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Age and *P*–*T* evolution of the Neoproterozoic Turkel Anorthosite Complex, Eastern Ghats Province, India

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ABSTRACT

Massif-type anorthosite complexes constitute a distinct component of the Proterozoic Eastern Ghats Province in India. They intruded the poly-deformed and poly-metamorphic granulite facies terrane near its western and northern tectonic contacts with the Archaean Bastar and Singhbhum cratons, respectively. Following their emplacement, the complexes were variously affected by high-grade metamorphism and deformation. The Turkel Anorthosite Complex comprises an anorthosite–leuconorite diapir encircled by voluminous crust-derived quartz–monzonite intrusions hosted within an expansive batholithic complex of megacrystic K-feldspar granite and remnants of an older gneissic unit. This contribution evaluates the pressure-temperature history of the anorthosite complex based on textural relations, paragenetic characteristics, and mineral chemistry, and provides for the first time, constraints on the timing of emplacement and subsequent metamorphism of the rocks through in situ U–Pb dating of zircon from several members of the suite.

Emplacement of the Turkel Anorthosite Complex occurred after the fabric-defining late Mesoproterozoic deformation (D_1–D_3) and high-grade metamorphism of the country rocks and was shortly preceded by the surrounding expansive intrusion of the megacrystic K-feldspar granite. The leuconorite-anorthosite suite crystallized at 980 ± 8 Ma while the other components including the monzonite, quartz–monzonite, and ferrodiorite were emplaced later between 956 ± 6 and 945 ± 5 Ma. The post-intrusion evolution of the complex is characterized by partial re-equilibration of the igneous parageneses and textures during an initial episode of cooling and decompression from the magmatic crystallization stage (1100–950 °C, 12–7 kbar) towards the ambient thermobaric regime, and following prolonged slow cooling by an episode of renewed compressional deformation (late-D_3; ca. 750 °C, 6.5–7.0 kbar) that caused the thorough high-grade recrystallization of the rocks and produced the monophase planar fabric of the complex. U–Pb spot ages from metamorphic domains of zircon grains constrain the age of this metamorphism to 901–879 Ma. The complex was moderately affected by the late Neoproterozoic to early Palaeozoic Pan-African tectonothermal event which led to internal tectonic segmentation and westward thrusting of the Khariar and Rampur domains of the northern Eastern Ghats Province onto the Bastar craton.

1. Introduction

The Eastern Ghats Belt (EGB) fringing the southeastern margin of the Archaean cratons in Peninsular India represents a polycyclic granulite facies terrane of Neoarchaean to Proterozoic age (e.g., Ramakrishnan et al., 1998; Dobmeier and Raith, 2003; Simmat and Raith, 2008; Dasgupta et al., 2013) (Fig. 1), widely considered to have formed during orogenic collisions between Eastern India and East Antarctica (Dobmeier and Raith, 2003 and references therein). The Belt comprises dominantly metasedimentary successions (khondalite, quartzite and calc-silicate granulite), along with intrusions of mafic granulites, enderbites, charnockites,

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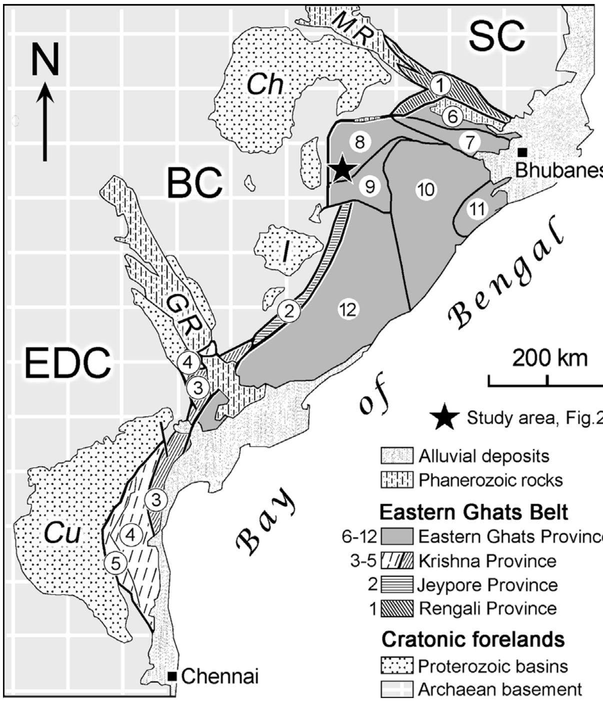

Fig. 1. Geological framework of the Eastern Ghats Belt with subdivisions into crustal provinces and domains following Dobmeier and Raith (2003). Domains of the Krishna Province: 3 Ongole, 4 Vinjamuru, 5 Udayagiri. Domains of the Eastern Ghats Province: 6 Angul, 7 Tikapara, 8 Khariar, 9 Rampur, 10 Phulbani, 11 Chilka Lake, 12 Visakhapatnam. Archaean forelands: EDC, Eastern Dharwar Craton; BC, Bastar Craton; SC, Singhbhum Craton. Proterozoic basins: Ch, Chhattisgarh; I, Indravati; Cu, Cuddapah. Phanerozoic rifts: GR, Godavari Rift; MR, Mahanadi Rift. The geology of the northern part of the Eastern Ghats Belt with locations of the known occurrences of massive-type anorthosites is shown in Fig. 2.

megacrystic K-feldspar granitoids, and massif-type anorthosites, all metamorphosed at granulite facies conditions with some having locally reached ultra-high temperatures (Dasgupta and Sengupta, 2003 and references therein).

Massif-type anorthosite complexes in the EGB are known from seven occurrences, all of which are located in the peripheral parts of the Proterozoic Eastern Ghats Province (Fig. 2): Chilka Lake (Sarkar et al., 1981; Bhattacharya et al., 1994; Mukherjee et al., 1999; Dobmeier and Simmat, 2002), Bolangir (Raith et al., 1997; Bhattacharya et al., 1998; Dobmeier, 2006; Nasipuri and Bhadra, 2013), Turkel (Maji et al., 1997; Maji and Sarkar, 2004), Jugsaipatna (Nanda and Panda, 1999; Mahapatro et al., 2010), Koraput (Bose, 1979), Angul (Bhattacharyya and De, 1964; Das et al., 2001) and Udayagiri (Mahapatro et al., 2013). The massifs are of different size (ca. 400 km^2 to <5 km^2) and occur as diapiric plutons emplaced within poly-deformed and poly-metamorphosed high-grade metamorphic rocks derived from sedimentary and magmatic precursors. The anorthosites and related rocks are themselves metamorphosed under high-grade conditions.

Earlier studies on the anorthosites in the Eastern Ghats Province have mainly focused on the structural, petrographic, and mineralogical characterization of the comagmatic and cogenetic members of the suite, their petrogenetic evolution and relative timing of emplacement in relation to regional deformation events (*op. cit.*). Not much, however, is known about the magmatic emplacement conditions, metamorphic *P–T* evolution and the timing of emplacement and subsequent metamorphism for several of the plutons (e.g., Koraput, Turkel, Angul, and Udayagiri). Furthermore, with exception of the Bolangir anorthosite complex (Mukherjee et al., 1986; Mukherjee, 1989; Prasad et al., 2005; Dobmeier, 2006; Nasipuri et al., 2011; Nasipuri and Bhadra, 2013), the deformation and metamorphic history of the country rocks hosting the intrusive bodies are insufficiently constrained. These deficiencies impede correlations of anorthosite magmatism with geodynamic events in relation to models of supercontinent assembly and breakup. For the Bolangir anorthosite complex, a plausible collisional tectonic setting resembling that proposed by Duchesne et al. (1999) for the Rogaland anorthosites has been suggested by Dobmeier (2006). It envisages the formation of parental magma in the upper portion of a lithospheric mantle wedge, which following differentiation processes in a deep-seated magma chamber, ascends as a buoyant crystal mush channelled along a lithosphere-scale shear zone separating the colliding terranes. In a recent study, Dharma Rao et al. (2014a) related the emplacement of the Jugsaipatna anorthosite complex and accompanying felsic igneous rocks to a post-collisional slab-breakoff setting in which the generation of the anorthosite and accompanying felsic crustal melts is attributed to upwelling of the asthenospheric mantle through the opening slab-window. In this context, the proximity of the anorthosite complexes to Mesoproterozoic riftogenic alkaline bodies girdling the terrane boundary between the Eastern Ghats Province and the cratonic forelands (Upadhyay, 2008) may point to a reactivation of this palaeozone of crustal extension during anorthosite magmatism (cf. Upadhyay et al., 2006b; Burke et al., 2003).

Recently published age data from the anorthosite complexes of Bolangir (933 ± 32 Ma; Krause et al., 2001), Chilka Lake (983 ± 2.5 Ma to 855 ± 31 Ma; Chatterjee et al., 2008; Chakrabarty et al., 2011), and Jugsaipatna (984 ± 10 Ma to 918 ± 33 Ma; Dharma Rao et al., 2014a) suggest that anorthosite magmatism in the Eastern Ghats Province occurred in a narrow time interval during the early Neoproterozoic. However, the lack of geochronological data and metamorphic *P–T* constraints from other anorthosite bodies such as those at Koraput, Turkel, Angul and Udayagiri are hampering efforts to explore the possibility of linking the magmatism to common geodynamic events in the Eastern Ghats Province. Very recently, Dharma Rao et al. (2014b) have reported an early Palaeoproterozoic emplacement age for the Turkel Anorthosite Complex based on LA-ICP-MS $^{207}Pb/^{206}Pb$ zircon ages of 2419 ± 32 Ma and 2505 ± 31 Ma obtained from two quartz diorite samples purportedly belonging to the complex. These results are in sharp contrast to the early Neoproterozoic emplacement age of the Turkel complex established in this study and the ages reported from the other anorthosite bodies in the Province (e.g., Bolangir: Krause et al., 2001; Chilka Lake: Chatterjee et al., 2008; Chakrabarty et al., 2011; Jugsaipatna: Dharma Rao et al., 2014a). Considering that Dharma Rao et al. (2014b) have not shown their sampling sites on the map, and that the bulk compositions of the quartz diorite samples reported by them do not match the major and trace element compositions of monzonitic rocks of the Turkel complex and the adjoining country gneisses (Maji et al., 1997; Maji and Sarkar, 2004), it appears likely that the authors have dated rocks of the cratonic gneissic basement rather than the anorthosite complex.

The present contribution documents detailed textural and mineralogical characteristics of the various members of the Turkel Anorthosite Complex from the magmatic crystallization stage to metamorphic overprinting. We use classical thermobarometry to reconstruct the *P–T* evolution of the complex. In addition, texturally controlled Laser Ablation-Inductively Coupled Plasma Mass Spectrometry (LA-ICPMS) U–Pb dating of zircon grains from a variety of lithologies is used to constrain the geochronological history of the complex. The results add to the growing body of evidence supporting a synchronous early Neoproterozoic emplacement of anorthosites in different parts of the Eastern Ghats Province postdating the major late Mesoproterozoic UHT-event in the high-grade terrane. The new findings thus argue against the coeval nature and genetic link of mantle-derived anorthosite magmatism and ultra-high temperature metamorphism in the