

ABSTRACT

Deformed and metamorphosed rocks of the tonalite-trondhjemite-granodiorite (TTG) series constitute primitive continental crust, which volumetrically dominates Archean cratons and preserves a primary archive for understanding planetary crust-mantle differentiation and the geodynamic evolution of the early Earth. The Bastar craton of central India is an integral yet relatively understudied component of the early Archean continental crust of the Indian Shield. The extensive preservation of the TTG suite of rocks and the near-absence of Paleoproterozoic greenstone belts in the Bastar craton serve as a natural laboratory for studying deep-level craton formation, its stabilization, and also subsequent tectono-thermal reworking. Based on distinct petrogenetic evolutionary histories of TTG domains, the present-day level of exhumation and associated supracrustal rocks, the extent of deformation and grade of metamorphism, and variations in their post-Paleoproterozoic geological evolution, three crustal terranes of Sukma, Kapsi, and Kondagaon have been delineated in the Bastar craton. The approach here is to utilize trace element geochemistry, coupled with isotope analyses and chronology, to resolve petrogenetic and age differences among the terranes and constrain Eo-Paleoproterozoic to Mesoproterozoic crustal evolution. The Sukma orthogneisses are ferroan, calcic, and metaluminous, which can be classified as medium- to high-pressure TTGs. Their strongly fractionated REE patterns indicate generation by high-pressure melting of mafic rocks and tonalites in equilibrium with a rutile-bearing eclogite residue, followed by plagioclase fractional crystallization. The Kapsi TTGs are ferroan, calcic, and metaluminous to weakly peraluminous, which can be classified as medium-pressure TTGs. Their moderately fractionated REE patterns indicate generation by medium-pressure melting of mafic rocks at garnet-amphibolite depths, followed by plagioclase + amphibole fractional crystallization. The Kondagaon gneisses are ferroan, alkali-calcic to calc-alkalic, and metaluminous to weakly peraluminous, which can be classified as low-pressure TTGs and enriched (potassic) granitoids. Their moderately fractionated REE patterns indicate generation by low-pressure melting of tonalites at amphibolite to rutile-free eclogite depths, followed by plagioclase fractional crystallization. In each comagmatic suite, more unradiogenic whole-rock $\epsilon_{\text{Nd}}(t)$ is consistently associated with longer crustal residence times (hybrid Δt). Subchondritic $\epsilon_{\text{Nd}}(t)$ values (median ~ -4.0) and moderate residence times (average $\Delta t \sim 0.4$ Ga) of the Sukma orthogneiss and Kapsi TTGs indicate formation of their magmas by partial melting of isotopically heterogeneous evolved sources under different melting regimes. In contrast, near-chondritic $\epsilon_{\text{Nd}}(t)$ values (median $+1.0$) and < 0.3 Ga residence times of the Kondagaon gneisses are compatible with a predominantly juvenile source character with a minor unradiogenic component, implying that recharge during differentiation was likely the principal petrogenetic process. The Sukma and Kapsi terranes comprise extensive Paleoproterozoic TTG crust, with preserved Eoarchean components, in which the 3.8–3.6 Ga TTGs, with near- to subchondritic zircon $\epsilon_{\text{Hf}}(t)$ values (-14.4 to -1.2) and Eoarchean to Hadean mantle extraction ages, were generated by partial melting of a Hadean mafic-felsic crust during chondritic mantle upwelling. Combined geochemical and isotopic proxies demonstrate that Eo-Paleoproterozoic TTG magmas formed at variable depths through partial melting of predominantly evolved sources mixed with juvenile input, most likely via the intracrustal reworking of an older, differentiated Hadean crust within a stagnant- or squishy-lid tectonic regime. The post-Paleoproterozoic evolution of the Bastar craton is best recorded in the Sukma terrane, where the Mesoproterozoic deposition of the Sukma Group (maximum depositional age < 3.1 Ga) represents one of the earliest occurrences of terrestrial to shallow marine siliciclastic sedimentation in passive-margin settings. The 2.99–2.94 Ga garnet growth in the Sukma Group supracrustals is linked to metamorphism at upper-amphibolite- to transitional-granulite-facies conditions due to convergent tectonics and crustal stacking during the Mesoproterozoic Sukma orogeny, which is most likely related to the

underthrusting of the Sukma terrane beneath the northern terranes. The final amalgamation of the Sukma, Kapsi, and Kondagaon terranes is marked by the widespread emplacement of the ~2.99 Ga Kanker Granite during an advanced post-collisional stage of the Sukma orogeny. These potassic granitoids were generated by partial melting of mildly unradiogenic crust, most likely the Kondagaon terrane basement, triggered by juvenile magmatic input during a crustal-scale tectono-magmatic event. During the late Neoproterozoic–early Paleoproterozoic, following terrane amalgamation, the Sukma orthogneiss and Sukma Group rocks, along with the Kondagaon gneisses, record metamorphism marked by garnet growth and isotopic resetting at upper-amphibolite- and granulite-facies conditions, respectively, and all three constituent terranes experienced varying degrees of deformation. Overall, the Bastar craton records a protracted (~1.3 Gyr) history of early Archean continental crust formation through near-coeval, yet distinct, TTG petrogenetic processes, followed by continental emergence and stable shelf deposition, Mesoproterozoic terrane amalgamation, and later tectono-thermal reworking. The results of this study therefore provide important constraints on the processes responsible for early continental growth and stabilization of Archean cratonic lithosphere.

Keywords: Bastar craton; Eo-Paleoproterozoic TTG; whole-rock Nd isotopes; zircon U-Pb-Hf isotopes; differentiated Hadean sources; intracrustal reworking; Sukma orogeny; Mesoproterozoic terrane amalgamation; garnet Sm-Nd and Lu-Hf dating; PbSL dating