CHAPTER 2

GEOLOGICAL BACKGROUND

The EGB is a NE-SW trending Meso-Neoproterozoic orogenic belt located at the eastern part of the peninsular India (Fig. 2.1). This belt is bordered by cratonic landmasses both at the northern and the western parts. These cratonic landmasses include the Singbhum craton at the northern part and the Bastar and Dharwar cratons at the western part. The belt is subdivided into four longitudinal lithological zones viz. the Western and Eastern Khondalite Zones, Central Migmatite Zone and the Western Charnockite Zone (Fig. 2.2) by Ramakrishnan et al. (1998). Ramakrishnan et al. (1998) further identified a Transition Zone separating the EGB from the adjacent Bastar craton (Fig. 2.2). This classification is based solely on lithological disposition of the rocks of the EGB without considering the metamorphic and geochronological history of the belt. Later studies identified several inconsistencies in this longitudinal classification including the status of the Transition Zone (reviewed in Dasgupta and Sengupta, 2003). Based on Sm-Nd, Rb-Sr and ^{207}Pb-^{206}Pb data, Rickers et al. (2001) proposed that EGB is a collage of four discrete isotopic domains with contrasting protolith ages and styles of metamorphism. These isotopic domains are named as domains 1 (1A and 1B), 2, 3 and 4 (Fig. 2.3a). Dobmeier and Raith (2003) used the isotopic data of Rickers et al. (2001) and clubbed with the existing metamorphic, structural and geochronological data of the entire EGB to propose the province- and domain-based classification of the belt. Accordingly, the EGB is an amalgamation of four major crustal provinces, each having discrete geological histories (Fig. 2.3b). These crustal provinces are named as the Krishna Province, the Jeypore Province, the Eastern Ghats Province and the Rengali Province, positioned south to north respectively. Among these, the Eastern Ghats Province (EGP) and the Krishna Province are composed of several crustal domains. The EGP is constituted of the Visakhapatnam, Phulbani, Rampur, Khariar, Tikarpara, Angul and Chilka lake domains while the Ongole, Udayagiri and Vinjamuru domains are the constituents of the Krishna Province (Fig. 2.3b). All the domains of the EGP are constituted of rocks belonging to granulite facies. On the other hand, the Ongole domain is the only granulite facies representative in the Krishna Province. It is worth mentioning here that the configuration of the EGP broadly coincides with the isotopic domains 2, 3 and parts of the domain 1A and 4 of Rickers et al. (2001). The Ongole domain corresponds to the major part of the domain 1A of Rickers et al. (2001). The Rengali and Jeypore provinces represent the isotopic domains 4 (major part) and 1B of Rickers et al. (2001), respectively. The tectonometamorphic histories of the above mentioned crustal provinces and the domains are briefly discussed in the following sections and summarized in Table 2.1.

2.1 Krishna Province

The Krishna Province consists of three domains, namely the Udayagiri, Vinjamuru and the Ongole domains (Dobmeier and Raith, 2003). Of these, the Ongole domain only recorded signatures of UHT metamorphism while the other two domains suffered much lower grade metamorphism. The geological details of these domains are described below.

2.1.1 Ongole domain

The Ongole domain is known for having mafic-ultramafic-anorthositic complexes, suspected ophiolitic complexes, suite of calc-alkaline rocks along with lesser amounts of metapelitic migmatite and late alkaline rocks (Dasgupta et al., 1997, 1999a, 2013; Sengupta et al., 1999; Rickers et al., 2001; Dasgupta and Sengupta, 2003; Bhui et al., 2007; Vijaya Kumar et al., 2010, 2011; Dharma Rao et al., 2011, 2012; Sarkar et al., 2015). The rocks of the Ongole domain are affected by a prominent phase of UHT metamorphism during ca. 1.60 Ga (Sarkar et al., 2014) through an anticlockwise *P-T* trajectory. The thermobaric condition of this UHT metamorphism is estimated to be >950°C and 6-7 kbar (Sarkar and Schenk, 2014 and references therein). Such UHT metamorphism is interpreted to be associated with intense arc-type magmatic activity (Upadhyay et al., 2009; Bose et al., 2011; Henderson et al., 2014; Sarkar et al. 2014). Dharma Rao et al. (2011) determined the emplacement age of the mafic-ultramafic complex as ca. 1.69 Ga which was possibly associated with extensive charnockite magmatism. The age of this charnockite magmatism is determined to be ca. 1.72 Ga (Kovach et al., 2001) and 1.75 Ga (Sarkar et al., 2015). The mafic-ultramafic and the charnockite magmatic activity are related to subduction and arc formation in Ongole domain during accretion of Columbia supercontinent (Reviewed in S. Dasgupta et al., 2017). It is pertinent to mention that an earlier phase of UHT metamorphism is also reported from the Ongole domain. The age of this UHT metamorphism is estimated to be ca. 1.76 Ga from an enclave of metapelitic granulite in mafic rock (Bose et al., 2011). S. Dasgupta et al. (2017) suggested that this earlier phase of UHT metamorphism could be related to the emplacement of the mafic-ultramafic complexes in an overall subduction-accretion type tectonic setting which was responsible for magmatism through opening of an ocean basin (represented by the Kandra Ophiolite Complex). The ca. 1.60 Ga UHT metamorphism in the Ongole domain was associated with emplacement of mafic dykes which was metamorphosed during later time (Bhui et al., 2007). Dasgupta et al. (1997) reported evidences of contact metamorphism in the Ongole domain which is characterized by development of spinel-orthopyroxene-cordierite-garnet- bearing mineral assemblages (>900°C at 6-7 kbar) at the contact of mafic-ultramafic igneous complex of the Chimakurthy area.

Metapelitic rocks near Chimakurthy also developed metasomatic zones with the stabilization of gedrite-bearing assemblage at its contact with enderbitic rocks (Dasgupta et al., 1999b). Stabilization of gedrite is reported to be confined along the ductile shear zones which played a crucial role for movement of Na-bearing fluid.

The ca. 1.60 Ga UHT metamorphism of Ongole domain was followed by a distinct metamorphic event at ca. 1.54 Ga (Sarkar and Schenk, 2014; Sarkar et al., 2014). These workers suggested that this latter metamorphic event took place at a higher pressure (9.5 kbar) and lower temperature (780°C) condition compared to the UHT metamorphism and was followed by near-isothermal decompression of deep crust (ca. 9.5 kbar) to ca. 4 kbar. This near-isothermal decompression is ascribed to the exhumation of the high-grade rocks. This latter event occurred due to collision of the magmatic arc with the Dharwar and the East Antarctic blocks and reflects the culmination of the accretionary process within Columbia and cratonization of the Ongole domain during this time. The ca. 1.54 Ga metamorphic event was succeeded by opening of an ocean basin and emplacement of alkaline rocks at approximately 1.45 Ga (Upadhyay, 2008) owing to a switchover from a compressional setting to an extensional one. Excepting the minor thermal overprinting of ca. 1.35 Ga and 1.10 Ga (Mezger and Cosca, 1999; Kovach et al., 2001; Simmat and Raith, 2008; Upadhyay et al., 2009), no other younger metamorphic events affected the Ongole domain.

2.1.2 Vinjamuru and Udayagiri domains

Located at the west of the Ongole domain, the Vinjamuru domain is characterized by garnet-bearing mafic schist and staurolite-kyanite bearing pelitic schists which are associated with thin slivers of granite gneiss, minor ferruginous quartzite and calc-silicate rocks (Ramam and Murty, 1997; Dobmeier and Raith, 2003; Saha et al., 2015). According to Chatterjee et al. (2016), the Vinjamuru domain witnessed two metamorphic pulses spanning ca. 1.63-1.59 Ga and ca. 1.55 Ga respectively. Estimated *P-T* conditions of these two metamorphic pulses are indicative of amphibolite facies metamorphism (Chatterjee et al., 2016). It is important to mention that the age of the metamorphic pulses broadly coincides with emplacement age of the Vinukonda granite of ca. 1.59 Ma (Dobmeier et al., 2006). Synkinematically grown phengitic white mica in the same granite suggests a low-grade metamorphic overprint at ca. 501–474 Ma (Dobmeier et al., 2006). According to Saha et al. (2015), the steep contact zone between the Ongole and the Vinjamuru domains is marked by a stack of east-vergent thrusts with a component of sinistral strike-slip movement.

Located to the further west of the Vinjamuru domain, the Udayagiri domain is consisted of phyllites and quartzites, intercalated with minor metatuff and mafic metavolcanics. Very few published work is available from this domain. According to Babu (1998), the grade of metamorphism of this domain is lower (greenschist facies) than the Vinjamuru domain. The greenschist facies rocks of the Udayagiri domain is overlain by higher grade rocks of Vinjamuru and Ongole domains in a pile of west-vergent thrust stack which was emplaced over the westerly placed Cuddapah basin.

2.2 Eastern Ghats Province

2.2.1 Isotopic domain 2 (Visakhapatnam domain)

This domain is dominantly composed of metapelitic migmatite and felsic gneiss along with the charnockitic gneiss. Proportions of mafic granulite and calc-silicate granulite are low in this domain although these rocks provided significant petrological information (Dasgupta et al., 1991; Dasgupta 1993; Bhowmik et al., 1995; Sengupta et al., 1997; Sengupta and Raith, 2002; Dasgupta and Pal, 2005).

Rickers et al. (2001) showed that the protolith ages of the rocks belong to this domain vary within the range of ca. 2.8-2.2 Ga which is interpreted to be the age of the source material derived from the adjoining Indian cratons. Based on Hf isotopic data, Upadhyay et al. (2009) proposed a juvenile provenance spanning 2.7-1.9 Ga which broadly coincides with the data of Rickers et al. (2001). In view of the detrital zircon population, Upadhyay et al. (2009) additionally suggested that sedimentation took place within this domain during 1.4-1.2 Ga in an ocean basin formed by rifting. In a recent study, Nanda et al. (2018) suggested that the basement formation occurred during ca. 1.5 Ga. Sediments deposited on the basement later experienced UHT metamorphism (~950-1000°C) at lower crustal condition (~8-9 kbar) along an anticlockwise P-T path and witnessed near-isobaric cooling down to 800°C (Sengupta et al., 1990; Dasgupta et al., 1995; Das et al. 2011; Korhonen et al., 2013a, b, 2014). The peak UHT metamorphic history is shown by the sapphirine+Al-orthopyroxene+quartz assemblages in aluminous granulites exposed in different places of the province (Sengupta et al., 1990; Pal and Bose, 1997; Bose et al., 2000; Sarkar et al., 2003b; Das et al., 2011). Mafic granulite and charnockite gneiss also witnessed this cooling as evident from textures (Dasgupta et al., 1991; Bose et al., 2003). Different opinions exist regarding the age of the protolith of the mafic granulite exposed in this domain. Shaw et al. (1997) obtained an age of ca. 1450 Ma (Sm-Nd age) from mafic granulite exposed at the Rayagada area and interpreted this as the age of the protolith of the mafic granulite. Kelsey et al. (2017), on the other hand, constrained the U-Pb zircon age of the mafic granulite protolith as ca. 1580 Ma. S. Dasgupta et al. (2017) correlated the rifting and subsequent UHT metamorphism as a part of the accretionary process of the supercontinent Rodinia. Based on the zircon and monazite ages, Bose et al. (2011) and Das et al. (2011) suggested that the UHT metamorphism occurred in this domain at ca. 1.03-0.99 Ga which was followed by charnockite and granite magmatism at ca. 0.98 Ga. This domain additionally witnessed a separate tectonothermal event during ca. 0.95-0.90 Ga (Bose et al., 2011; Das et al., 2011) when cordierite-bearing mineral assemblage produced an intergrowth of orthopyroxene+sillimanite+quartz at granulite facies condition (~800°C, 7-8 kbar). This latter event is correlated with the final assembly of cratonic India and east Antarctica (Das et al., 2011; Dasgupta et al., 2013; S. Dasgupta et al., 2017) that continued up to ca. 0.90 Ga (Harley, 2003). Korhonen et al. (2013b) disagreed on this issue and suggested that the EGP evolved through a single-cycle metamorphism spanning ca. 1.13-0.93 Ma. This prolonged evolutionary history of ~200 m.y. by the latter has been refuted in a recent study (Kelsey et al., 2017).

2.2.2 Isotopic domain 3 (Chilka Lake and Phulbani domain)

This domain lies to the north of the isotopic domain 2 and surrounded by two major crustal-scale shear zones namely the Mahanadi Shear Zone at the north and Nagavalli-Vamsadhara Shear zone at the west. Despite showing younger protolith ages (ca. 2.20-1.80 Ga by Rickers et al., 2001), Dobmeier and Raith (2003) preferred to combine it with the domain 2. Although metapelitic migmatites, quartzofeldspathic gneisses including charnockite, minor calc-silicate and mafic granulites are present in this domain similar to the domain 2, domain 3 additionally contains several bodies of massif-type anorthosite. These anorthosite bodies have been variably dated as ca. 0.79 Ga (Krause et al., 2001), ca. 0.85 Ga (Chakrabarti et al., 2011) and ca. 0.98 Ga (Chatterjee et al., 2008). According to Sen et al. (1995), the Chilka lake granulites experienced a multistage tectonometamorphic evolution and reached a maximum *P-T* of about 12 kbar and

1000°C which was refuted by Dasgupta and Sengupta (2003). Raith et al. (2007) and Sengupta et al. (2008) documented evidences of UHT metamorphism (>1000°C, 7.5 kbar) in pelitic and calc-silicate rocks which have contacts with the anorthosite massifs. Simmat and Raith (2008) obtained age of ca. 1.0 Ga and designated it as a major tectonothermal event in this domain which was followed by younger events as evidenced from monazite spot dates spanning ca. 0.8-0.5 Ma. Bose et al. (2016b) studied the granulites of the Chilka lake area and demonstrated a multistage evolutionary history on the basis of combined petrological, geochronological and fluid inclusion data. Accordingly, the domain 3 experienced peak UHT metamorphism (900-950°C, 8.5-9 kbar) at approximately ca. 0.98 Ga with a possible clockwise *P*-*T* path and subsequently overprinted by three tectonometamorphic events at approximately ca. 0.78 Ga (800°C, 7 kbar), ca. 0.75 Ga (700°C, 6 kbar) and at ca. 0.52 Ga (800°C, 6 kbar). The ca. 0.78 Ga and ca. 0.52 Ga events has been correlated with the break-up of Rodinia and the thermal overprinting during Pan-African metamorphism respectively. Based on the style of metamorphism, timing of metamorphism and feldspar ^{207}Pb-^{206}Pb signatures (Flowerdew et al., 2013) of the Chilka lake domain, Bose et al. (2016b) further argued that it was attached to the Prydz Bay, East Antarctica and became separated at 0.78 Ga during break-up of Rodinia which was followed by 0.52 Ga event when it became united with the greater Indian landmass as a part of east Gondwana.

The Phulbani domain also belongs to the isotopic domain 3 based on the data of Rickers et al. (2001). Very few petrological and structural data are available from this domain (described in Dobmeier and Raith, 2003). This domain is interpreted to be separated from the westerly situated Rampur domain and the southerly placed Visakhapatnam domain by the combined Koraput-Sonepur and Nagavalli-Vamsadhara shear zones (Fig. 2.3b of this study, Fig. 2b of

Dobmeier and Raith, 2003). Its northern boundary with the Tikarpara domain is marked by the Ranipathar shear zone while the eastern boundary with the Chilka Lake domain is marked by no prominent lineament (Fig. 2.3b). Apart from some published ages on the emplacement of charnockites (ca. 0.98 Ga of Paul et al., 1990; Crowe, 2003 mentioned in Dobmeier and Raith, 2003), no systematic metamorphic and structural data are available from the Phulbani domain. Based on U–Pb zircon and U–Th–Pb monazite chemical age of pelitic granulite samples, Upadhyay et al. (2009) suggested that this domain suffered UHT metamorphism at ca. 1.2 Ga. In a review of the EGB, Dobmeier and Raith (2003) considered the Phulbani domain as an indenter-like protrusion surrounded by shear zones. However, such an interpretation needs to be checked with a comprehensive *P-T-D-t* analysis.

2.2.3 Isotopic domain 4 (Angul domain)

This domain is located to north of the domain 3 and has a protolith age of ca. 2.90-2.50 Ga (Rickers et al., 2001). Angul domain, which is a part of the original domain 4, is later included within the EGP by Dobmeier and Raith (2003). Except the deformation history of the granulites and the migmatitic gneisses of this domain (Halden et al., 1982; Sarkar et al., 2007), detailed petrological and geochronological data are not available in the current literature. The preliminary study of Sarkar et al. (2007) suggest an early granulite-facies metamorphism at about 800°C, 8 kbar (according to the authors the temperature could have been higher) along a clockwise (?) *P-T* path which was followed by near-isothermal decompression. Based on the work of Mezger and Cosca (1999), Sarkar et al. (2007) suggested approximately 960 Ma to be the age of the granulite-facies metamorphism. A second amphibolite facies metamorphism reworked the granulite-facies assemblages at about 650°C, 6 kbar, possibly at 700-650 Ma (Mezger and Cosca

1999). Considering the above data, the tectonothermal evolution of the domain 4 rocks appears to be similar to that of the domain 3. Importantly, Aftalion et al. (1988) reported upper intercept age of 1159 +59/−30 Ma from the zircon grain of augen gneiss of Angul domain which they assigned as the crystallization age of a part of the basement. Simmat and Raith (2008) on the other hand, documented ca. 1260–1200 Ma and ca. 995–975 Ma ages from monazite of metapelitic rocks which they interpreted respectively as the early granulite facies metamorphism and the last fabric-defining high temperature tectonometamorphic event.

2.2.4. Other domains of the EGP

The other domains include the Rampur, Tikarpara and the Khariar that occur at the northern and north-western part of the EGP (Fig. 2.3b). No published petrological, structural and geochronological data are available for the Rampur and Tikarpara domains. The Khariar Domain is located at the western most part of the northern EGP and share boundaries with the Rampur and the Phulbani domains at the south. Additionally, this domain has contact with the westerly placed Bastar craton. This domain was affected by alkaline magmatism at ca. 1471 Ma (Ranjan et al., 2018) and the magmatic rock is now preserved as nepheline syenite. In an earlier work, Upadhyay et al. (2006) obtained the igneous emplacement age of the alkaline magma as ca. 1480 Ma which is broadly consistent with the result of Ranjan et al. (2018). The Khariar Domain witnessed anorthosite mgamatism with emplacement ages of ca. 933 Ma (Krause et al., 2001 from the Bolangir area) and ca. 980 Ma (Raith et al., 2014 from the Turkel area). Based on the published U-Pb zircon ages (Upadhyay et al., 2006; Raith et al., 2014; Ranjan et al., 2018), it can be argued that the ca. 1000-900 Ma metamorphism is unrepresented in the Khariar domain. Simmat and Raith (2008) obtained ca. 1159 Ma age from monazite grains armored within the porphyroblastic garnet of high-Mg aluminous granulite and mylonitized khondalite and this age was interpreted to be the age of high-temperature metamorphism in the Khariar Domain. These authors additionally obtained relatively younger age of ca. 1065 Ma from monazite of high-Mg aluminous granulite which they interpreted as the age of the UHT metamorphism. The Khariar domain was moderately affected by the late Neoproterozoic to early Palaeozoic Pan-African tectonothermal event which was responsible for westward thrusting of this domain onto the Bastar craton.

It is important to note that the domain names of the EGP were coined by Dobmeier and Raith (2003) and their boundaries were drawn mostly from Nd isotopic data of Rickers et al. (2001) along with discrete metamorphic ages across major lineaments interpreted as ductile shear zones (Dobmeier and Raith, 2003). Barring a few studies (e.g. Chetty et al., 2003; Saha and Karmakar, 2015), the domain boundaries remain mostly undefined. The significance of the ages showing distinct populations across the shear zones is also not clear. It is interpreted that these domains are separated by these shear zones (Chetty, 2010), yet the metamorphic characters and the timings of these shearing events are mostly unknown. These domains have complex histories and a clear understanding of each one in the *P-T-D-t* space is required to gain a complete understanding of the evolution of the EGP with respect to its Indo-Antarctic counterpart.

Along the western margin of the Khariar Domain, the EGP is juxtaposed against the Bastar craton along the Terrane Boundary Shear Zone (TBSZ), which shows a thrust slip character in the west and southwest and strike slip in the north (Biswal et al., 2007). The EGP on the NW front displays a fold-thrust belt structure consisting of a stack of granulitic thrust sheets with the TBSZ acting as a basal décollement. Based on the SHRIMP age of synkinematic nepheline syenite plutons emplaced along the TBSZ, a Pan-African age of juxtaposition of the EGP with the Bastar craton is proposed (Biswal et al., 2007).

2.3 Rengali Province *(part of isotopic domain 4)*

Rengali Province is located at the north of the Angul domain and it belongs to the domain 4 of Rickers et al. (2001). Detail petrological studies suggest that the Rengali Province is characterized by granulite-facies gneisses/charnockites and amphibolites-facies metasedimentary and metavolcanic rocks (Mahalik, 1994; Nash et al., 1996; Rickers et al., 2001; Crowe et al. 2003; Mohanty et al., 2009; Mahapatro et al., 2012; Bose et al., 2015; Chattopadhyay et al., 2015; Ghosh et al., 2016) and interpreted to represent thermal pulses related to the southward growth of the Singbhum craton during ca. 3.0-2.5 Ga (Mahapatro et al., 2012; Bose et al., 2016a). A major granulite facies metamorphism occurred at ca. 2.8 Ga which was broadly synchronous with the emplacement of charnockite magma followed by granitoid magmatism (Bose et al., 2016a). Geochemical signatures of the charnockite and the granitoids suggest a within plate post collisional setting in which gneissic basement rocks of the Rengali Province was formed as a southern extension of the Singbhum craton (A. Dasgupta et al., 2017). The ca. 2.8 Ga orogeny juxtaposed the deeper crustal mafic granulite against the shallower level pelitic granulites (Bose et al., 2015). Bhattacharya et al. (2016) and Misra and Gupta (2014), however, argued that the high-grade rocks of the Rengali Province possibly developed as a septum or crustal component of the adjacent Bastar craton and was not the result of the southward growth of the Singbhum craton as suggested by Bose et al. (2016a), Mahapatro et al. (2012) and A. Dasgupta et al. (2017). The low-grade supracrustal sequences of the province witnessed multiple cycles of sedimentation related to the basin tectonics over a prolonged time frame (Das et al., 2017a). An amphibolite facies metamorphism took place in the Rengali Province along a clockwise *P-T* path at 0.98 Ga (Chattopadhyay et al., 2015) and based on this, these authors suggested the Rengali Province along with the Angul domain of EGP got stitched with the Singbhum craton during ca. 0.98-0.95 Ga. The Rengali Province witnessed a regional transpression at ca. 0.52-0.50 Ga which exhumed the middle crust over the upper crust in a crustal-scale flower structure (Ghosh et al., 2016).

2.4 Jeypore Province

This province is located at westernmost part of the northern EGB at the contact with the Bastar craton. Apart from some sporadic geochronological data, little is known about this province. The Jeypore Province consists of granulite facies meta-igneous rocks (mafic granulite and enderbite) which were originated from fractionation of tholeiite and intermediate magma (Subba Rao et al., 1998). Based on geochemical signatures, these authors argued that the enderbitic rocks have calc-alkaline affinity and possibly developed in an arc-related environment. According to Rickers et al. (2001), the Nd model ages of the enderbitic rocks lie within the range of ca. 3.9-3.0 Ga. A high-grade metamorphic event at ca. 2.8 Ga is additionally constrained from the enderbitic rocks of Jeypore Province by Kovach et al. (2001). Kovach et al. (2001, 2004) also argued that the province witnessed high-grade metamorphism during ca. 2.5 Ga similar to the Rengali Province. Jeypore Province witnessed alkaline magmatism at ca. 1387 Ma (Ranjan et al., 2018) which is now preserved as Koraput alkaline complex. The alkaline rocks of this complex suffered major Neoproterozoic overprints at ca. 947 Ma, ca. 808 Ma and ca. 661 Ma (Ranjan et al., 2018).

2.5 EGB and its boundary relations with the cratons

2.5.1 EGB-Singbhum craton contact

Direct contact between EGB and the Singbhum craton is not found due to the presence of Rengali Province in between these two terranes. This is considered to be a separate unit as the geological evolution of Rengali Province appears to be different than EGB (Dobmeier and Raith, 2003). In recent times, the Rengali Province gained attention due to Meso-Neoarchean high temperature metamorphism which is totally absent in the EGB. This high temperature metamorphism occurred under granulite–amphibolite facies metamorphic condition and accompanied by felsic magmatism in the time span of ca. 3050-2500 Ma (Bhattacharya et al., 2016; Bose et al., 2016a; Chattopadhyay et al., 2015; A. Dasgupta et al., 2017; Mahapatro et al., 2012). Structural and geochronological data additionally indicate that the Rengali Province grew as a southward extension of the Singbhum craton (Ghosh et al., 2010, 2016; Mahapatro et al., 2012; Das et al., 2017a). If it is considered that the Rengali Province is an extension of the craton, then the northern boundary of the EGB must lie somewhere in-between, possibly along the Kerajung Fault Zone (Fig. 2.4). Although a major part of this fault is buried under the Phanerozoic Gondwana basin, the exposed parts do not show any evidence of ca. 1000-900 Ma metamorphism or magmatism. It is worth mentioning that there is a report of a ca. 500 Ma thermal/shearing event close to the Kerajung Fault which could be related to the reactivation of the fault zone (Ghosh et al., 2016). Apart from some sporadic records of ca. 900 Ma event in monazite from the rocks near the eastern fringe of Rengali Province i.e. the northernmost extension of the EGB (Simmat and Raith, 2008), there is no record of ca. 1000-900 Ma granulite facies metamorphism on the high-grade gneisses or the low-grade supracrustals located at the southern part of the Rengali Province. Strangely, the low-grade supracrustals which resides over the gneissic basement recorded multiple cycles of basin opening (Das et al., 2017a), but did not register the strong event of the R-EG orogeny. Interestingly, the Malaygiri supracrustal sequence located to the north of Rengali province records ca. 950 Ma Barrovian metamorphism imprinted on garnet–staurolite schist (Chattopadhyay et al., 2015). Based on this, Chattopadhyay et al. (2015) argued that the ca. 950 Ma event is the response of the EGB orogeny by the Singbhum craton. Bose and Dasgupta (2018), however, found this argument problematic because if the cratonic block witnessed Barrovian metamorphism along a clockwise P–T path, then the continental block must have underthrusted below the EGB front. There is no evidence of high-grade EGB rocks in the vicinity. These latter authors suggested that it is possible that the ca. 950 Ma event was related to tectonism of broadly similar age of R-EG orogeny in the Prydz Bay, Vestfold Hills of East Antarctica. However, there is no report of magmatism here which precludes the possibility of getting a suture here.

2.5.2 EGB-Bastar craton contact

The contact between the EGB and the Bastar craton is considered as a tectonic discontinuity and is referred to as the 'Eastern Ghats Frontal Thrust' (Neogi and Das, 2000). This discontinuity is however, also known as the 'Eastern Ghats Boundary Shear Zone' (Dobmeier and Raith, 2003) and the 'Terrane Boundary Shear Zone' (Biswal et al., 2007) (Fig. 2.4). This contact is characterized by a wide mylonitic zone (Bhadra et al., 2004; Gupta and Bhattacharya, 2000; Neogi and Das, 2000), along which the hot granulitic lower crust was thrusted on the craton. Such thrusting caused heating of the craton and simultaneous cooling and decompression of the granulitic thrust sheets (Gupta et al., 2000; Bhadra et al., 2004; Das et al., 2008; Chatterjee et al., 2017a, b). Structural modeling of Biswal et al. (2007) shows that the boundary thrust actually represents either the listric frontal thrust or the basal décollement of the EGB indicating the formation of a fold-and-thrust sequence with a number of stacked thrust sheets. Although the kinematics of this thrusting is well characterized, the timing of the same remained hitherto unknown. Two discrete group ages of ca. 1000-900 Ma and ca. 550-500 Ma are reported from the northern part of the contact zone (Simmat and Raith, 2008), but it remained unclear that how these ages are linked to the thrusting event. In a recent work, Chatterjee et al. (2017a, b) documented the presence of an age zonation across the contact. Accordingly, the ca. 1000-900 Ma age event largely cratonized the northern EGB (EGP) with the cratonic South Indian Block and was later reworked during the ca. 550-500 Ma thrusting. It is important to note that the adjacent cratonic block (footwall) was affected only by the later event. There is no record of magmatism and other crucial evidences for ocean closure along the contact, defying its status as a true suture. Therefore, the ca. 550-500 Ma event most likely represents an intracratonic orogenic front in response to farfield stresses imparted by the Pan-African orogeny occurring in East Gondwana. If this was the scenario, the cratonization of northern EGB was mostly completed during ca. 900 Ma.

2.5.3 EGB-Dharwar craton contact

A major portion of the contact of EGB and Dharwar craton is buried under the sedimentary successions of the Cuddapah basin. A number of fold-thrust belts having low- to medium-grade metamorphic characters are present along the contact zone. The southern part of EGB (Ongole domain) is flanked by the Nellore schist belt which belongs to Vinjamuru Group, the Kandra ophiolite complex, the Kanigiri ophiolitic mélange and the Udayagiri Group (Saha et al., 2015). Having Archean protolith signatures, the Vinjamuru Group was metamorphosed at amphibolite facies condition and juxtaposed to Kandra ophiolite complex after ca. 1.9 Ga (Saha, 2011; Vijaya Kumar et al., 2010, 2011). The Vinjamuru Group witnessed syntectonic granite emplacement (Vinukonda granite) along the eastern boundary of the Nallamalai Fold belt at ca. 1589 Ma (Dobmeier et al., 2006). The Kandra ophiolite belt is characterized by imbricate thrust slices of dismembered oceanic lithosphere and interpreted to develop in a supra-subduction zone setting at ca. 1.9 Ga (Saha, 2011; Vijaya Kumar et al., 2010, 2011). Another exotic unit, named as the Kanigiri ophiolitic mélange, bears similar supra-subduction setting signature and interpreted to have been emplaced at ca. 1334 Ma (Dharma Rao et al., 2011). These ophiolitic sequences are interpreted to represent relics of subduction–accretion process which was active over the time span of ca. 1800-1300 Ma at the eastern margin of the Dharwar craton and are broadly correlated with the assembly and breakup of the supercontinent Columbia (Dasgupta et al., 2013; S. Dasgupta et al., 2017; Saha et al., 2015). Late granites associated with alkaline magmatism (Prakasam Alkaline complex) were emplaced in the northern part of the Nellore schist belt and are interpreted to represent a Mesoproterozoic rifting episode along the contact (Sai, 2013; Upadhyay et al., 2006). The last major tectonothermal event in the Ongole domain occurred at ca. 1540 Ma when it was cratonized with the Dharwar craton (Sarkar and Schenk, 2014). Recently, Sheppard et al. (2017) obtained Pan-African age of ca. 531 Ma from in situ monazite dating of metamorphosed shale and siltstone from the Nallamalai Fold belt of the Cuddapah basin and interpreted to be responsible for folding, nappe stacking and low-grade metamorphism. Although it remained ambiguous how monazite grew in such low temperature conditions, this new age constraints indicate Pan-African tectonism in the sedimentary basin close to the Ongole domain during the final assembly of Gondwana.