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Modelling petrogenesis of Meso- and Neoarchean andesitic rocks: an example from Singhbhum craton, India

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Petrogenetic processes of the Archean (>2500 Ma) andesitic rocks are strongly debated because of their distinct geochemical similarities to the modern subduction zone andesites contrast with sparse evidence for Archean lithospheric subduction. Therefore, processes responsible for generation of the andesitic rocks preserved in an Archean craton would potentially place constraints on the Archean geodynamic process. The Western Iron Ore Group (W-IOG) volcano-sedimentary succession in Singhbhum craton is overlain by unmetamorphosed Jagannathpur amygdular volcanics (basaltic andesite – andesite). The W-IOG preserves deformed lower greenschist-facies tholeiitic basalt and calc-alkaline basaltic andesite interlayered with BIF and Fe-Mn-rich phyllite and shale. Previously, petrogenesis of the basaltic andesite in W-IOG was interpreted as having formed in a subduction zone whereas the origin of Jagannathpur volcanics has remained unclear. Therefore, geochemical modelling using trace elements and Sm–Nd geochronology of these basaltic-andesitic rocks were performed to constrain the petrogenetic process and timing of volcanic eruption of these metavolcanic rocks.

Primitive mantle-normalized trace element patterns, chondrite-normalized REE patterns and Nb/Th, Zr/Th ratios of the W-IOG and Jagannathpur basaltic andesite – andesite show enrichment in large ion lithophile elements (LILE), light rare earth elements (LREE), Zr and Th indicating incompatible trace element enrichment in their petrogenesis. The W-IOG tholeiitic basalt is depleted in LILE, LREE, Zr and Th and an absence of Nb-Ta-Ti anomalies that imply a depleted mantle source. The W-IOG basaltic andesite yield an isochron age of 3041±94 Ma (2SD) with Nd_i = 0.50875±0.00009, MSWD = 0.62 (n=10) and $\varepsilon_{Nd(T)}$ = +1.1±1.6; whereas the tholeiitic basalt yielded an isochron age of 3050±71 Ma (2SD) with Nd_i = 0.50885±0.00010, MSWD = 0.17 (n=10) and $\varepsilon_{Nd(T)}$ = +3.3±1.6. Geochemical modelling indicates that the W-IOG basaltic andesite could have been generated by 20-40% assimilation-fractional crystallization (AFC) (r=0.2, ratio of rate of assimilation to the rate of fractional crystallization) of primitive tholeiitic magma that is derived by 14% partial melting of depleted MORB-type mantle (DMM) under spinel lherzolite depth in an extensional setting. The Jagannathpur basaltic andesite – andesite yielded an Sm-Nd isochron age of 2799±67 Ma (2SD) with Nd_i = 0.50895±0.00006, MSWD = 0.36 (n=16) and $\varepsilon_{Nd(T)}$ = -1.1±0.5 and represents one of the oldest Neoarchean intracratonic flood basaltic volcanism. These basaltic andesite – andesite could have been produced by 20-60% AFC (r=0.2) of hybrid magma during lithospheric extension. Generation of the hybrid magma has been modelled by two end member components involving ~18% partial melt of enriched-DMM that interacted with low degree (~5%) partial melt of metasomatised subcontinental lithospheric mantle (SCLM). In addition, our geochemical model results suggest that Meso- to Neoarchean basaltic andesite – andesite rocks in Singhbhum craton were not generated by 1) assimilation of crustal material with primitive tholeiitic magma without fractional crystallization, 2) direct partial melting of different enriched mantle reservoirs (enriched-DMM, EM I, EM II) and mantle wedge peridotite in a subduction environment and 3) partial melting of solely metasomatised SCLM.