ABSTRACT

The processes involved in the formation of felsic continental crust on Earth is one of the most important problems in Archean geology and has been approached from the both petrologic and geochemical perspectives and has recently been supported by numerical modelling. Results from experimental and petrological studies indicate that the tonalite-trondhjemite and granodiorite (TTG) suite of rocks crystallized from partial melts of a hydrated mafic crust under moderate- to high-pressure conditions. These basalts preserve compositional variations in the earliest volcanic crust (greenstone belts) that formed by partial melting of mantle lherzolite, and on a hotter early Earth would have inevitably re melted to form stable, high-silica crust. Therefore, the formation of the early Archean greenstone belts, representing preserved bulk of basaltic and minor felsic volcanism within a craton, places constraints on the growth and evolution of continental crust.

The Singhbhum craton, eastern India, preserves the largest volume of Paleoarchean continental crust built by batholiths comprising sodic TTG suite of rocks with intervening greenstone belts that are classified as the volcanic-dominated southern Iron Ore Group (S-IOG), eastern Iron Ore Group (E-IOG) and shale-dominated western Iron Ore Group (W-IOG). Spectacular intracratonic dyke swarm sets represent feeder dykes to now eroded large igneous provinces (LIP). Neither the timing and duration nor the petrogenesis and tectonic processes of the greenstone belts (southern and eastern Iron Ore Group) volcanisms are well constrained. Furthermore, despite the importance of associated tholeiitic and calc-alkaline mafic volcanic rocks to constrain plate tectonic processes relating to either oceanic or continental affinity or mantle source, the timing of eruption and petrogenesis of western Iron Ore Group basal volcanics are not constrained. Importantly, the source and magmatic processes responsible for generating late Archean large igneous provinces and linkage of the large volcanic activities with their feeder dykes are largely unconstrained.

These issues are addressed in this study, where the geochemical variations, their petrogenetic modelling from mantle sources and their Sm-Nd and Lu-Hf geochronology have been used to track the changes in composition of their source mantle over the time interval from Paleo- to early Neoarchean.

Petrogenesis of ~3.57 Ga Paleoarchean greenstone S-IOG non-arc tholeiitic basaltic (Nb/Th = 3.61–10.3) volcanic rocks (interbedded minor alumina depleted [ADK] and undepleted komatiite [AUK], komatiitic basalt, dacite and chert) can best be explained by plume-mantle interaction and partial melting of ambient mantle followed by assimilation fractional crystallization of parental magmas, and does not preclude recycling of pre-existing crust. The ADK of S-IOG was modelled by 37% partial melting of garnet lherzolite, komatiitic basalt was derived from ADK magma by ~25% assimilation fractional crystallization (AFC) and ~ 16% AFC of this magma formed tholeiitic basalt. Derived from depleted parental magmas, the ~3.31 Ga E-IOG magmas underwent ~ 32% AFC of primary ADK magma which formed the komatiitic basalt that evolved to tholeiitic basalt magma (~24% AFC) which later on evolved to basaltic andesite - andesite magma by ~15% AFC. The AUK of E-IOG was modelled by ~45% partial melting and ADK modelled by ~33% melting of garnet lherzolite mantle.

Geochemical modelling indicates that basal volcanics of the ~3.05 Ga W-IOG were generated by 20–40% AFC of ~14% partial melt of depleted mantle. The source magma to the tholeiitic basalt formed by partial melting of depleted mantle followed by minor AFC, whereas the basaltic andesite represents higher extents of AFC of the tholeiitic magma; this minor basal volcanism likely formed during lithospheric extension of the Singhbhum craton.

The arc-like trace element composition (e.g. pronounced negative Nb-Ta-Ti anomalies) of the ~2.80 Ga Neoarchean dykes and coeval volcanics have a mismatch with their intracratonic extensional setting and suggest interaction with metasomatised subcontinental lithospheric mantle (SCLM) which formed ≥2800 Ma ago. Generation of their primitive magmas was modelled by two end member components involving 18% partial melt from enriched-DMM (depleted MORB mantle) [100–70%] and interaction with low degree (5%) partial melt of metasomatised SCLM [0–30%]. These magmas then ponded at Moho depths and underwent assimilation-fractional crystallization (AFC) forming the diverse dykes and basaltic andesitic-andesitic volcanics.

Keywords: Singhbhum craton, Archean mafic-ultramafic magmatism, Greenstone and intracratonic volcanism, Iron Ore Group, Keshargaria and Ghatgaon dyke swarms, Jagannthpur volcanics, Geochemical modelling, Sm-Nd Lu-Hf Geochronology.