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Sub-surface structure of a craton–mobile belt interface: Evidence from geological and gravity studies across the Rengali Province–Eastern Ghats Belt boundary, eastern India

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ABSTRACT

Bouguer gravity anomalies characteristically vary from negative to positive values across craton–mobile belt boundaries in Precambrian shields. This transition is also documented in eastern India, where Proterozoic granulites of the Eastern Ghats Belt (EGB) form part of a mobile belt to the south of the late Archaean, amphibolite facies Rengali Province. The northern margin of the EGB with the Rengali Province is a sub-vertical Cambro-Ordovician strike-slip shear zone, on which the Talchir Gondwana sedimentary basin was deposited during late Palaeozoic extension. This extension also led to partial uplift of the lower crust below the terrane boundary. Closely coordinated geological and gravity studies were conducted through the basin, across the craton–mobile belt contact. Modeling of the Bouguer anomaly using 2-D and 3-D compact inversion schemes, along with 2-D forward modeling, indicates significant differences in the density configurations of the uppermost crusts of the EGB and the Rengali Province, as indicated by the surface geology. However, both inverse and forward models consistently predict that below ~7 km, density configurations across the contact are similar and have low upper crustal values, suggesting that typically cratonic crust lies below both terranes. Since it is highly unlikely that lower crust can remain unaffected during granulite facies metamorphism, it is inferred that the present sub-surface EGB crust could not have experienced the high grade event. Rather, the EGB rocks were probably overthrust onto the craton significantly after granulite metamorphism. The top of the thrust sheet may have been eroded prior to or post-dating the overthrusting, leaving the present EGB granulites stranded on low density cratonic crust below.

1. Introduction

Contacts between cratons and bounding high grade, granulite facies mobile belts in many Precambrian shield areas have been interpreted as ancient suture zones (e.g. Adetunji et al., 2014; Bierlein and Betts, 2004; Black et al., 1979; Mosley, 1993; Pharaoh, 1999; Ramesh et al., 2010; Roering et al., 1992; Stockwell, 1970). Geophysical studies across these suspected ancient sutures have revealed that they are commonly associated with a characteristic Bouguer gravity anomaly signature, with high positive values over the mobile belt dropping steeply to negative values across the contact into the adjoining craton (e.g. Black et al., 1979; Fountain and Salisbury, 1981; Gibb and Thomas, 1976; Gibb et al., 1983; Mathur, 1974; Mishra and Ravi Kumar, 2014; Nyblade and Pollack, 1992; Subrahmanyam and Verma, 1986; Tesha et al., 1997; Thomas and Tanner, 1975; Veeraswamy and Raval, 2004; Vijaya Rao et al., 2006). The negative part of this paired anomaly is commonly attributed to depression of the Moho in the craton adjacent to the suture, either because of crustal thickening at the collisional front (e.g. Gibb et al., 1983), or due to flexure of the downgoing cratonic lithosphere due to subsurface loading as a consequence of the subduction process (e.g. Pilkington, 1990). On the other hand, the positive part of the Bouguer anomaly is assumed to result either from the intrinsically denser and thicker granulitic crust of the mobile belt (Gibb and Thomas, 1976; Gibb et al., 1983), or alternatively, from uplift of a denser lower crust of the mobile belt to shallower levels following collision and erosion (Kearey, 1976; Kearey et al., 1975, 2009).

Discriminating between the above models requires knowledge of the subsurface lithological configuration of the craton and the mobile belt across the suspected suture. However, wavelengths of subsurface density anomalies become broader and lower in amplitude with depth, making the correlation of their gravity anomalies with lithology increasingly ambiguous. In this study, therefore, we have conducted integrated geological and gravity studies across a craton–mobile belt contact in the eastern Indian shield, where the lower and middle crust across the earlier contact has been uplifted to shallower levels by

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post-juxtaposition extensional tectonics. We model the gravity data by extrapolating the densities of exposed surface lithologies deeper into the subsurface, which enables us to obtain constraints on the subsurface density distribution immediately below the exposed crust in the two domains across the contact. For a more robust control on the subsurface density distribution, density constrained 2-D (Last and Kubik, 1983; Mandal, 2013) and 3-D (Mandal et al., 2013, in press) compact inversion approaches have been employed to model the observed anomaly prior to applying the more common 2-D forward (Burger et al., 2006) modeling approach. The present inverse approach can model geological bodies with greater precision and fewer inputs by minimizing the area/volume of the causative bodies (Last and Kubik, 1983; Guillen and Menichetti, 1984). This has enabled us to more effectively delineate the maximum possible dimension of lithologies exposed at the surface, and also to constrain the maximum subsurface extension of specific litho-units.

Our results suggest that the high density granulitic rocks of the mobile belt exposed at the surface can be extrapolated to a depth of only a few kilometers below the surface, and predict that less dense upper crustal material underlies the surface granulites. This appears to invalidate earlier proposed models of deep crustal structure across Precambrian suture zones, and requires alternative models that can explain the change in Bouguer gravity values across the studied craton–mobile belt boundary.

2. Broad geological set-up

In peninsular India, the Proterozoic Eastern Ghats Belt (EGB) is a granulite facies mobile belt that lies to the east of the Archean cratons of Dharwar and Bastar, and south of the Singhbhum craton (Fig. 1). The NE–SW trending western boundary of the Eastern Ghats Belt with the Dharwar and Bastar cratons is considered to be a suture zone that has been modified by post-amalgamation thrusting (Gupta et al., 2000; Bhadra et al., 2004; Biswal et al., 2007; Dharma Rao et al., 2011; Gupta, 2012). On the other hand, along the northern boundary of the EGB, the earlier collisional interface with the Singhbhum craton has been modified by a near orthogonal (WNW-ESE trending) Cambro-Ordovician dextral strike-slip shear system. A fragment of the Bastar craton, referred to as the Rengali Province (Crowe et al., 2003), is preserved within a dilational strike-slip step-over zone to the northwest of the contact with the EGB (Nash et al., 1996; Lisker and Fachmann, 2001; Misra and Gupta, 2014). The Singhbum craton sensu stricto is now located to the north and east of the Rengali Province, along the northeastern boundary of the EGB (Ghosh et al., 2010; Mahapatro et al., 2012).

The Rengali Province is composed of granulites (charnockites) and quartzofeldspathic gneisses overlain by supracrustals (quartzites and mica schists) that have subsequently undergone amphibolite facies metamorphism (Mahalik, 1994; Crowe et al., 2003; Misra and Gupta, 2014). The amphibolite facies gneisses of the Rengali Province are dated to be 2.9–2.8 Ga (Misra et al., 2000), and intrude the granulites which are therefore also inferred to be Archaean (Dobmeier and Raith, 2003; Misra and Gupta, 2014). The northern part of the Eastern Ghats Belt (EGB), on the other hand, is represented by a complex assemblage of polyphase deformed migmatitic gneisses that host a variety of granulite facies metasedimentary (dominantly garnet sillimanite gneisses or khondalites) and meta-igneous (charnockites, enderbites and augen gneisses) lithologies (Halden et al., 1982; Sarkar et al., 2007). Unlike the Rengali Province granulites, the EGB north of the Godavari graben (referred to as the Eastern Ghats Province) is characterized by a ubiquitous granulite facies imprint at ~ 1.0 Ga (Mezger and Cosca, 1999; Dobmeier and Raith, 2003; Gupta, 2012; Korhonen et al., 2013a, b, 2014). The WNW-ESE trending Kerajang Shear Zone (Fig. 1) marks the boundary between the Rengali Province in the north and the EGB to the south (Misra and Gupta, 2014). The EGB is cross-cut by WNW-ESE trending shear zones (Mahalik, 1994; Sarkar et al., 2007), while shear zones bounding and within the Rengali Province have similar trends (Nash et al., 1996; Crowe et al., 2003; Misra and Gupta, 2014).

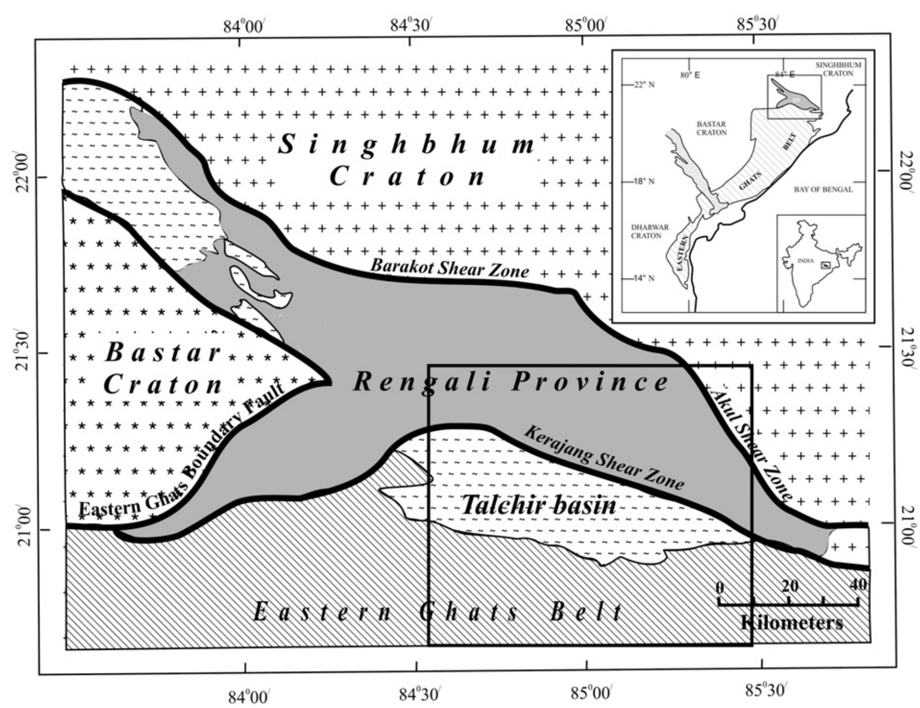

Fig. 1. Geology of the study area, showing the relative positions of the Rengali Province, the Eastern Ghats Belt, the Bastar Craton and the Singhbhum Craton (map simplified from Crowe et al., 2003). Note that the Rengali Province is bound by the Barakot and Akul Shear zones in the north, and the Eastern Ghats Boundary Fault in the south-west. The Kerajang Shear Zone separates the the Rengali Province from the Eastern Ghats Belt and the Talchir sedimentary basin to the south. Inset maps show the position of the study area in India, and the relative position of the area with respect to the peninsular Indian shield.