB is proposed in order to interpret the metamorphic findings of thermal transition, tectonic thickening along a cooler thermal gradient, repeated burial-exhumation cycles in the orogenic wedge and tectonic mixing of the three cycles (M_2 -M_3 -M_4) of metamorphic rocks. These in a sequence are: (a) the development of hot and thin peel-off zone (cf. M_2 cycle), (b) the transition to a thickened crustal zone tectonic domain (cf. M_3 cycle), with both the domains being part of the lithospheric peel-back driven convergence setting and (c) finally continental collision tectonics (cf. M_4 cycle). It is suggested that the tectonic model can be taken as a general template of global tectonic transition across the Archaean-Proterozoic boundary.

Key words: Mesoarchean, Neoarchean, Western Dharwar Craton, Phase equilibria modelling, Metamorphic P-T paths, Monazite U-Pb dating, Archaean tectonics.