Paleogeography of the Indian Peninsula vis-à-vis geodynamic and petrotectonic significance of the Vindhyan basin with special reference to Neo-Meso Proterozoic

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1. ABSTRACT

Indian Peninsula emerged as a result of assembly of several cratons viz., Aravalli–Bundelkhand (Rajasthan), Dharwar along with the Southern Granulite Province, Bastar, Singhbhum and Meghalaya formed as cratonic nuclei around 3.0 Ga. All these cratons were formed as three independent groups and stabilized around 2.5 Ga. These cratons lived through progressive stabilization, post stabilization intrusive events including mafic dyke swarms and Proterozoic sedimentary basins development within the cratons. Mafic dyke swarms are the indicators of crustal extension and can represent supercontinent assembly and/or dispersal, subduction, large igneous province emplacement, and crust/mantle interaction. The cratonic group consisting of Dharwar along with the Southern Granulite Province collided and subducted below the cratonic group Aravalli–Bundelkhand (Rajasthan) craton along Central India Tectonic Zone (CITZ) closing the basin along CITZ at around 2.0 Ga. Vindhyan basin is the product of back-arc extension. The subduction along CITZ has evolved a trench, an arc and a back-arc zone covering almost entire Vindhyan basin. The east-west trending linear almost parallel zone of low-gravity and high gravity; and isolated circular low gravity closures strongly support the occurrence of trench, arc and back-arc basin. The basal Aravali volcanics of 2.075 – 2.150 Ga indicates that the sedimentation in the Vindhyan basin started earlier than 2.1 Ga after the cratonic stabilization. However, the radiometric age suggests that the Vindhyan Supergroup spans an age range from 1.75 to 0.6 Ga.

The exact nature of collision of Bastar, Singhbhum and Meghalaya as one cratonic group with the above two groups is not clear but most probably was a transpressional welding. The occurrences of Cauveri extensional basin, Godavari rift basin, Rewa-Mahanadi rift basin, Singhbhum shear zone and Ghatal-Bardwan-Purnea master basin; and the structural fabrics of the Eastern Ghat Terrane suggest a transpressional tectonics between the two. India Peninsula existed as a separate cratonic assemblage near high to mid-latitudes until the rifting event occurred in the western margin of Laurentia between 800 – 700 Ma. The drifting of Australia and Mawson continent from western margin of Laurentia around 750 Ma entered in the process of Gondwanaland assembly with India and eventually western Australia Yilgarn and Pilbara cratons were occurring close to Meghalaya craton of Indian Peninsula.

Vindhyan basin contains one of the largest and thickest sedimentary successions of the world namely Vindhyan Supergroup. As high as 6000 m thick sequence of sandstone, shale and limestone deposition indicate that the basin has undergone very unstable tectonic activities changing the depositional environment frequently. About 500 km long elongated basin has further undergone the impact of volcanic, tectonic and sedimentary loading during the breakup of Gondwana from Kerguelan hot spot. Mantle-lithospheric thickening, sedimentary & volcanic loading, lower crust melting and crustal thinning beneath the Vindhyan basin resulted in large scale subsidence to form a deeper basin environment with the progressive development of the rift-zone aligned with Narmada-Son Rift. En-echelon arrangement of Rawatbhata-Aklera structural elements of the Vindhyan basin bears the evidence of extensional strike-slip component. Deccan volcanics overlying Vindhyan Supergroup suggest
shallow mantle and high density material flow in the lower crust beneath the Vindhyan basin. Long prevailing extensional tectonic environment is responsible for the development of deep seated geo-fractures for magmatic activities and mineralization in the Vindhyan basin region. The tholeiitic nature of Deccan volcanics further supports an extensional and diverging tectonic environment. The tholeiitic nature of Deccan volcanics also advocates for containing highly enriched LIL (large-ion lithophile) elements.

Key Words: Indian Peninsula, Cratons assembly, Paleogeography, Geodynamics, Petrotectonics, Vindhyan basin.

2. INTRODUCTION

The Indian peninsula covers approximately 5,000,000 km². Although India is connected geographically to the Eurasian continent, the subcontinent and Himalayan sectors make up a distinct lithospheric plate. The Precambrian geology of Peninsular India covers nearly 3.0 billion years of time. It comprises several cratonic nuclei namely, Aravalli–Bundelkhand, Dharwar (divided into western & eastern) along with the Southern Granulite Province, Bastar, Singhbhum and Meghalaya Cratons (Fig. 1).

Figure 1: Cratons and Proterozoic basins of India. DFB: Delhi Fold Belt, AFB: Aravalli Fold Belt, VB: Vindhyan basin, CITZ: Central India Tectonic Zone, CIS: Central Indian Suture, ChB: Chhatissgarh basin, NSL: Narmada-Son Lineament, IB: Indravati basin, MR: Mahanadi Rift, EGMB: Eastern Ghat Mobile Belt, GB: Godavari basin, CuB: Cuddappah Basin, CG: Clospet Granite, BPMB: Bhavani–Palghat Mobile Belt.
Cratonization of India was polyphase, but a stable configuration between the major elements was largely complete by 2.5 Ga (Meert et al., 2010) with progressive stabilization of the cratons. Each of the major cratons was intruded by various age granitoids, mafic dykes and ultramafic bodies through-out the Proterozoic. The geological history of Peninsular India encompasses the constituent cratonic nuclei, their bordering orogenic belts, intrusive and extrusive cover and the sedimentary basins. Post-stabilization intrusive events including mafic dyke swarms and Proterozoic sedimentary basins developed within the cratons. The cratons of India have mostly evolved as independent nucleuses and assembled from independent geographic palaeo-positions. The assembly process has undergone through a variable geodynamic state of art resulting in variable petroprotectic characters. The present understanding of the nature of cratonic assembly and resulting geotectonic elements, magmatism, mineralization of Indian Peninsula is in the state of controversy. The present study is an attempt to through some light towards arriving a common understanding.

3. BRIEF GEOLOGY OF THE CRATONS

3.1. Dharwar Craton

The Archaean Dharwar craton (also called Karnataka craton) is an extensively studied terrain of the Indian shield. It is made up of granite-gneiss-greenstone (GGG trinity belts). The craton occupies a little less than half a million sq. Km area. It is limited in the south by the Neoproterozoic Southern Granulite Belt (SGT) or Pandyan Mobile Belt of Ramakrishnan (1993), in the north by the Deccan Trap (late Cretaceous), in the northeast by the Karimnagar Granulite Belt (2.6 Ga old) which occupies the southern flank of the Godavari graben, and in the east by the Eastern Ghats Mobile Belt (EGMB) of Proterozoic age. Dharwar craton, as the northern block of southern Indian shield is a dominant suite of tonalite-trondhjemite-granodiorite (TTG) gneisses which are collectively described under the familiar term Peninsular gneisses. The TTG suiteis believed to be the product of hydrous melting of mafic crust and a last stage differentiates of mantle, accounting for crustal growth, horizontally and vertically. The available geochronological data indicate that the magmatic protolith of the TTG accreted at about 3.4 Ga, 3.3 – 3.2 Ga and 3.0 – 2.9 Ga (Sharma, 2009). The greenstones are mainly voluminous basalts with subordinate fine clastics and chemical sediments and in certain areas with basal conglomerate and shallow water clastics (ripple-bedded quartzites) and shelf sediments (limestone and dolomite). In the Dharwar craton, both volcanics and sediments are the supracrustal rocks overlying basement of Peninsular gneiss (>3.0 Ga). During Dharwar orogeny, the volcanics have been metamorphosed into greenschist (chlorite schist) and amphibolite and even higher grade basic granulites while the associated sediments have been recrystallized into quartzite, crystalline marbles and meta-pelites (Ramiengar, 1978). The late Archaean Closepet granite of southern India is bounded by N-S trending shear zone. At the southern end of the granite both charnockite and granite veins are spatially associated with ductile shears. These shears continue further north and are confined to the contact zones in the central part of the granite outcrop. The main component of the shear zone are highly deformed granite sheets, augen gneisses and mylonites. Field observations and microstructural fabric of mylonites indicate a dextral sense of shear movement (Jayananda and Mahabaleswar, 1991).
3.2. Bastar craton

The Bastar craton (BC) is also called Bastar – Bhandara craton located NE of Dharwar craton. It is bordered by the Pranhita–Godavari rift to the south, the Mahandi Rift in the northeast, Satpura Mobile Belt in the north, the Eastern Ghats Mobile Belt to the east and Deccan Traps cover to the west. The craton consists mainly of granites and granitic gneisses and contains three major features: (1) a trio of supracrustal sequences, (2) mafic dyke swarms, and (3) the Satpura orogenic belt (Naqvi and Rogers, 1987; Srivastava et al., 2004). The “Gneissic Complex” is dominated by suite of tonalite-trondhjemite-granodiorite (TTG) assemblages dated to between 2500 and 2600 Ma that are interpreted to reflect a major interval of crustal accretion (Ramakrishnan and Vaidyanadhan, 2008). A tonalite sample yielded a U–Pb upper intercept age of 3561 ± 11 Ma (Ghosh, 2004) thought to reflect the oldest age of the gneissic protolith. Sarkar et al., (1993) report an age of 3509 +14/−7 Ma for another gneissic protolith with in the complex. On the NW of the Bastar craton there also occurs a vast exposure of gneissic complex, known in the literature as Tirodi gneiss, which is a two-feldspar gneiss with biotite and occasionally garnet. The Bastar Craton contains at least three major supracrustal sequences of rocks viz., the Dongargarh, the Sakoli, and the Sausar suites. Of these three suites, only the Dongargarh Supergroup has been dated. Ancient supracrustals consisting of quartzite-carbonate-pelite (QCP) with BIF and minor mafic-ultramafic rocks, collectively called Sukma Group in the south and Amgaon Group in the north, occur as scattered enclaves and narrow belts within Archean gneiss and granites. The succeeding metasedimentary belt is called Bengpal Group. The sequence is intruded by Archaean granites and the Bengpal Group is considered Neoarchaean (2.5 - 2.6 Ga). Unconformably overlain on the Bengpal Group Schists are BIF (Bailaddila Group). The next succession is felsic and mafic volcanics with pyroclastics (Nandgaon Group) intruded by 2.3–2.1 Ga old granites. In Bastar craton the gneisses are classified into five types (Sharma, 2009) i.e., the Sukma granitic gneiss (Group 1), Barsur migmatic gneiss (Group 2), leucocratic granite (Group 3) occurring as plutons with migmatitic gneiss, pegmatoidal or very coarse granite (Group 4), and fine-grained granite (Group 5) occurring amidst the Sukma gneisses. The gneisses of Groups 1 and 2 are chemically and mineralogically similar to the Archaean TTG, while the gneisses of Groups 3, 4 and 5 are of granitic nature.

3.3. Aravalli–Bundelkhand craton (Rajasthan craton)

The Aravalli–Bundelkhand protocontinent (Fig. 1) occupies the north-central region of the Indian subcontinent. The Rajasthan craton (RC) is an amalgamation of two cratonic blocks viz., the Banded Gneissic Complex–Berach Granite (BBC) and the Bundelkhand Granite massif (BKC). Rajasthan craton is in fact a large Rajasthan–Bundelkhand craton. These two cratonic blocks are separated by a vast tract of cover rocks, beside the occurrence of the Great Boundary Fault at the eastern limit of the BBC block, making the correlation between the two cratonic areas difficult. However, the two blocks have a common lithology that includes gneisses, migmatites, meta-volcanic and meta-sedimentary rocks and a number of granitic intrusions. These cratons are bounded to the north-east by the Mesoproterozoic-aged Vindhyan Basin and Phanerozoic alluvium and to the south by the northern edge of the Deccan Traps volcanic rocks. The Bundelkhand and Aravalli Cratons are also separated from the Bastar and Singhbhum Cratons by the Narmada-Son lineament. Both BBC and BKC blocks have been affected by similar deformational events (Naqvi and Rogers, 1987). The two blocks also share same geodynamic settings in Proterozoic as revealed by geochemistry of their mafic magmatic rocks (Mondal and Ahmad, 2001) and same geochronological ages
(Mondal, 2003). According to Gupta (1934) and Heron (1953) the following broad division of the Precambrian rocks of Rajasthan and the ages from recent publications are obtained.

Malani Rhyolites (730 – 750 Ma)
Erinpura Granite (850 – 900 Ma)
Delhi System
-----------unconformity-----------
Raialo Series
-----------unconformity-----------
Aravalli System
-----------unconformity-----------
Banded Gneiss Complex (3.4 Ga)

The lithological association indicates local rifting of the BGC rocks of the Rajasthan craton during Late Archaean. The rifted basin with its rock deposits were subsequently deformed and metamorphosed during which the 2.9 and 2.6 Ga old granitoid phases of Untala and Gingla were intruded within BGC. With the emplacement of typical Potassic granites of 2.5 Ga age, notably the Berach Granite and Ahar River Granite, the Rajasthan craton was finally stabilized (Sharma, 2009).

3.4. Singbhum craton

The Singhbum craton (SBC) is also called Singhbhum-Orissa craton in eastern India. It is made of Archaean rocks that are exposed in an area of ~40,000 km² in Singhbhum district of Jharkhand (formerly Bihar) and northern part of the State of Orissa. The craton is bordered by Chhotanagpur Gneissic Complex to the north, Eastern Ghats mobile belt to the southeast, Bastar craton to the southwest, and alluvium to the east. Much of the geological information about Singhbhum craton (SC) or Singhbhum Granite Complex (SGC) is due to Saha (1994). The following rock-suite constitute the Singhbhum craton:

1. Singbhum Granite (I, II, III phases) with enclaves of (i) Older Metamorphic Group (OMG), and (ii) Older Metamorphic Tonalite Gneiss (OMTG).
2. Iron Ore Group (IOG,) dominantly Banded Iron formation (BIF) at the margin of the Singhbhum Granite.
3. Volcanics or greenstone belts (Simlipal, Dhanjori, Dalma etc.)

The Older Metamorphic Group (OMG) (Sarkar and Saha, 1977, 1983) is a supra-crustal suite of rocks composed of amphibolita facies politic schists, garnetiferous quartzite, calc-magnesium meta-sediments and meta-basic rocks. Komatitic lavas are missing from the OMG, unlike other Archaean terrains of the world. Radiometric dating of rocks of the OMG does reveal ages older than 3300 Ma. The OMG rocks are synkinematically intruded by tonalite gneiss grading into trondhjemite and designated as the Older Metamorphic Tonalite Gneiss (OMTG). The OMTG (whole rock) has been dated both by Sm—Nd and Rb—Sr systematics. The Sm—Nd age of 3800 Ma for the OMTG is considered as the crystallization age of the magma, although it might also represent the time of generation of mafic melt in the mantle with crystallization of the melt at the base of the crust (Basu et al., 1981). Both OMG and OMTG document two phases of deformation and exhibit a structural accordance, suggesting that the Archaean
deformation occurred after the emplacement of the OMTG. The general strike of the OMTG is NE-SW (Saha, 1994), but folding has changed this to NW-SE. According to Saha (*ibid*) the OMG intruded by the OMTG are the oldest formations in the Singhbhum region (Sarkar and Saha, 1983). They have been folded first about steep NE plunging axes and later about the SE plunging axes, with variable dips, seen in the northern region of the Archaean craton. The Older Metamorphic Group in the type area has the axial planes of the first generation strike NW, with axes plunging NE. These have been affected by folds plunging towards SE (Sarkar and Saha, 1983).

3.5. Meghalya craton

The Precambrian rocks in the eastern India occur in the Shillong Plateau of the Meghalaya State and in the Mikir Hills (also called Kabri Hills) Plateau located in the State of Assam. The oldest unit in the Meghalaya craton is the Archaean Gneissic Complex or Older Metamorphic Group (Mazumder, 1976). It consists of granite gneiss, augen gneiss and upper amphibolite to granulite facies metamorphic rocks. The latter rocks are cordierite-sillimanite gneiss, quartz-feldspar gneiss (orthogneiss) and biotite schists with or without hornblende (Rahman, 1999). Bidyananda and Deomurari (2007) dated zircons from quartz-feldspathic gneisses of the Meghalaya craton. The $^{207}\text{Pb}/^{206}\text{Pb}$ isotope gave $2637 \pm 55$ Ma for core and $2230 \pm 13$ Ma for rim of the mineral, indicating that the cratonic gneisses are Archaean, not unlike other cratonic regions of the Indian shield, and that the thermal overprinting on these basement rocks occurred during Proterozoic event(s).

4. GEOLOGY OF THE VINDHYAN BASIN

The Vindhyan Basin is one of several “Purana” (ancient) sedimentary basins of the Indian subcontinent. It is a sickle-shape basin that outcrops between the Archaean Aravalli–Bundelkhand province to the north and west and the Cretaceous Deccan Traps to the south; the Great Boundary Fault marks the western limit of this basin (Fig. 2). The Vindhyan Basin is composed of several smaller sub-basins, the largest of these are referred to as the Rajasthan sector and the Son Valley sector (Fig. 3).

![Figure 2: Sketch map of the major units in the Aravalli–Bundelkhand protocontinent, NW India (after Naqvi and Rogers, 1987; Ramakrishnan and Vaidyanadhan, 2008; Meert et al., 2010).](image-url)
Vindhyan rocks are also exposed in the Bundelkhand sector. Substantially thick Vindhyan rocks have also been recognized under the Gangetic plain. The trondhjemitic gneisses of the Bundelkhand Igneous complex act as a basement ridge between the Rajasthan and the Son valley sectors (Prasad and Rao, 2006). Stratigraphically, Vindhyan Basin can be divided into two sequences: The Lower Vindhyan Sequence formed by Semri Series (Satola, Sand, Lasrawan and Khorip Groups) and the Upper Vindhyan Sequence subdivided into the Kaimur, Rewa and Bhander Groups, respectively (Chaudhari et al., 1999; Prasad, 1984) (Fig. 4). The basin is bounded by the Son-Narmada Geofracture in the south, the Great Boundary Fault in the west, the Monghyr-Saharsa Ridge in the east, and the Bundelkhand Massif and Indo-Gangetic Plains in the north. Bundelkhand Massif divides this basin into two parts – the Son Valley on the southeastern side and the Chambal Valley where exposures occur from Agra (Uttar Pradesh) to Chittorgarh (Rajasthan). The southern margin of the Vindhyan basin is marked by a major ENE–WSW trending lineament termed Narmada–Son lineament south of which occurs the Satpura orogen. A NE–SW trending major lineament known as Great Boundary Fault separating the Aravalli–Delhi orogen from the Vindhyan, also marks the western margin of the Vindhyan basin in the Rajasthan sector. The Vindhyan strata define a broad, regional syncline trending ENE–WSW. The axis of the syncline is slightly curved and plunges gently towards west as revealed from Bouguer gravity anomaly pattern (Bhoj et al., 2012). The Vindhyan Basin was formed as a result of a large crustal downwarp and basin subsidence progressed due to sedimentary and volcanic loading of both crust and upper mantle and is interpreted as a back-arc basin. The geodynamic control on the formation of this basin will be discussed in the preceding section.

The initial transgression is inferred to have taken place from north in the eastern part of the basin over the Bijawars. At the onset of Vindhyan sedimentation, the fault system in the downwarp zone along the Son-Narmada became active with the formation of the southern limit of Vindhyan deposition. After the deposition of Kajrahat Limestone, the Son-Narmada Lineament again became active resulting in emission of volcanic material, which was deposited as the Jardepahar Porcellanite. In the subsequent regression, the shore line shifted towards northwest. The Fawn Limestone was deposited over the shelf in a tidal flat.

<table>
<thead>
<tr>
<th>Vindhyan Supergroup</th>
<th>Rajasthan</th>
<th>Son Valley</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower (Semri Series)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Betola Group</td>
<td>(835 m)</td>
<td></td>
</tr>
<tr>
<td>Sand Group</td>
<td>(210 m)</td>
<td></td>
</tr>
<tr>
<td>Lasrawan Group</td>
<td>(272 m)</td>
<td></td>
</tr>
<tr>
<td>Khorip Group</td>
<td>(475 m)</td>
<td></td>
</tr>
<tr>
<td>Rewa Group</td>
<td>(285 m)</td>
<td></td>
</tr>
<tr>
<td>Kaimur Group</td>
<td>(180 m)</td>
<td></td>
</tr>
<tr>
<td>Bhander Group</td>
<td>(&lt;1200 m)</td>
<td></td>
</tr>
<tr>
<td>Rajatpur L.:</td>
<td>(≥90 Ma)</td>
<td></td>
</tr>
<tr>
<td>Rautpur St.:</td>
<td>(≥12 Ma)</td>
<td></td>
</tr>
<tr>
<td>Bhander La.:</td>
<td>(≥700 Ma)</td>
<td></td>
</tr>
<tr>
<td>Isotopic curve:</td>
<td>±2.0</td>
<td></td>
</tr>
<tr>
<td>Bhander Group</td>
<td>(&gt;1200 m)</td>
<td></td>
</tr>
<tr>
<td>Rewa Group</td>
<td>(296 m)</td>
<td></td>
</tr>
<tr>
<td>Kaimur Group</td>
<td>(425 m)</td>
<td></td>
</tr>
<tr>
<td>Rohtasar Group</td>
<td>(454 m)</td>
<td></td>
</tr>
<tr>
<td>Khetijoga Group</td>
<td>(1050 m)</td>
<td></td>
</tr>
<tr>
<td>Doonpur Group</td>
<td>(1200 m)</td>
<td></td>
</tr>
<tr>
<td>Mesapur Group</td>
<td>(990 m)</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3: Generalized stratigraphic columns of the Vindhyan Supergroup in the Rajasthan sector (left column) and the Son valley sector (right column) along with published age constraints (Malone et al., 2008). The stratigraphic representations here are designed to show correlations and age relationships rather than absolute thickness or stratigraphic continuity (Adopted from Meert et al., 2010).
environment. This was followed by shallowing of the basin as is evident from the overlying Glauconitic Sandstone. The fresh marine transgression resulted in the deposition of marine shales followed by Rohtas Limestone.

5. GEODYNAMIC & PETROTECTONIC SIGNIFICANCE

The Indian Peninsula is a result of the assembly of the cratons, namely Aravilli, Bundelkhand, Dharwar including Southern Granulite, Bastar, Singhbhum and Meghalaya. All these cratons became stabilized around 2.5 Ga. In the present study, the cratons are grouped into three separate groups based on their variations in the age of nucleation, stabilization age, metamorphic events, igneous events and sedimentary basins formation (Fig. 5).

Three major cratonic nuclei viz., a) Aravalli-Bundelkhand, b) Dharwar-Southern Granulite, c) Bastar-Singhbhum is proposed. The cratonization age of Aravalli-Bundelkhand range between

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**Table 1:** Precambrian History of Indian Peninsula

<table>
<thead>
<tr>
<th>Craton</th>
<th>Oldest age</th>
<th>Stabilization age</th>
<th>Metamorphic events</th>
<th>Igneous events</th>
<th>Sedimentary basins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aravalli</td>
<td>3.5 Ga</td>
<td>2.5 Ga</td>
<td>-2.0 Ga (g, d)</td>
<td>1711-1900 Ma (g)</td>
<td>Marwar (&lt;0.5 Ma)</td>
</tr>
<tr>
<td>Bundelkhand</td>
<td>3.3 Ga</td>
<td>2.5 Ga</td>
<td>3.1 Ga (d, g)</td>
<td>2.15 Ga (d)</td>
<td>Vindhyan 1.5-1.0 Ga</td>
</tr>
<tr>
<td>Singhbhum</td>
<td>3.5-3.8 Ga</td>
<td>2.5 Ga</td>
<td>3.1 Ga (d, g)</td>
<td>3.0 Ga (d)</td>
<td>Dharwar (&lt;2.5 Ga)</td>
</tr>
<tr>
<td>Bastar</td>
<td>3.5 Ga</td>
<td>2.5 Ga</td>
<td>3.1 Ga (d, g)</td>
<td>2.5 Ga (d)</td>
<td>Kolar (&lt;1.1 Ga)</td>
</tr>
<tr>
<td>E. Dharwar</td>
<td>2.7 Ga</td>
<td>2.5 Ga</td>
<td>3.1 Ga (d, g)</td>
<td>2.1 Ga (d)</td>
<td>Kolar (&lt;1.1 Ga)</td>
</tr>
<tr>
<td>W. Dharwar</td>
<td>3.6 Ga</td>
<td>2.5 Ga</td>
<td>3.5 Ga (d)</td>
<td>1.1 Ga (d)</td>
<td>Kolar (&lt;1.1 Ga)</td>
</tr>
<tr>
<td>S. Granulite</td>
<td>3.5 Ga</td>
<td>2.5 Ga</td>
<td>-2.5 Ga (d)</td>
<td>300 Ma (g)</td>
<td>None</td>
</tr>
</tbody>
</table>

**Figure 4:** Distribution of Vindhyan Supergroup and basin configuration demonstrate a parallelism of its long-axis with CITZ. (After Ray, 2006).

**Figure 5:** Tectonothermic, metamorphism, igneous activities and basin formation ages of the cratons.
3.3 – 3.5 Ga, Dharwar-Southern Granulite between 2.7 – 3.6 Ga, and Bastar-Singbhum between 3.5 – 3.8 Ga. The $^{207}\text{Pb}/^{206}\text{Pb}$ isotopic age of 2.6 Ga for Meghalaya craton seems anomalous and could neither be grouped with Bastar-Singbhum nor there is enough evidence to put it as a separate cratonic nucleus. Although, the stabilization age of the craton groups are same, the ages of metamorphic events, igneous events and basin formations are distinctly different. The metamorphic events dates range between 0.5 – 3.3 Ga in Dhawar craton and 0.8 – 3.3 Ga in Aravalli-Bundelkhand, while in Bastar it varies between 1.1 – 2.5 Ga. The igneous events age in Dharwar range between 1.0 – 3.35 Ga, and in Bastar-Singbhum 0.9 – 3.5 Ga. The basins in Dharwar craton were formed between 0.6 – 1.8 Ga and in Aravalli-Bundelkhand craton also between 0.6 – 1.8 Ga. The same time-frame in basin formations for both Dharwar and Aravalli-Bundelkhand signify that in both the cratonic groups the basins have been formed from tectonic loading of both crust and upper mantle. The basin formation process initiated when Dhawar craton converged and collided with the Aravalli-Bundelkhand craton. Hence, Dharwar craton collided with Aravalli-Bundelkhand eventually closing the basin between the two during Neo- to Meso-Proterozoic. Bastar-Singbhum cratonic nucleus welded with Dharwar in a transpressional tectonic environment. The assembly of Meghalaya craton with other cratons of Indian Peninsula seems anomalous, however, the correlation of tectono-thermal events between the Central Indian Tectonic Zone and the Albany Mobile Belt of Western Australia by Harris (1993) indicates that Meghalaya craton might have been linked to Yilgarn craton of Western Australia during Neo-Proterozoic.

The above proposed cratonic assembly mechanism of Indian Peninsula is based on the hypothesis given by Shervais (2006).

Figure 6: Schematic model for transition from Hadean-style tectonics to late Archean Phanerozoic-style plate-tectonics: (1) Greenstone-granite terranes accumulate at triple junctions between convergent plates; (2) waning plume volcanism on one plate allows the adjacent plate to expand as the convergence zone shifts toward the waning plume; (3) finally, the expanding plate begins to sink under the hotter, more buoyant shrinking plate to form an asymmetrical convergent boundary. The expanding plate (left side) is denser because it is farther from its parent plume and because thinning of the overlying crust on the expanding plate enhances cooling and thickening of its subjacent mantle lithosphere. The onset of asymmetrical convergence (3) will induce passive upwelling of the asthenosphere along linear rifts, transforming the radially expanding plumes into ridge-centered plumes on oceanic spreading centers. (After Shervais, 2006).
According to Shervais (2006) (Fig.6), the transition from Hadean-style convective overturn, driven by heating from below, and Phanerozoic-style plate tectonics, driven by the sinking of cool lithospheric slabs, was a major turning point in the thermal evolution of the Earth. Prior to this transition the formation of stable, long-lived crust was rare; after this transition, the formation and amalgamation of continental crust became a central theme of tectonic processes. Evidence for Phanerozoic-style plate tectonics includes (1) the formation of oceanic crust at mid-oceanic ridge spreading centers, (2) the formation of island arc volcanic and plutonic complexes, and (3) the formation of accretionary mélange complexes during the subduction of oceanic crust.

It is inferred that after the assembly was completed, the amalgamated Indian Peninsula mostly was located independently in the mid-latitudes, since there is no report on the occurrence of dropstones from the Vindhyan basins or any other Proterozoic basins of the peninsula. The formation of East Gondwana and the assembly of India and Australia started after the breakup of Rodinia during 750 Ma event. The 750 Ma reconstructions have been proposed by Meert and Torsvik (2003) (Fig. 7) shows the breakup along the western margin of Laurentia and the elements of East Gondwana.

The gravity map of the Vindhyan basin (Bhoj, 2012)(Fig, 8) has been used to propose a tectonic model defining the nature of the continent – continent collision between Dharwar and Aravalli-Bundelkhand. The model exhibits that a proto-sea existed between Dharwar craton and Aravalli-Bundelkhand craton. The oceanic crust subducted northward under Aravalli-Bundelkhand along Central India Tectonic Zone (CITZ) giving rise to NE – SW trending trench, a parallel volcanic arc due to the partial melting of the subducting slab and back-arc basin zone in the Vindhyan crustal domain. Eventually, extension, subsidence and basin

Figure 7: 750 Ma reconstruction modified from Meert (2003) showing the western margin breakup of the Rodinia supercontinent. In this reconstruction, eastern Gondwana is broken up into two large segments. (After Meert and Torsvik, 2003).
formation occurred due to sedimentary and tectonic loading of the crust and upper mantle in the Vindhyan crustal domain.

Figure 8: Bouguer gravity anomaly map of Vindhyan basin. The red areas are marked by high trend (high density) and blue areas are marked by low trend (low density). Note the crustal upwarping to the south of the trench. This type of crustal upwarping may occur in the subducting slab immediately before the trench where plate begins to bend. The high density linear feature north of the trench is a volcanic arc in the arc proper. North of the volcanic arc is the back-arc basin zone separated by a NE–SW trending basement ridge.

Figure 9: A proposed petro-tectonic model of Central India Tectonic Zone and Vindhyan basin. (The framework of the model is derived from Dewey and Burke (1973).)
The occurrence of 160 m Khairmalia andesite in the Lower Vindhyan Semri Group (www.infraline.com/.../nelp-vii/vindhyan_basin_nelp_vii.pdf) further suggests the role of tectonic loading by andesitic volcanism from partial melting of the subducting slab on the formation of Vindhyan basin. Although, the Vindhyan basin is an intra-cratonic basin but its genetic evolution suggests a back-arc basin of continent – continent collision of Mesoproterozoic. A petro-tectonic scheme of continent-continent collision of Central India Tectonic Zone (CITZ) and the Vindhyan basin is proposed here (Fig. 9). Various rocks derived from tectono-thermal activities are also proposed. The rock types listed in the model of the Figure 9 is believed to occur in the Vindhyan basin segment. The Vindhyan basin has also undergone with the experiences of Cenozoic tectono-thermal events that is envisaged from the relatively shallow Moho beneath the Central India (Kaila et al., 1979, Kaila et al., 1981) (Fig. 10).

Figure 10: The East-West and the North-South deep seismic sounding of the Central India clearly demonstrates a shallow mantle which is interpreted as derived from Cenozoic mantle plume beneath the triple junction of Kerguelan hot spot.

The Cenozoic tectonothermal source of the Indian Peninsula is attributed to the development of Kerguelan hot spot during the rifting phase of East Gondwana. Hall (2009) has referred P-wave tomographic model of Bijwaard & Spakman (2000) that shows seismic P-wave velocity perturbation at 1100 km depth beneath the Central India (Fig. 11).
6. CONCLUSIONS

The cratons of Indian Peninsula were formed as three independent groups and stabilized around 2.5 Ga until before the Dharwar craton managed to subduct beneath the Aravalli-Bundelkhan craton along the present-day Central India Tectonic Zone (CITZ). The amalgamation mechanism of Baster-Singbhum cratonic nucleus with rest of the cratons of Indian Peninsula is not very clear but the structural fabrics do suggest for a transpressional convergence. Vindhyan basin, although an intracratonic basin of Aravalli-Bundelkhand craton but its formation has been derived from the back-arc extension due to tectonic loading of both crust and upper mantle. An occurrence of 160 m thick Khairmalia andesite in the Lower Vindhyan Semri Group is the indication of partial melting of the subducting slab along a volcanic arc. The Vindhyan basin is characterized by deep-seated geo-fractures as revealed from deep seismic soundings (DSS) and a petro-tectonic and tectono-thermal characterization is proposed wherein the likely-hood occurrence of various rocks derived from tectono-thermal activities are expected.

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Figure 11: 1100 km depth slice of seismic P-wave velocity perturbation of Cenozoic tectonothermal episode under the Central India Peninsula.
8. REFERENCES


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