CHAPTER 2

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Geological background

The WNW-ESE trending elongated litho-structural unit for the present study have been variously described as the Rengali Assemblage (Mahalik, 1994), the Rengali Domain (Nash et. al., 1996) and the Rengali Province (Crowe et. al., 2003; Dobmeier and Raith, 2003). This unit was previously considered as a part of the Eastern Ghats Belt (Ramakrishnan et al., 1998), but later subdivisions exclude this possibility (Dobmeier and Raith, 2003). As it evolved as a separate crustal province, the term Rengali Province is considered to be appropriate and has been used in this study. As mentioned in the previous chapter, this province is bounded by Singhbhum Craton on the north, Bastar Craton on the west and the Eastern Ghats Belt in the south. Before going into the details of the current study, a brief discussion about regional geological setting has been presented in this chapter.

2.1 Singhbhum Craton

The Singhbhum Craton (Fig. 2.1) is a complex mosaic of Archean granite-greenstone succession flanked by Proterozoic supracrustal rocks (Acharyya, 1993; Saha, 1994; Mukopadhyay, 2001). At the central part, the nucleus is composed of basement consisting of pelitic and metabasic rocks of the Older Metamorphic Group (OMG), the Older Tonalite-Trondhjemite-Gneisses (OMTG) and several phases of granitic intrusion (Singhbhum Granite or SBG phase-I, II and III). The other major constituent of the cratonic nucleus, the Iron Ore Group (IOG) which essentially is a greenstone succession composed of volcaniclastic sediments and Banded Iron Formation (BIF) along with cherts, shales, carbonates and associated mafic and felsic volcanic rocks flank the SBG massif in east, west and south as separate basins. This Archean nucleus is separated from the Singhbhum Mobile Belt and the

Rengali Province by crustal-scale shear zones in the north and south respectively. The tonalite-trondhjemite-granodiorites of the OMTG are Mesoarchean in age (ca. 3.45–3.32 Ga; Moorbath et al., 1986; Goswami et. al., 1995; Misra et al., 1999; Acharyya et al., 2010; Tait et al., 2011; Upadhyay et al., 2014; Nelson et al., 2014). OMTG rocks show an intrusive relation to the 3.5 Ga old (Goswami et al., 1995) OMG rocks. The latter is essentially composed of supracrustals of meta-igneous (ortho-amphibolites) and metasedimentary (pelitic schists, quartzites, para-amphibolites) characters. The IOG rocks show low-grade metamorphism and were formed between ca. 3.51 Ga and ca. 3.20-3.10 Ga (Mukhopadhyay et al., 2008; Misra et al., 1999). This is considered as the oldest greenstone succession from eastern Indian shield and possibly the Indian subcontinent (Mukhopadhyay et al., 2008). The regional scale, oval-shaped SBG is composed of several smaller batholiths which were emplaced in three different phases constituting the major part of the Archean nucleus of the craton. The Archean nucleus is surrounded by an elongated, arcuate belt composed of sedimentary and volcanic rock deformed and metamorphosed to maximum greenschist facies. These supracrustal sequences belong to Palaeo-Mesoproterozoic era.

2.2 Bastar Craton

The Bastar Craton is dominantly composed of tonalite-trondhjemite gneisses (~3500–2500 Ma; Ghosh, 2004; Sarkar et al., 1993); granitoids with ~2500–2200 Ma ages (Krishnamurthy et al., 1988; Pandey et al., 1989; Sarkar et al., 1981) and greenstone belts (Mondal et al., 2006). Several dolerite, rhyolite and trachyte dykes have intruded the craton around ~1400 Ma (Mallikarjuna Rao et al., 1995). It also hosts several Mesoproterozoic supracrustal sedimentary basins (Chhattisgarh Main Basin, Khariar Basin, Ampani Basin, Sukma Basin, P-G valley basin and Indravati Basin) roughly aligned in a northeast-southwest trend (Fig. 2.2). Sedimentation histories of these basins have been constrained from recent geochronological data. The sedimentation in the Ampani Basin occurred between ~2050 Ma and 1400 Ma (Saha et al., 2016). The basement granite gneiss of sedimentary succession of Ampani Basin yields an emplacement age of 2489±9 Ma (Saha et al., 2016). The presence of mylonitic pebbles in a conglomerate of the Khariar Basin suggests that the sedimentation was continued, at least, up to ~517 Ma (Ratre et al., 2010). Recently, Bhadra and Gupta, (2016) suggested that the Khariar Basin evolved through, at least, two phases of thrusting of the Eastern Ghats Belt on the Bastar Craton during cratonization of the former. These authors further proposed that the Khariar Basin was closed and developed as a foreland fold-thrust belt (accretionary wedge) by westward propagation of the thrust nappe during the final phase of the orogeny.

2.3 Eastern Ghats Belt

Eastern Ghats Belt is one of the few terranes which record several cycles of orogenesis during amalgamation of Precambrian supercontinents (reviewed in Dasgupta et al., 2013, 2017). The terrane exposes deep crustal sections with unique relics of ultrahigh temperature (UHT) metamorphosed crust (Dasgupta et al., 2017 and references therein). The rocks present in this terrane include pelitic granulite (locally khondalite), charnockite gneiss, mafic granulite, calc-silicate granulite, granitic gneiss (leptynite), alkaline rock suites, mafic-ultramafic suite and anorthosite. Later intrusives of dolerite and pegmatite are conspicuous at places. This belt has been classified and subdivided into several groups. Ramakrishnan et al. (1998) proposed a lithological subdivision where the entire belt was divided into four lithological zones, namely the Western Charnockite Zone (WCZ), Western Khondalite Zone (WKZ), Central Migmatite Zone (CMZ) and Eastern Khondalite Zone (EKZ) (Fig. 2.3a). These authors also invoked the presence of a Transitional Zone (TZ) at the western margin of the belt. This classification received criticism later (Dasgupta and Sengupta, 2003) due to problem in identifying zones solely based on lithological characters. Chetty (2001) identified several regional scale lineaments and interpreted that these were shear zones that amalgamated the Archean and Proterozoic domains of the Eastern Ghats Belt. However, this classification was also received criticism due to lack of geochronological support. Rickers et al. (2001) subdivided the entire belt into four crustal domains on the basis of Sm-Nd, Rb-Sr and ^{207}Pb-^{206}Pb isotopic characters (Fig. 2.3b). This classification received much attention due to its robust chemical background. Combining the earlier subdivisions with the data of Rickers et al. (2001), Dobmeier and Raith (2003) identified several crustal provinces within the belt, each containing several domains having similar lithological, metamorphic and isotopic characters (Fig. 2.3c). The centrally located Eastern Ghats Province occupies the major part of the belt, while the Jeypore Province and Krishna Province occur as thinner units occurring at the western and southern part of the belt. The Rengali Province occurs at the north of the Eastern Ghats Province with a possible thrust contact (Ghosh et al., 2016).

The Eastern Ghats Belt plays a crucial role in understanding the evolution of Proterozoic orogenic system(s) that united and dispersed continental blocks of India and East Antarctica. Recently published data on this belt not only vindicated the existing ideas and hypotheses but also opened up new possibilities of transcontinental correlation. The earlier classifications based on isotopic signatures provide some hints that there are at least two global-scale orogenic imprints preserved the EGB. New petrochronological data clearly show imprints of three distinct orogenic events. The Ongole Domain of the southern Eastern Ghats Province evolved during the ca. 1.7-1.54 Ga orogenesis (Bose et al., 2011; Henderson et al., 2014; Dasgupta et al., 2013; Sarkar and Schenk, 2014; Sarkar et al., 2014; 2015). The Eastern Ghats Province north of the Godavari rift evolved during the 1.07-0.90 Ga Grenvillian orogenesis (Bose et al., 2011; Dasgupta et al., 2013; Korhonen et al., 2013a). The northern part of the Eastern Ghats Province and adjacent Rengali Province witnessed orogenic events during 0.55-0.50 Ga Pan African orogenesis (Chattopadhyay et al., 2015; Bose et al., 2016a).

The Ongole domain evolved as a part of the accretionary belt of Columbia between the Napier and Dharwar blocks around ca.1.8-1.6 Ga (Dasgupta et al., 2013, 2017). Recent report of a high-pressure metamorphism at ca. 1.54 Ga (Sarkar and Schenk, 2014; Sarkar et al., 2014) has been interpreted to result from the final collision of the Indian and east Antarctic blocks. Since this domain did not experience any major tectonothermal event subsequently, it is postulated to have cratonized after ca. 1.54 Ga. The ca. 0.95-0.90 Ga metamorphic events in the Eastern Ghats Province match with the Rayner Province of East Antarctica and these two belts evolved simultaneously as a part of Rodinia (Dasgupta et al., 2013). UHT metamorphism in Eastern Ghats is unique and possibly developed in a back-arc basin within an accretionary system (Dasgupta et al., 2013). The final docking was complete by ca. 0.90 Ga when the Eastern Ghats Province was mostly cratonized.

2.4 Rengali Province

Rengali Province separates the low-grade metasedimentary and metavolcanic rocks of Singhbhum Craton from the high-grade charnockite-khondalite suite of the Eastern Ghats Province (Dobmeier and Raith, 2003). Although early workers consider Rengali Province as the northernmost unit of the Eastern Ghats Belt (Mahalik, 1994), it preserves distinctive structural, petrological and geochronological features (Crowe et al., 2001, 2003; Misra et al., 2000; Misra, 2006; Mahapatro et al., 2012; Bose et al., 2016; Bhattacharya et al., 2016) which are grossly contrasting compared to the Eastern Ghats Belt. The wedge-shaped terrane (Fig. 2.4) is composed of a gneissic basement, which is commonly known as the Pal Lahara Gneiss (Saha, 1994). This gneiss is a composite of several components of granitic to granodioritic affinity. The gneissic rocks show mostly amphibolite facies metamorphism, but granulite facies rocks also occur within the gneissic basement as enclaves (Bose et al., 2015, 2016). A thick quartzite-conglomerate unit lies unconformably over this basement gneiss (Mukhopadhyay et al., 2012; Das et al., 2017). These latter rocks are variably deformed and metamorphosed to greenschist facies and eventually truncated at the south by the E-W-trending Sukinda Thrust. An intervening strip of Gondwana rocks locally separates the rocks of Rengali Province from Eastern Ghats Province lying in the south.

Mahalik (1994) studied the contact region between the North Orissa Craton (part of the Singhbhum Craton) and the Eastern Ghats Belt to infer that this wide zone was affected by several east-west running regional-scale faults, with fault fragments of both blocks intertwined with each other. He proposed that the high-grade granulites and gneissic rocks from the terrane can be subdivided into the northern lying Rengali Assemblage and southerly lying Angul Assemblage, both of which belong to the Eastern Ghats Belt. On the other hand, the low-grade supracrustals containing BIF, quartzite and volcano-sedimentary sequences were subdivided into Tikra, Malaygiri and Deogarh Assemblages that belong to the North Orissa Craton. Some granitic intrusions are also associated with these supracrustals. Mahalik (1994) also inferred that the Eastern Ghats granulites are older than the supracrustals and granite intrusives while migmatization and charockitization of the high-grade rocks were associated with deep-seated fault tectonics related to the Proterozoic events of the Eastern Ghats Belt (ca. 1.0-0.8 Ga). This argument has been proved untenable from the geochronological point of view as recent age data clearly show Neoarchean-Paleoproterozoic status of the Rengali Assemblage (Chattopadhyay, et al., 2015; Bose et al., 2016; Bhattacharya et al., 2016; Das et al., 2017). Crowe et al. (2001, 2003) considered Rengali Province as a transitional zone with distinct geological characters which largely differs from that Eastern Ghats Belt, as well as adjacent Bastar and Singhbhum Cratons. According to these workers, the Rengali Province represents a regional-scale shear zone-bound terrane comprising of high-grade basement gneiss and meta-volcano-sedimentary lithologies.

Petrological data from the Rengali Province are scarce. Based on textural, geothermobarometric and monazite U-Th-total Pb data from only one pelitic granulite from the eastern Rengali Province, Mahapatro et al. (2012) argued that the peak granulite facies conditions involved 7.8 kbar, 849 °C during 3057 ± 17 Ma. A reheating of retrogressed granulite is thought to have occurred during 2781 ± 16 Ma. Recently, Bose et al. (2015) published petrological data for mafic and pelitic granulites from the eastern Rengali Province. Their data suggest that peak conditions experienced by the mafic granulite involved 10-12 kbar, 860 °C. Reheating of retrogressed mafic granulite caused dehydration melting in pelitic granulite at ~6 kbar, 580–730 °C. The contrasting P–T paths shown by the mafic granulite (decompression followed by heating) and the pelitic granulite (heating followed by cooling) have been interpreted as the result of crustal juxtaposition within a major orogenic setting (Bose et al., 2015).

Very few high-quality geochronological data are available from the Rengali Province. Metasedimentary and meta-igneous rocks from this province have 2800-2200 and 3900-2900 Ma Nd-model ages (Rickers et al., 2001). Since the latter overlaps with the emplacement ages of igneous rocks within the Singhbhum Craton, Rickers et al. (2001) argued that the crustal materials of the Rengali Province (their isotopic Domain 4) were derived mainly from the Singhbhum Craton without much addition of juvenile material. It is to be noted that sampling of Rickers et al. was very limited (two samples only) from the Rengali Province, and a more extensive work is required to characterize the protolith of entire Rengali Province. Bounding granitoid near Bhuban area at the eastern part of the province gives ca. 2800 Ma emplacement age ($^{207}Pb/^{206}Pb$ zircon by Misra et al., 2000). Rb-Sr data from some of the charnockites yield ca. 2750-2730 Ma ages (Sarkar et al., 2000) which are rather imprecise as argued by later workers (Dobmeier and Raith, 2003). Amphibolite-facies rocks give much younger age data of ca. 700–420 Ma based on $^{40}Ar/^{39}Ar$ systematics on hornblende and biotite grains (Crowe et al., 2001). This is an unrealistically prolonged time frame for activity of an orogenic belt.

Crowe et al. (2001) argued that the exhumation of the Eastern Ghats Belt to the same structural levels of the Rengali Province occurred at ca. 550-500 Ma with a prominent N-S shortening followed by greenschist facies metamorphism. Although Mahapatro et al. (2012) showed that the Rengali Province has a lineage of the Singhbhum Craton, Misra and Gupta (2014) argued that the entire Rengali Province is essentially a fragment of the Bastar Craton that has undergone internal rotation of ~120° during the dextral shearing event as part of an evolving dilatational step-over system. They also interpreted that earlier structures of Bastar Craton were oriented in the shortening zone with respect to the WNW-ESE oriented dextral shearing and were consequently shortened simultaneously with rotation. Sawant et al. (2017) proposed a correlation between the Rengali Province and the Rauer Group of East Antarctica. Chattopadhyay et al. (2015) studied the Malaygiri supracrustal rocks present along the NE boundary of Rengali Province, and on the basis of tectonometamorphic and geochronological evidences, they suggested that these rocks share a common geological history with the Eastern Ghats Province since the early Neoproterozoic. Prior to the early Neoproterozoic, the two units had separate geological histories. Their study also showed that Malaygiri records a metamorphic event at ca. 2.47-2.42 Ga, which is absent in the Eastern Ghats granulites. Supported by radiometric age data from Malaygiri supracrustals and synchronous ages from Singhbhum Craton, they further suggest that the Rengali Province evolved at the southern margin of the Singhbhum Craton as proposed earlier (Mahapatro et al., 2012; Nelson et al., 2014; Bose et al., 2015; Ghosh et al., 2010). This also refutes the proposition of that Rengali Province was a rotated fragment of the Bastar Craton by Misra and Gupta (2014).

Bhattacharya et al. (2016) suggested that part of the basement gneiss occurring at the northwestern Rengali Province could be derived from the Bastar Craton. They further proposed, albeit without data, that the supracrustal belts flanking the Rengali basement actually represents accretionary wedges of Pan-African age, resulting from docking of the Eastern Ghats Province against the cratons (Bastar/Singhbhum) that supplied the protoliths. This hypothesis has been challenged by recent geochronological data from the supracrustal sequences (Das et al., 2017).

Recently, Das et al. (2017) obtained U-Pb detrital zircon ages the supracrustal belts of the Rengali Province to estimate the age of sedimentation and the thermal events in the provenance. The U-Pb age from these samples yielded younger than 2235 ± 28 Ma for Northern Supracrustal Belt, while that of the Southern Supracrustal Belt is consistently younger (<1835 Ma). They argued that development of sedimentary basins at the southern margin of the Singhbhum Craton was associated with four cycles of sedimentation at ca. 3100-2800 Ma, ca. 2800-2450 Ma, ca. 2450-2235 Ma and ca. 2235-1835 Ma. These cycles resulted in the southward growth of the Singhbhum Craton through successive opening and closing of basins. They argued that the provenance of the sediments could be proximal (cratonic India), but a transcontinental block in East Antarctica has also been invoked.

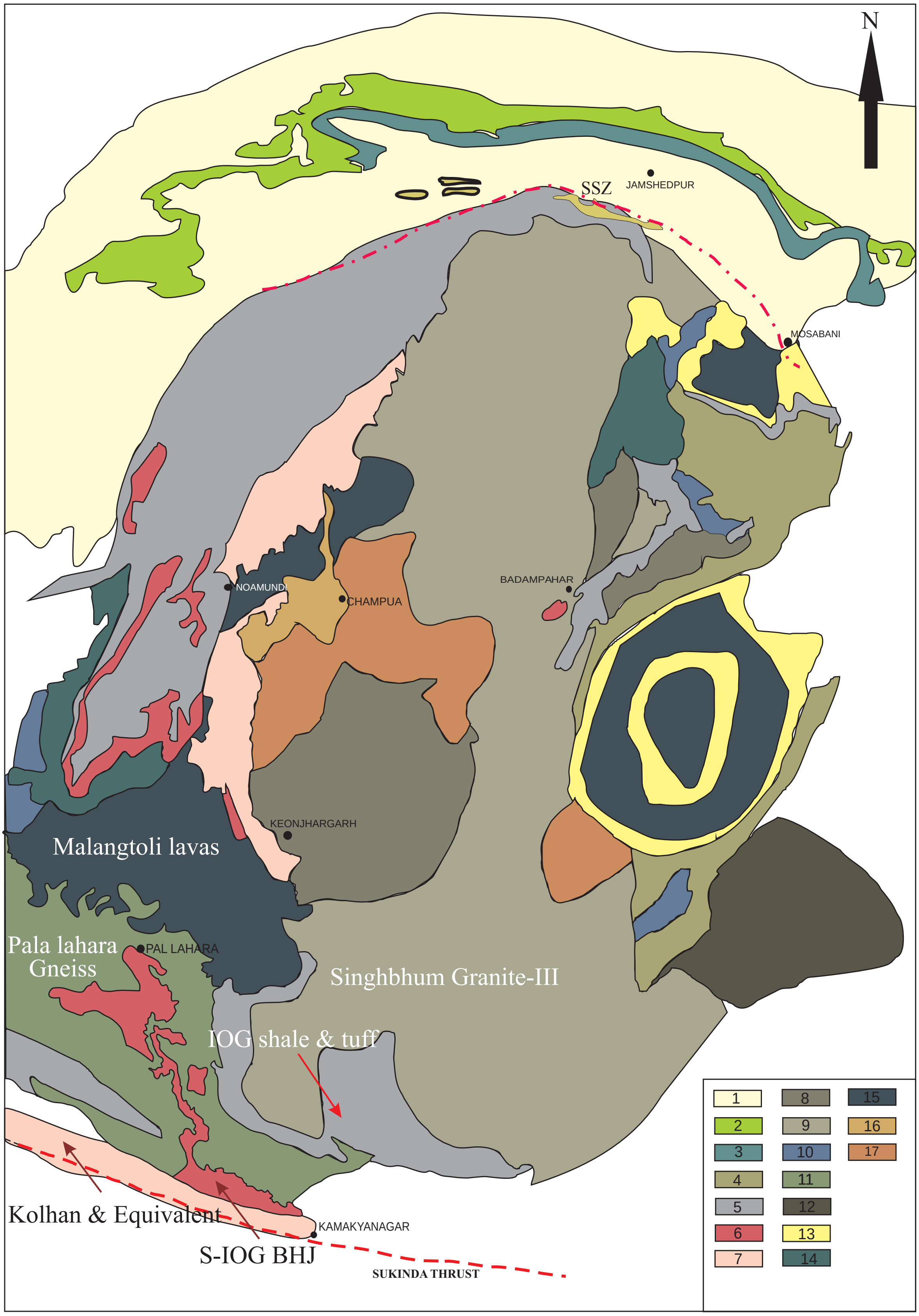


Fig. 2.1: Geological map of Singhbhum-North Orissa region (modified after Saha, 1994)

1.Singhbhum Group Pellites 2.Dalma Lavas 3.Singhbhum Group Mafic bodies
4.Mayurbhanj Granite 5. IOG Shale and Tuff 6.BHQ,BHJ and Sandstone-Conglomerate of IOG
7.Kolhan Group and equivalents 8.Singbhum Granite phase-II 9.Singhbhum Granite phase-III
10.Proterozoic Gabbro-Anorthosite-Ultramafics 11.Pala Lahara Gneiss 12.Nilgiri Granite
13.Quartzite-Conglomerate of Dhanjori group 14.IOG lavas and Ultramafics
15.Dhanjori-Simplipal-Malangtoli lavas 16.OMG 17.OMTG

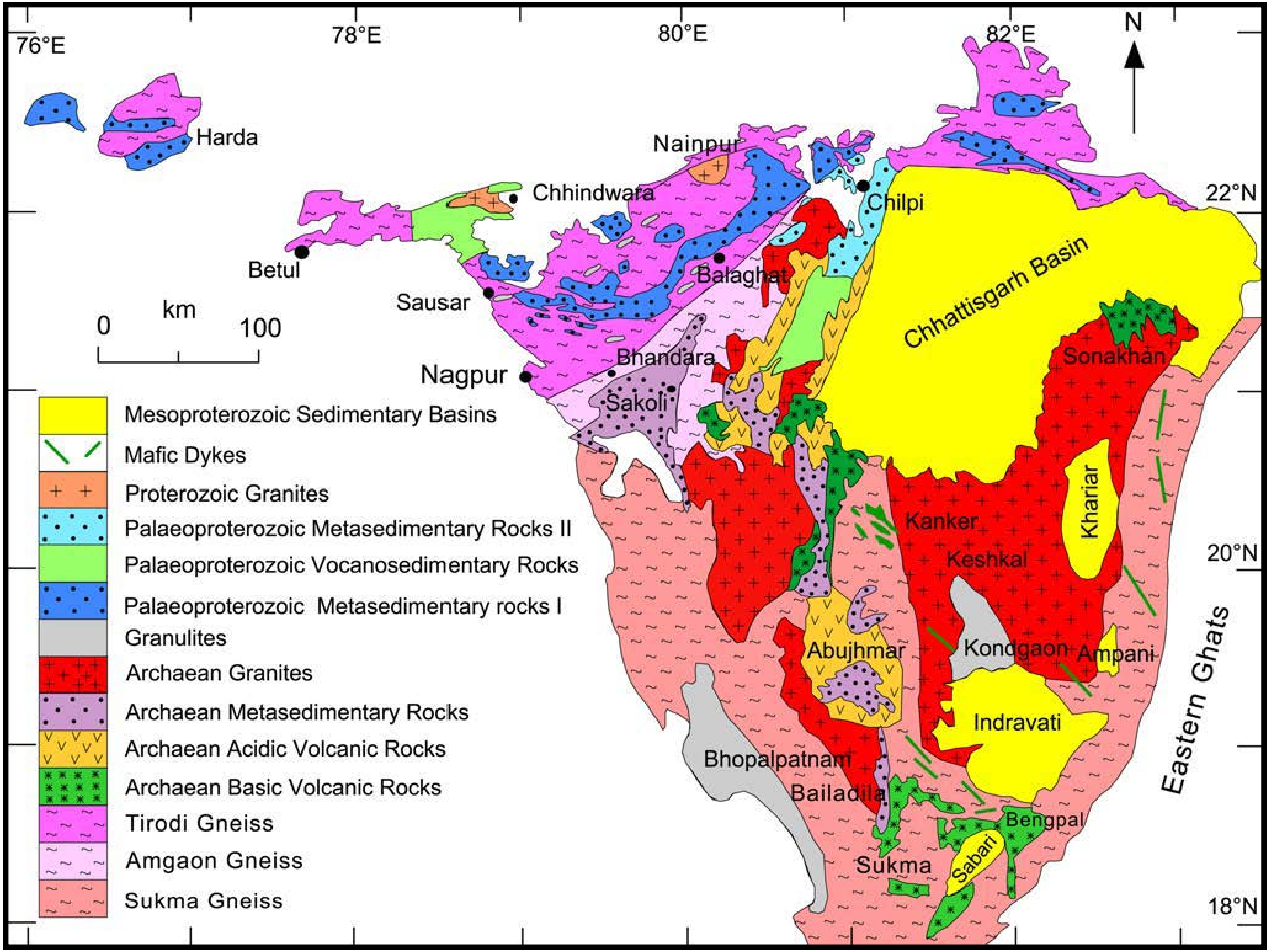


Fig. 2.2: Geological map of Bastar Craton with detailed lithological associations. (modified after Mohanty et. al., 2012)

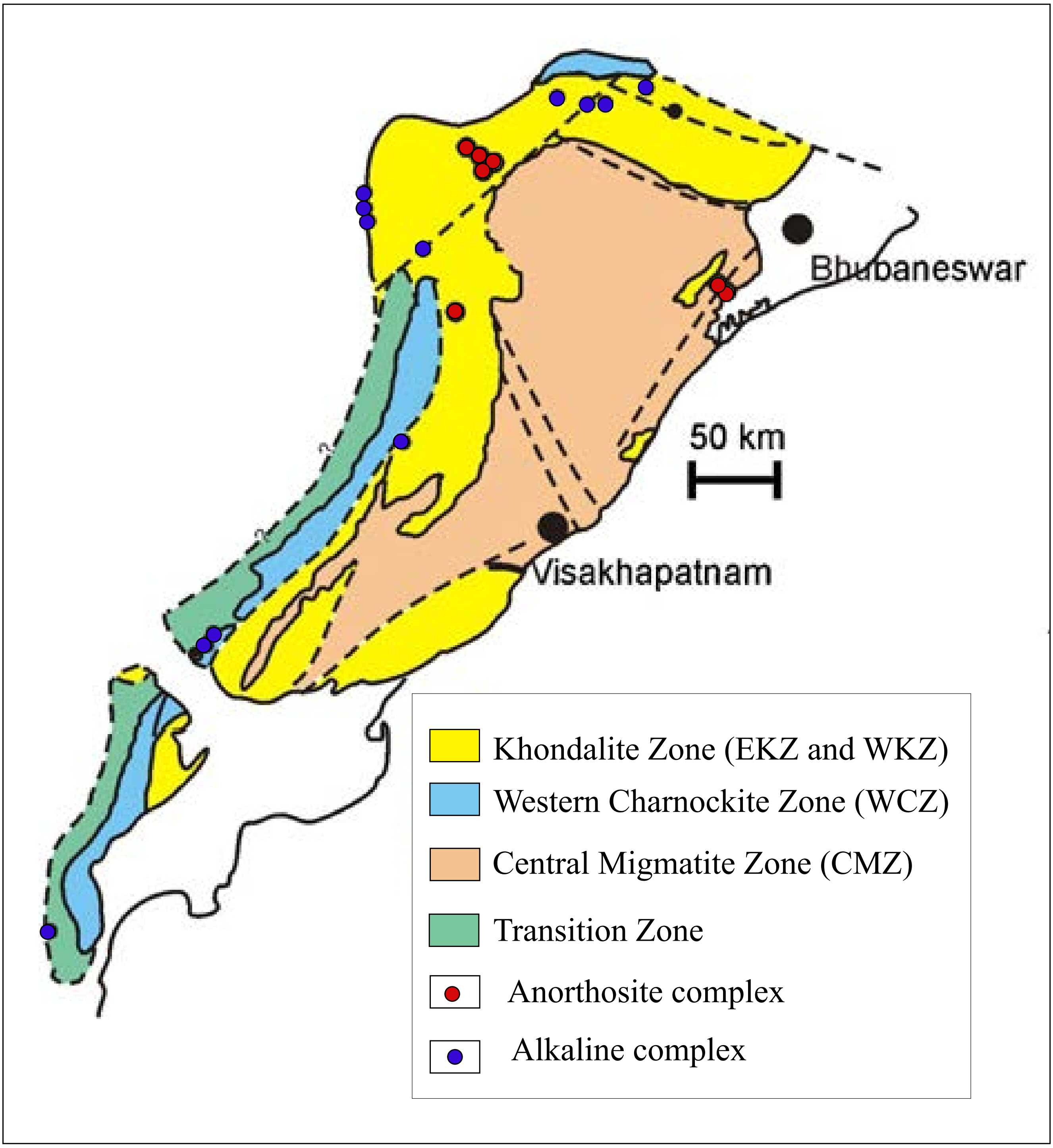
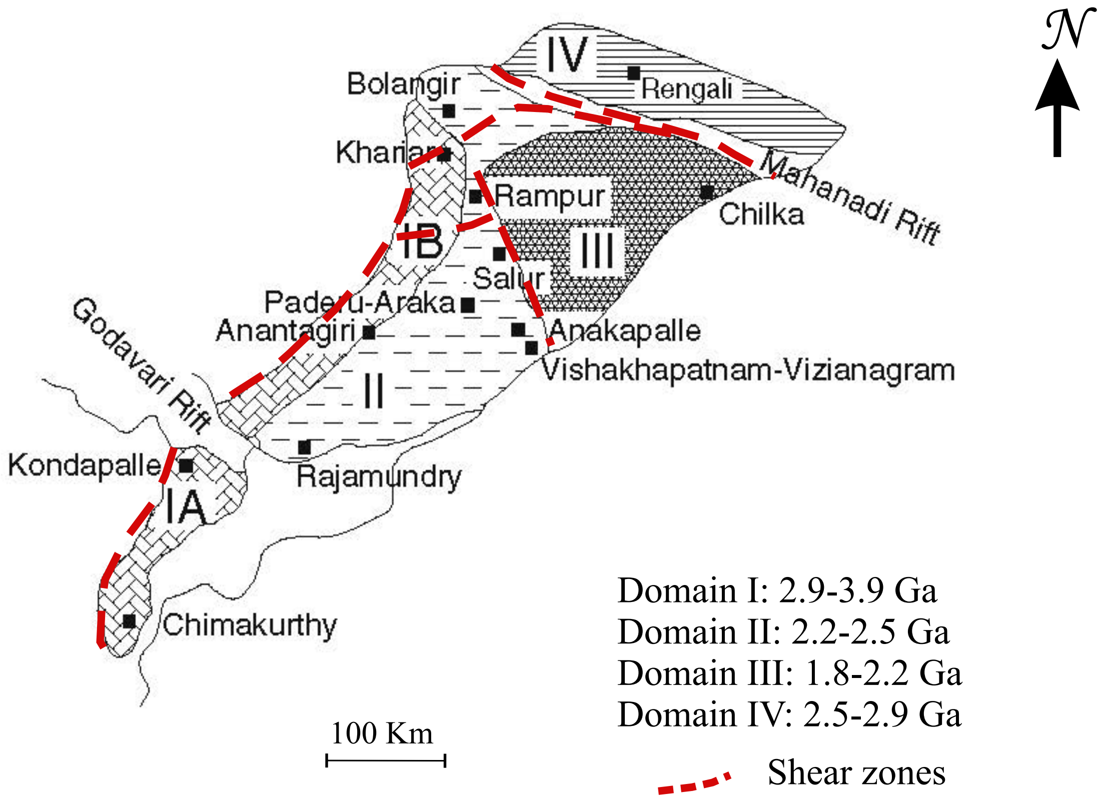


Fig. 2.3 (a) Division and classifcation of Eastern Ghats Belt on the basis of lithological characters (modified after Ramakrishnan et al., 1998)

(b)



(c)

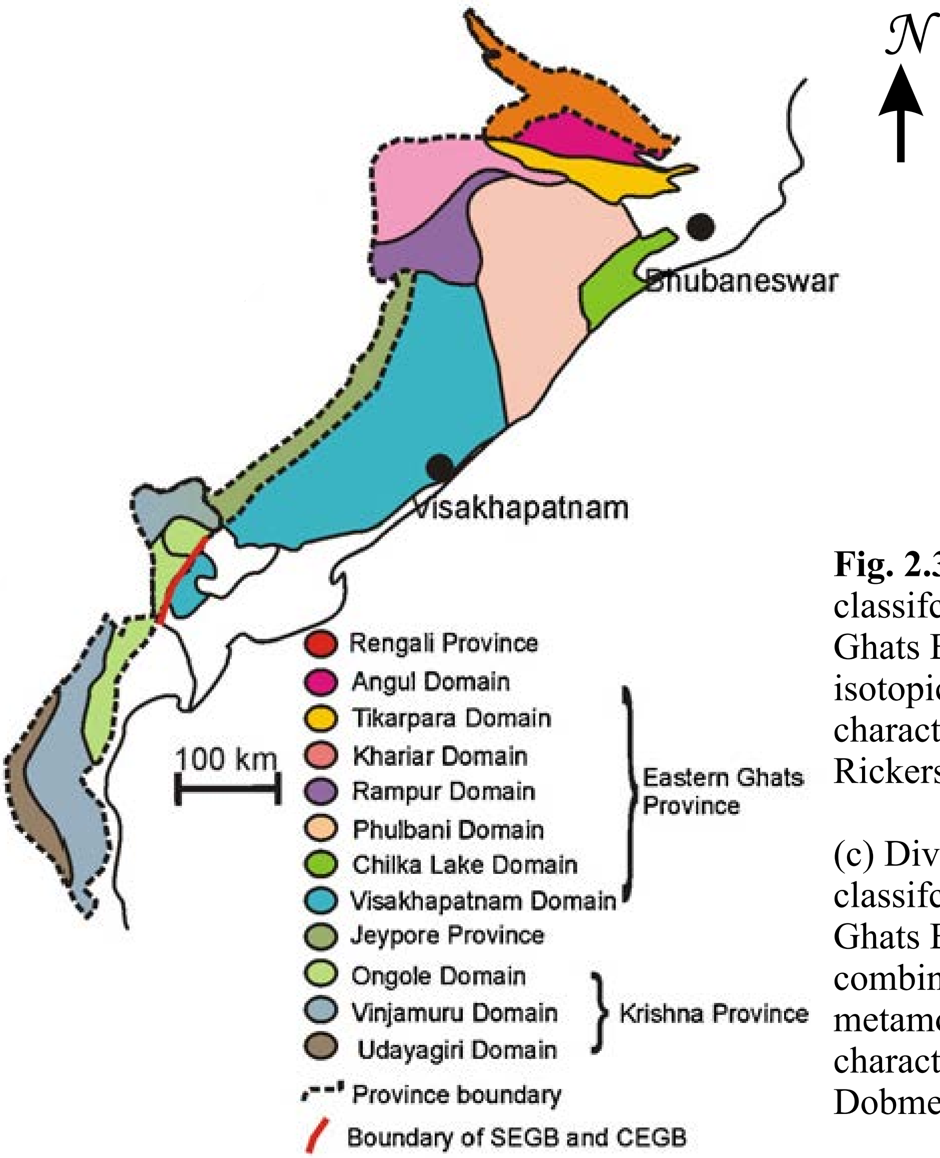


Fig. 2.3 (b) Division and classifcation of Eastern Ghats Belt on the basis of isotopic (Nd-model age) characters (modified after Rickers et al., 2001).

(c) Division and classifcation of Eastern Ghats Belt on the basis of combination of lithological, metamorphic and isotopic characters (modified after Dobmeier and Raith, 2003).

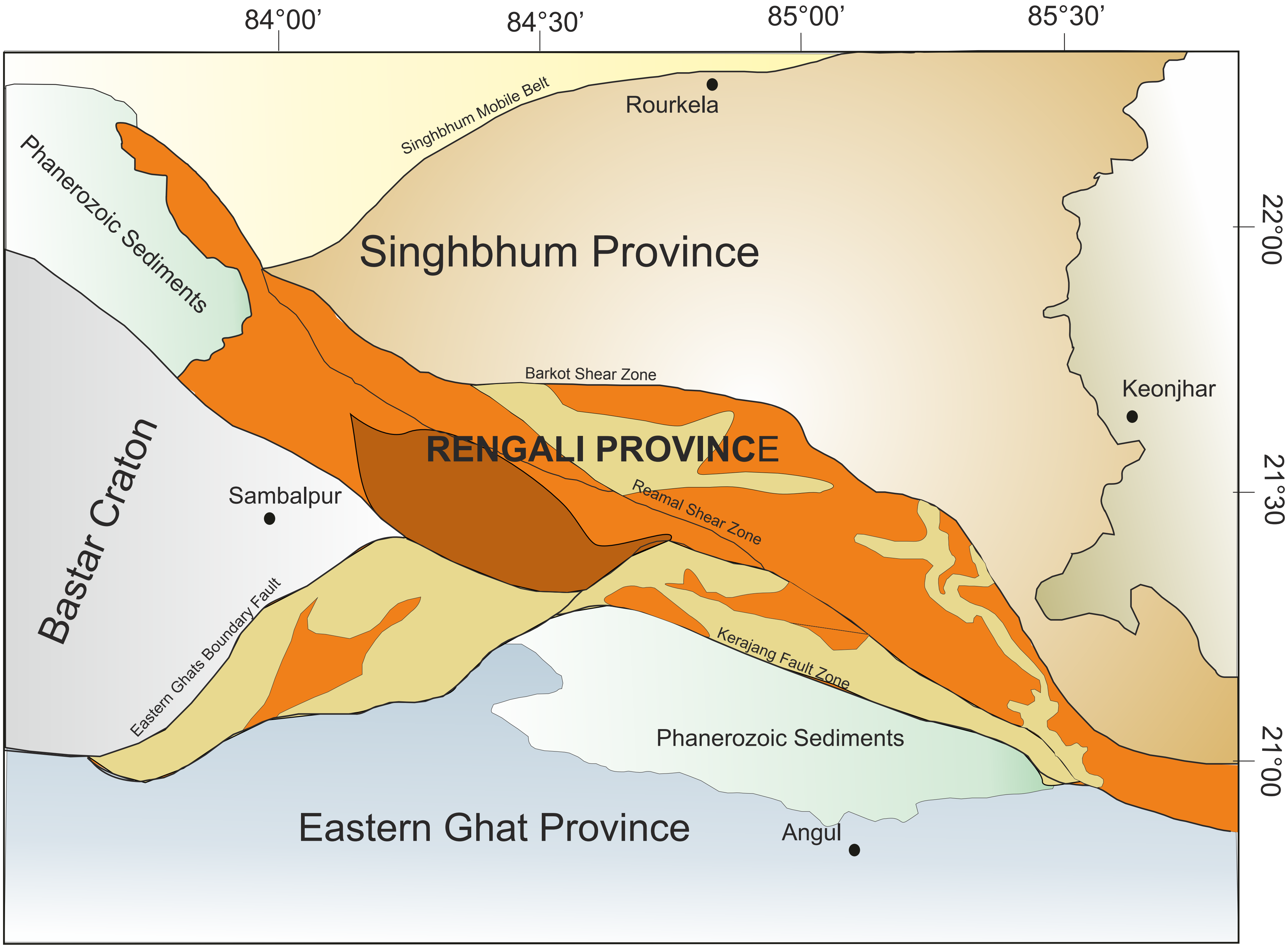


Fig. 2.4: Regional map of Rengali Province. Location of Rengali Province, with respect to adjacent cratons are shown here (modified from Crowe et. al., 2003)