Chapter2

An Overview of the Precambrian Stratigraphy of the Singhbhum Craton

2.1. Introduction

Peninsular India comprises of mainly five Archean cratonic nuclei: Aravalli craton, Bundelkhand craton, Bastar-Bhandara craton, Eastern and Western Dharwar craton, and Singhbhum craton (Fig. 2.1) (Naqvi 2005). Singhbhum craton occupies eastern part of India. The core of the craton is granite-greenstone, that records granite emplacement at three phases ranging in age between 3.4 Ga to 3.1 Ga (the Singhbhum Granite Phases I, II and III). The granitoids are essentially Archean TTG components. The craton is bordered by Mesoarchean to Mesoproterozoic supracrustal cover sequences and mobile belts (Fig. 2.2) (Saha 1994). The mobile belt in the north is referred to as North Singhbhum Mobile Belt (NSMB) between the Singhbhum craton and the Chottanagpur Granite Gneissic Complex (CGGC) with a crustal scale ductile shear zone, the Singhbhum Shear Zone (SSZ), along the northern margin of the Singhbhum craton. The NSMB includes siliciclastics of the Singhbhum Group; metavolcanics dominated Dalma Volcanics and is separated from the Singhbhum craton by the Singhbhum Shear Zone. The southern margin of the craton is in tectonic contact with the high-grade Eastern Ghats and the Rengali Mobile Belts (Das et al. 2017). The three prominent synformal keels of greenstone belt with thick BIF-hosted iron ore deposits in each are referred to as Eastern, Western and Southern Iron Ore Group (IOG) (Saha 1994, Acharyya 1993; Beukes et al. 2008). Numerous small greenstone and amphibolite grade metasedimentary and metavolcanic enclaves within the granitoids are collectively referred to as Older Metamorphic Group (OMG) (Saha 1994). U-Pb zircon ages from the metalavas from southern IOG suggest a Paleoarchean (3.51 Ga) age (Mukhopadhyay et al. 2008a) for the oldest greenstone component in the craton so far. Subsequent stratigraphic development is recorded in the siliciclastics dominated successions of the Dhanjori Group in the northern (ranging in age from >2.8 Ga to 2.2 Ga, Acharyya et al. 2010a, 2010b; Mazumder et al. 2012) and Mahagiri Quartzite and the siliciclastic succession around Keonjhar and Mankaharchua (Mukhopadhyay et al. 2016) along the southern and western peripheries of the craton, respectively. The Mesoarchean to Paleoproterozoic successions are followed upwards by the carbonate-siliciclastic succession of the Mesoproterozoic Kolhan Group (Mukhopadhyay et al. 2006).

2.2. Precambrian stratigraphy of the Singhbhum craton

A systematic study reveals that Singhbhum region of eastern India is covered by Mesoarchean to Paleoproterozoic rock records. This province is known as Singhbhum craton (also known as Singhbhum-Orissa craton or Singhbhum-Orissa Iron Ore craton or Eastern Indian craton). From the economic point of view this Precambrian craton is as important as Phanerozoic time. The Singhbhum craton comprises of seven principal stratigraphic units (Table 2.1) (Bose 1986; Naqvi and Rogers 1987; Saha et al. 1988; Acharyya 1993; Saha 1994; Goswami et al. 1995; Mazumdar 1996; Sengupta et al. 1997; Mishra et al. 1999, Misra et al. 2000; Mukhopadhyay 2001; Misra 2006; Mukhopadhyay et al. 2006, 2007 and 2008a, 2008b, 2008c; Sharma 2009; Ghosh et al. 2010, 2015; Tait et al. 2011), that are follows:

a. Older Metamorphic Group (OMG) supracrustal deposits
b. Older Metamorphic Tonalite Gneiss (OMTG) intrusive into the OMG

c. Singhbhum Granite (phases I, II and III), Bonai Granite, Kaptipada Granite, Mayurbhanj Granite and Pallahara Gneiss

d. Iron Ore Group (IOG) at the south, west and eastern periphery of the Singhbhum Granite

e. Proterozoic supracrustals: greenstone belts dominantly comprising basic volcano-sedimentary successions of Dhanjori, Singhbhum, Dalma, Simlipal, Jaganathpur Lava , Malangtoli Lava

f. Siliciclastic- carbonate succession: Kolhan Group

g. Newer Dolerite dyke

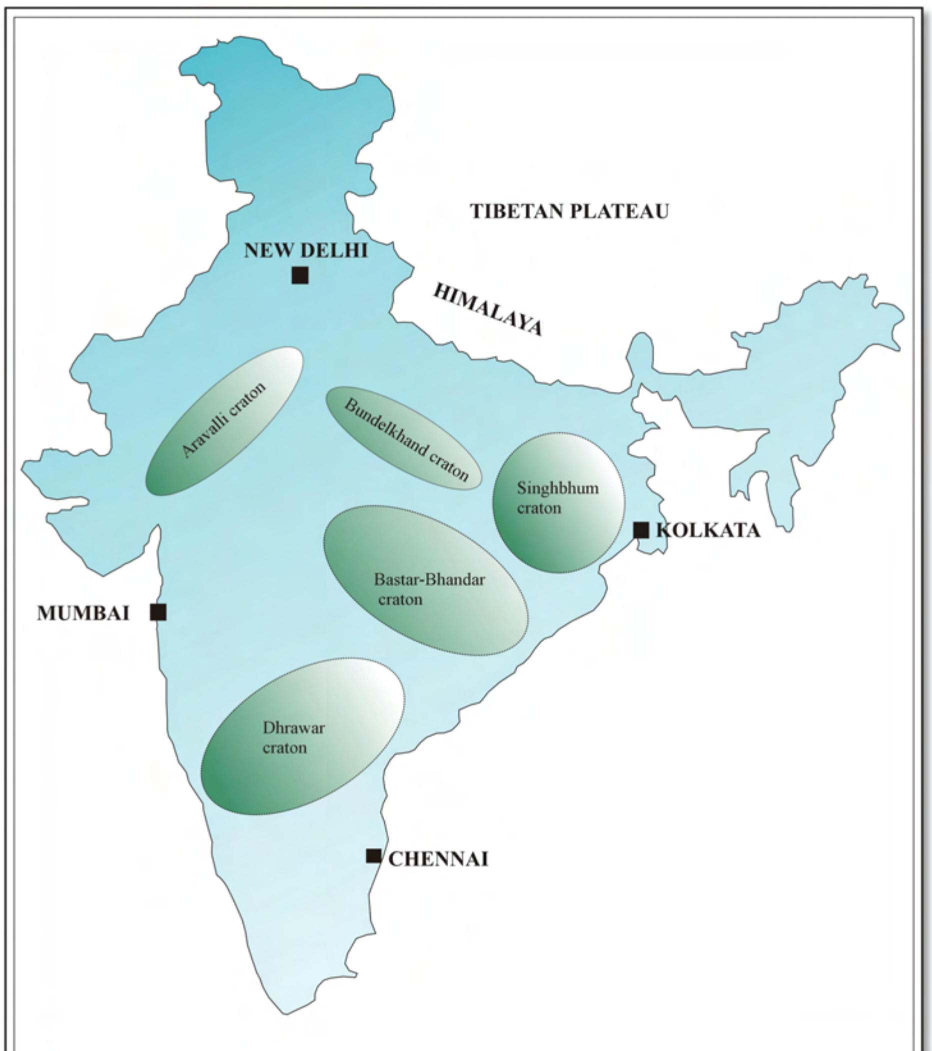

Fig. 2.1. Distribution of Archean cratons in India (modified after Naqvi 2005)

2.2.1. Older Metamorphic Group (OMG)

Older Metamorphic Group collectively refers to metasedimentary-metavolcanic enclaves within Singhbhum granitoid. The metasedimentaries include quartzite-phyllite-mica schists and banded quartz-cummingtonite-grunerite rocks (metamorphosed BIF) and metachert/fucshite quartzites (Saha 1994). Banded calc-gneiss and para- and ortho-amphibolites are interbedded with schists and quartzites. The OMG is variably folded with imprints of more than one generation of folding and development of planar structures. The OMGs are intruded by tonalitic gneisses and granites of different phases. This Older Metamorphic Group (OMG) is intruded by and subsequently co-folded with the oldest granitoid in the Singhbhum craton (Saha 1994; Goswami et al. 1995; Acharyya et al. 2010a, 2010b). The average chemical compositions of pelites are slightly higher in SiO_2, K_2O, K_2O/Na_2O ratio, Cr, Ni, Cu and to some extent in V and Ga and poorer in TiO_2, CaO, Al_2O_3, Sr, Li, Y. The orthoamphibolites from OMG have a tholeitic affinity (Saha 1994) or boninitic affinity (Manikyamba et al. 2015) suggesting that these are metabasic volcanics. The OMG ortho-amphibolite shows slightly richer in LREE and nearly flat HREE pattern and have yielded ages not older than ~3.3 Ga or boninitic affinity (Ray et al. 1991; Sharma et al. 1994). This group is representative of oldest sedimentation and volcanism episode during Paleo- Mesoarchean time. The U-Pb detrital zircon ages from the OMG range from 3.55-3.2 Ga (Goswami et al. 1995; Mishra et al. 1999; Misra 2006; Hofmann and Mazumder 2015).

Table 2.1. Generalized stratigraphic succession of the Precambrian of the Singhbhum craton (modified after Saha 1994 incorporating radiometric dates from subsequent workers Mazumdar 1996; Mishra et al. 1999, 2000; Misra 2006; Mukhopadhyay et al. 2006, 2008a; 2014; Tait et al. 2011; Sarkar and Gupta 2012; Upadhyay et al. 2014; Hofmann and Mazumder 2015; Ghosh et al. 2016; Dey et al. 2017; Chaudhuri et al. 2018).

Chronostratigraphic units	Stratigraphic status and Radiometric ages
Kolhan Group	Mesoproterozoic (Mukhopadhyay et al. 2006)
Chaibasa metasediments (overlying Dhanjori Group)	<2.1 Ga (metamorphic event at~ 1.6-1.5 Ga)
Soda Granite	1.63-1.66 Ga (Rb-Sr) (metamorphic event), 2.2 Ga (Pb–Pb) (Sarkar et al. 1986)
Jagannathpur basaltic lava	2.25 Ga (Pb-Pb) (Misra and Johnson 2005)
DalmaVolcanics (Lower)	2.0 Ga (Ar-Ar) , 2.3-2.2 Ga (Sarkar et al. 1969; Roy 1998)
Dhanjori Volcanics (Upper) Dhanjori Volcanics (Lower)	2.1 Ga (Sm-Nd) (Roy et al. 2002) 2.4-2.3 Ga (Ar-Ar) (*in* Sarkar and Gupta 2012, p. 417))
Newer Dolerite dyke system	2.2-1.2 Ga (Rb-Sr); 2.6 Ga (Rb-Sr)
Tamperkola Granite-Pallahara Gneiss	2.8 Ga
Keonjhar- Mahagiri Quartzite	~3.0 Ga (Mukhopadhyay et al. 2014)
Singhbhum Granite (SGB-B), Mayurbhanj Granite	3.1 Ga (Pb–Pb), 3.28 Ga (SHRIMP Pb-Pb, zircon), 2.37-1.90 Ga (Rb-Sr), 2.8-0.8 Ga (U-Pb) (Misra et al. 1999; Vohra et al. 1991)
Iron Ore Group (IOG-eastern)- Badampahar-Gorumahisani belt	>3.12 Ga (intruded by SGB)
Sinhgbhum Granite (SBG-A), Kaptipada Granite, Bonai Granite (Tonalitic)	3.3 Ga (Pb–Pb, Rb-Sr, Sm-Nd), 3.38 Ga (SHRIMP, Pb-Pb, zircon), 3.45-3.44 Ga (Pb–Pb zircon) (Moorbath et al. 1986;Vohra et al. 1991; Sengupta et al. 1991; Saha 1994; Misra et al. 1999; Nelson et al. 2007; Upadhyay et al. 2014; Dey et al. 2017)
Iron Ore Group (IOG-Western)	3.39 Ga (U-Pb LA-ICPMS zircon ages) (Basu et al.2008)
Older Metamorphic Tonalitic Gneiss (OMTG)	3.4-3.35 Ga (Pb-Pb, Rb-Sr); 3.44 Ga (Pb-Pb); 3.4 Ga (Sm-Nd, Ar-Ar); 3.5-3.4 Ga (U-Pb, zircon), mantle zircon xenocryst (around 4.2 Ga, Chaudhuri et al. 2018) (Moorbath and Taylor 1988; Misra et al. 1999)
Older Metamorphic Group (OMG) IOG-south (Daitari-Tomka)	3.3 Ga (Sm-Nd); 3.6-3.5 Ga (Pb-Pb); 3.6-3.55 Ga (Pb-Pb); 3.51 Ga (SHRIMP Pb-Pb, zircon)(Sharma et al. 1994; Goswami et al. 1995; Misra et al. 1999; Mukhopadhyay et al. 2008a)

2.2.2. Older Metamorphic Tonalite-Gneiss (OMTG)

The oldest pluton in the craton is tonalite gneiss that intrudes the OMG and is known as Older Metamorphic Tonalite Gneiss (OMTG). The OMTG includes components of tonalite-trondhjemite and granodiorites typical of similar Archean granite plutons. Tonalites are enriched in Mn and Sr and are somewhat depleted in Ti, V, Y, Ba, Rb and Zr. REE-pattern in general has gentle slope with moderate LREE enrichment without Eu-anomaly (Eu/Eu* = 0.89-1.08) and moderate HREE depletion. Mishra et al. (1999) suggested a mean age of ~3440 Ma for the OMTG. Acharyya et al. (2010a and 2010b) documented LA-ICPMS U-Pb zircon ages of 3448 ± 19 Ma and 3527 ± 17 Ma from the OMTG. Recently, Chaudhuri et al. (2018) reported Hadean zircons (4.0 to 4.2 Ga) of enriched mantle affinity from the OMTG.

2.2.3. Singhbhum Granite (phases I, II and III), Bonai Granite, Kaptipada Granite, Mayurbhanj Granite and Pallahara Gneiss

2.2.3.1. Singhbhum Granite

Singhbhum Granite forms the core of the craton. Saha (1972), described 12 different magmatic bodies identified in SBG are grouped into Phase I, II and III, based on the petrological and geochemical characteristics (Saha 1972; Saha 1994). Singhbum Granite (SBG) includes three phases of emplacement between ~3.4 Ga and 3.1 Ga (Phase-I: 3.44 Ga, Phase-II: 3.3 Ga and Phase-III: 3.1Ga) (Saha 1994; Ghosh et al. 1996; Misra et al. 1999; Mukhopadhyay 2001; Misra 2006; Acharyya et al. 2010a, 2010b; Tait et al. 2011). Upadhyay et al. (2014), however, suggests that two phases of granitoids emplacement, the first phase of emplacement occurs at 3.45-3.44 Ga and second phase at 3.35-3.32 Ga. Based on REE distribution patterns Saha (1994) grouped the SBGs into clearly into two distinct types: SBG Type A and SBG Type B

(Saha et al. 1984). Type A includes the units from Singhbhum Granite Phase I and Phase II whether Type B belongs to the Phase III. SBG Type A is characterized by gently sloping REE with depleted HREE pattern and with very weakly negative or without Eu- an anomaly. Type B Singhbhum Granite shows enrichment of LREE and flat HREE pattern and is characterized by strong negative Eu- anomaly (Saha et al. 1984). Petrogenetic modeling, SBG-A parent magma was generated by partial melting of OMG orthoamphibolite (Saha 1994).

2.2.3.2.Bonai Granite

Bonai Granite occurs in the western part of the Singhbhum craton and is separated by Jamda-Koira western IOG basin from the SBG (Fig. 2.2). Bonai Granite dominantly comprises of granite-granodiorite and is rarely composed of tonalite. The major and REE elemental distribution shows distinctive characteristics. The major element component shows positive enrichment of SiO_2 and alkalies, depleted in MgO, CaO and Fe-oxides and equal proportion in Na_2O and K_2O (Saha 1994). REE distribution pattern indicates LREE depletion and negative Eu anomaly for xenolithic trondhjemites, whereas positive enrichment of LREE, flat HREE with moderate to strong negative Eu- anomaly patterns for porphyritic granitoid and equigranular trondhjemite (Sengupta et al. 1991; Saha 1994).

2.2.3.3. Kaptipada Granite

The south-eastern part of the Singhbhum Granite near Nilgiri district granite batholith is known as *Kaptipada Granite*. The major component of this batholith composed of amphibolite, migmatite, and tonalite- trondhjemite-granodiorite (Saha 1994). Geochemical distribution pattern of this granitoids shows positive enrichment of CaO, Sr, Zr , depleted in SiO_2 and K_2O and negative Eu anomaly compared to

OMTG (Vohra et al. 1991; Saha 1994; Mukhopadhyay 2001). The age of the granite-granodiorite is an around 3275 ± 81 Ma by Rb-Sr whole-rock dating method (Vohra et al. 1991; Dasgupta et al. 1992; Saha 1994; Mukhopadhyay 2001).

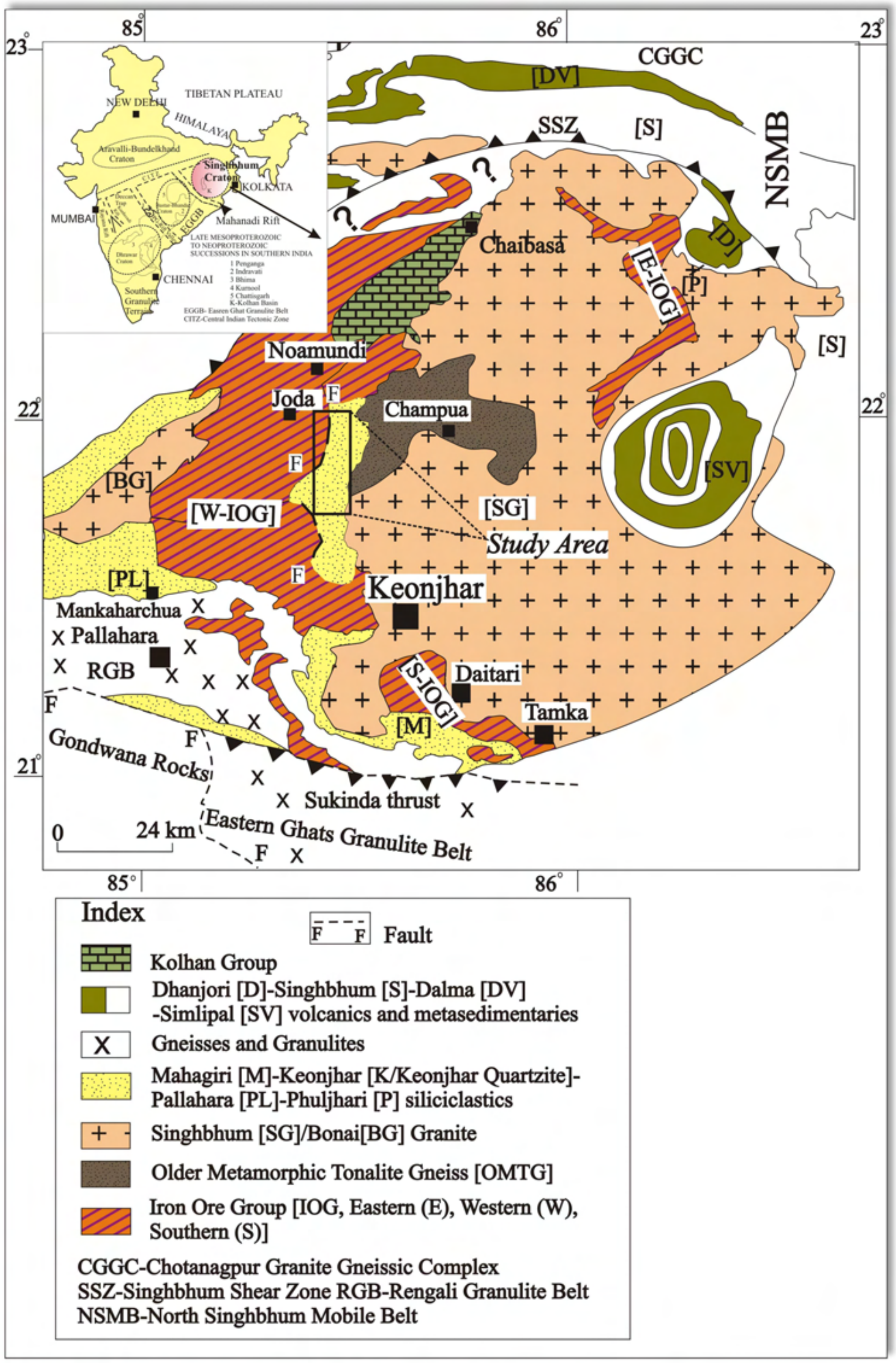

Fig. 2.2. Generalized geological map of the Singhbhum craton (modified after Saha 1994). Inset with distribution of Archean cratons of the peninsular India.

2.2.3.4.Mayurbhanj Granite

Mayurbhanj Granite is a small granitoid body situated in eastern part of Singhbhum craton. It is composed of ferrohastingsite-biotite granite, granophyric-microgranite, aplogranite rocks. Geochemically granite body is positively enriched with K_2O and slight LREE and flat HREE pattern (Saha 1994).The age of the Mayurbhanj Granite is debated. Saha (1994) suggested a Paleoproterozoic age, alternatively, a Neoarchean age has been reported by Misra (2006).

2.2.3.5.Pallahara Gneiss

Pallahara Gneiss is formed south western part of the Singhbhum craton. It is bounded by the Rengali Mobile Belt to the south and is bounded by Mankaharchua basin, other volcano-sedimentary basins and Malangtoli Lava towards north and the Malayagiri greenstone belt in the eastern part (Saha 1994). The main components of Pallahara gneissic complex are syeno-monzonite, monzo-granite and granite with metaluminous to peraluminous nature (Saha 1994; Mohanty et al. 2008). It is shows a complex REE distribution pattern with strong positive LREE, flat HREE and negative Eu-anomaly (Mohanty et al. 2008).

2.2.4. Iron Ore Group (IOG)

The Iron Ore Group (IOG) occurs in the three detached synformal outcrop towards eastern, western and southern flanks of the Singhbhum craton (Saha 1994). These IOG belts are surrounded by the Singhbhum batholiths in eastern, western and southern margins and are known as Eastern IOG, Western IOG and Southern IOG (Fig.2.2). Main rock types are low grade metasediments including phyllites, tuffaceous shales, banded hematite jasper (BHJ) with iron ore, ferruginous quartzite, local dolomite, acid-intermediate and mafic volcanics, podiform chromiferous untramafics (Jones 1934; Dunn and Dey 1942; Prasad Rao et al. 1964; Banerji 1977; Banerjee 1982, 1997; Iyenger and Murthy 1982; Bose 1982, 1990; Saha 1994; Sengupta et al. 1997; Acharya 2002; Saha et al. 2004; Mondal et al. 2006; 2007;Ghosh and Mukhopadhyay 2007; Beukes et al. 2008; Mukhopadhyay et al. 2008a, 2008b, 2008c, 2012; Ghosh et al. 2010; Singh et al. 2016). The stratigraphic status of the IOG rocks remains controversial. U-Pb SHRIMP zircon ages from the southern IOG suggest the oldest among them is as old as 3.51 Ga (Mukhopadhyay et al. 2008a). The western IOG yielded 3.39 Ga U-Pb LA-ICPMS age from acid volcanics (Basu et al. 2008). Minimum age of deposition for the Eastern IOG is proposed at 3.1 Ga from intrusive granite relationship.

2.2.5. Neoarchean-Paleoproterozoic supracrustals

2.2.5.1.Dhanjori Formation

Dhanjori Formation unconformably overlies the eastern IOG and Singhbhum Granite in the north eastern part of Singhbhum craton (Dunn and Dey 1942; Sarkar and Saha 1962, 1963; Sarkar et al. 1977; Saha 1994). The quartzite and mica schist directly overlie the Singhbhum Granite batholiths and top of the formation comprised with mafic and ultramafic tuffs and intrusives, and tholeiitic lavas (Dunn and Dey 1942; Gupta et al. 1985; Saha 1994; Mazumder 2012).

2.2.5.2.Dalma Volcanics and Simlipal Volcanics

Dalma Volcanics are situated in north eastern part of the Singhbhum craton and lies between Chottanagpur Granitic Gneissic Complex (CGGC) and Northern Singhbhum Mobile belt (NSMB). This unit of the eastern India craton is basically characterized by two units: lower one comprised of magnesian ultrabasics and upper one comprised of mafic lavas (Dunn and Dey 1942; Saha 1994). Geochemically, this volcanic shows high abundance of SiO_2, MgO, Ni and Cr and low abundance of Al_2O_3, Na, K, Rb, Ti, P, Sr and Ba of these elements (Dunn and Dey 1942; Saha 1994).

Saha (1994) documented a large ovoid shape basin of mafic volcanics in the eastern part of the Singhbhum craton, overlies the Archean basement. This volcanic named as Simlipal basin (Iyenger and Banerjee 1964). This volcanics are mainly comprised of spilitic lava and tuffs with low in Al_2O_3 and K_2O and relatively rich in MgO and MgO/FeO is 1.

2.2.5.3.Jagannathpur Lava

This mafic lava lies in between Jagannathpur and Noamundi-Joda region. It unconformably overlies the Singhbhum Granite towards east and south, and by the Kolhan Group towards north of this successions (Saha 1994). Chemical elemental analysis of the Jagannathpur volcanic reveals the composition of this lava,which consistsof meta-andesite, meta-oligoclase andesites and meta-basalts, (Saha 1994). Besides having MgO, Ni and Cr that are higher than normal range for andesitic tholeite (Alvi and Raza 1991; Saha 1994).

2.2.6. Kolhan Group

Kolhan Group of the Singhbhum craton unconformably overlies the western IOG and the Singhbhum Granite (Dunn 1940; Saha 1994). The western margin of the Kolhan Group is faulted against western IOG near Noamundi. The Kolhan Group includes the Mungra Sandtone, Jhinkpani Limestone and the Jetia Shale in ascending order. The Mungra Sandstone is a shallow shelf sandstone with evidences of storm deposits, the Jhinkpani Limestone is a deep-water distal ramp limestone-mudstone

(Mukhopadhyay et al. 2006) which grades upwards to a deep-water Jetia Shale (Mukhopadhyay et al. 2006). Recently, Ghosh et al. (2018) reported thrust-related deformations from the Kolhan Group. There is no radiometric age data for accurately placing the Kolhan succession in chronostratigraphy, however, based on comparative sedimentological characters and stratigraphic build ups, the Kolhans are considered as a part of the extensive deep-water carbonate platform during the terminal Mesoproterozoic Purana basins of peninsular India (Mukhopadhyay et al. 2006).

2.2.7. Newer Dolerite Dyke swarm

A prominent set of reticulating mafic dyke swarm with very wide age of emplacement from Neoarchean to Mesoproterozoic or even younger is found to traverse (NNE-NE and occasionally with NW trend) the Precambrian Singhbhum granitic complex and other supracrustals in the district of Singhbhum, Keonjhar and Mayurbhanj in the eastern India Shield (Dunn 1929; Jones 1934; Krishan 1937; Dunn and Dey 1942; Iyenger and Alwar 1965; Saha and Guha 1968; Saha1972; Saha et al. 1973; and Saha 1994). The major rock type is quartz dolerite associated with norite. Also rare occurrence of granophyre, microgranite, syenodiorite are associated with the dolerites (Saha 1994; Mukhopadhyay 2001).