

Indian Shield: Pristine Shape, Size and Tectonic Framework



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Abstract The Precambrian terrane of Peninsular India is commonly referred to as the Indian Shield. Geological evidences suggest that the pre-existing terrane which evolved as the Indian Shield occupied a much wider area than that of Peninsular India. Known as ‘Greater India’ the pristine Indian Shield underwent repeated decimation during the Phanerozoic, which began with the Jurassic break-up of the Gondwana Land. However, relying on the information from Peninsular India, it is possible to trace out not only the history of destruction, but also the clue to divide this Precambrian crustal block into two major tectonic blocks: the initially formed Precambrian Continental core or Proto-India which formed due to amalgamation of several Protocontinents. The Proto-Indian changed into Indian Shield due to the accretion of granulite/charnockite belts, called the Suspect terranes. The six smaller Precambrian crustal blocks which together constituted the Proto-India include Dharwar, Bastar, Singhbhum, Rajmahal, Bundelkhand, and Aravalli. The Protocontinents are separated from each other by Joins marked by Lineament like the Narmada-Son, or by the Gondwana rift basins like the Godavari, Mahanadi and the Damodar Valley. Geological history of the individual Protocontinent suggests distinctive tectonic pattern, history of evolution and metallogenic traits implying independent growth of each of the Precambrian crustal blocks. Further, strictly independent growth history of the individual Protocontinents rule out operation of any global scale process in the evolution of these fundamental crustal units analogous to the modern Plate Tectonics.

Keywords Indian shield · Greater india · Protocontinents · Phanerozoic reconstitution · Suspect terranes

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The Concept of Indian Shield

The term 'Indian Shield' very often finds place in literature although several aspects of this Precambrian crustal block continue to be ill defined or almost unknown. By definition, a Shield is a large area of exposed Precambrian crystalline (igneous and metamorphic) rocks that remained tectonically stable over a considerable period of geological time. Ideally, the Shield rocks should not have an age younger than that of the youngest Precambrian. The oldest rocks in the Shield areas are generally older than 3.4 billion years.

Use of the term 'Shield' for the Precambrian crustal block of Peninsular India having a typical triangular shape, may appear misnomer considering that the term itself implies a shield-like shape, i.e., the shape of an armour used by ancient warriors to protect their bodies. The shape norm is typified by the Canadian Shield which shows a similar shaped aerial extent. Even if the triangular shaped Peninsular India does not fulfil the shape criterion, southern crustal block of the Indian Subcontinent that lies south of the Indo-Gangetic Alluvial Plain has preserved records of many features which at least partially fulfil the definition of a Shield (Fig. 1). It may be rationally suggested that Precambrian terrane of Peninsular India once constituted a part of much larger crustal block that evolved as a Shield like the Canadian or some other Shield areas of the world. The concept of 'Greater India' in all possibility started emerging from such an understanding about nine decades ago (Argand 1924).

Size and Shape of the Pristine Indian Shield

The pristine shape and size of the Precambrian crustal block presently appearing as the Indian Subcontinent is difficult to ascertain because of the fact that a considerable part of it in the north has undergone extensive reconstitution during the 'Continent-Continent' collision leading to the emergence of the Himalayas during the late Cenozoic (Fig. 2). The geological and geophysical data from the Himalayas also provide evidence that much of its edifice is made of components sliced off from the Indian Shield (Qureshy 1969; Qureshy and Kumar 1992; Warsi and Molnar 1977). The concept is also ingrained in the term 'Extra-Peninsular rocks' used for all the ancient Precambrian elements in this youngest mountain belt by the 'late-eighteenth-early nineteenth century' geologists of the Geological Survey of India (Medlicott and Blandford 1879–81).

Several attempts have been made trying to reconstruct at least partially the true spatial extent (or the size) of the Indian Shield in its northern part. Though differ in detail, the central strand in all these models is that the pristine Indian Precambrian crustal block constituting the Indian Shield had an extension varying between 500 and 950 km (Ali and Aitchison 2008) in the north of the Main Boundary Thrust (the southernmost base of the Himalayas, Valdiya 1998). These estimates are



Fig. 1 The geomorphic division of the Indian Subcontinent comprising three major geomorphic terrains. Modified after Roy (2012)

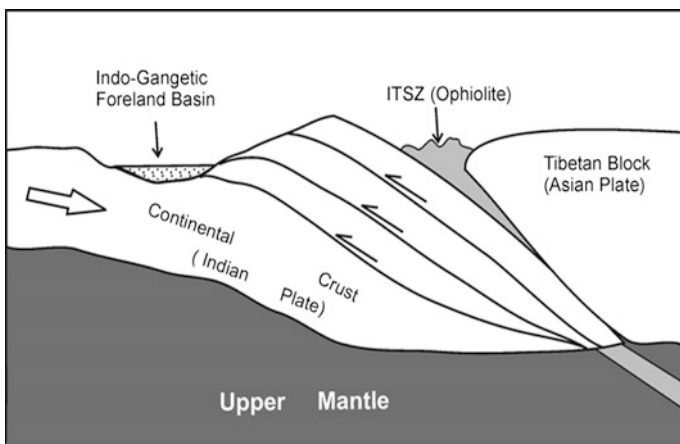


Fig. 2 Schematic illustration of the evolution of the Himalayas resulting from ‘piggy-back riding’ of slices in the northern part of the Precambrian Indian Shield during the collision of the Indian Plate with that of the Tibet (after Roy 2012)

compatible with some of the suggested geodynamic and geophysical models depicting the subducted Indian Lithosphere beneath Tibet, as well as the estimates of the Himalayan shortening (Warsi and Molnar 1977; Le Fort 1975; Molnar and Tapponnier 1975; Valdiya 1984; Searle et al. 1987; Viridi 1987; Dewey et al. 1989; DeCelles et al. 2002).

Apart from its reconstitution along the northern part, the decimation of Indian Shield was caused by separation of Antarctica in southeast, and Madagascar and Seychelles islands in the southwest during the late Phanerozoic. This has added further complications in reconstructing the original dimension of the Indian Shield prior to its reconstitution during the late Phanerozoic (Roy 2004).

There are studies suggesting Indo-Antarctic connection based on the correlation of granulite belts of the two regions (Sen et al. 1995; Sengupta et al. 1999; Dasgupta and Sengupta 2003; Bhadra et al. 2004; Gupta et al. 2005; Kelly et al. 2002). Such a correlation implies that the boundary of the Indian Shield does not end at the eastern margin of the Eastern Ghats 'Granulite' belt but extends far into East Antarctica. However, because of lack of geological information, it is impossible even to guess what could even vaguely be the actual eastern boundary of the granulite belt in Antarctica (placing Antarctica against the present day India!). Like the granulite belt of Eastern Ghats and its continuity into the east Antarctica, the Southern Granulite belt along with Sri Lanka and Madagascar formed a continuous Precambrian terrane in the south and southwest of Peninsular India (Harris et al. 1994; Jayananda and Peucat 1996; Kröner et al. 1991; Radhakrishna et al. 1994, 1999; Storey et al. 1995; Torsvik et al. 2000; Valsangkar et al. 1981; Veeraswamy and Raval 2004). This suggests that the extension of 'Greater Indian Shield' much beyond the boundary of the southern and southeastern Peninsular India (Fig. 1). The Precambrian terrane of the Peninsular India constitute only a part of the 'Greater Indian Shield' which evolved during the Precambrian, and remained virtually undisturbed (by any orogenic event or by thermal perturbation caused by Plume impingement) till the initiation of its break-up in the Phanerozoic.

Summarising, the Indian Shield which evolved as a stabilised Precambrian crustal block covered a wider spatial extent than that of the crustal block of Peninsular India. However, it is not possible to specify the actual size or shape of this Precambrian crustal block because of the successive events of break-up and reconstitution that have taken place during the Phanerozoic (Roy 2004).

Subdivision of Indian Shield: Concept and Perspective

Because of reconstitution as well as destruction of a considerable part of the 'Greater Indian Shield', we have to depend on the geological information only from the region of Peninsular Indian to understand the growth and the framework of the Indian Shield. This is in spite of the fact that a considerable part of the region is under the cover of Phanerozoic rocks like the Deccan Traps, Gondwana formations

and other younger sediments. In the following discussion the Precambrian domain of Peninsular India has been considered as the '*de facto*' Indian Shield for understanding its growth, evolution and tectonic framework.

Krishnan (1948) was amongst the earliest geologists who proposed subdivision of Precambrian terrane of the Peninsular India (henceforth orth described as Indian Shield) by noting divergent patterns of structural trend-lines in different parts. Implied in the Krishnan's suggestion is the fact that the Indian Shield is made of disparate crustal blocks having distinctive tectonic pattern. This must have played in the minds of Naqvi et al. (1974) while suggested that the Indian Shield is made up of a collage of 'Protocontinents' (*smaller fragments of Precambrian Crust forming continental nuclei*). In the present paper, the term Protocontinent suggested by Naqvi et al. (1974) has been used for the individual nuclei of the initially growing Crust. Rogers' (1986) nondescript term 'Join' has been used as the separation plane (trace of which appear as line or linear zone on the surface) between the individual Protocontinent. In the context of the Indian Shield most of these Joins are the sites of Gondwana Rift basins generally overlying 'unclassified Precambrian granitoids', except along the Godavari (P-G) Valley where cratonic-platformal Proterozoic sediments form the basement for the Gondwana rift basins. Implication of using the nondescript term is that it speaks of the contact surface between two separate crustal blocks without stipulating any tectonic model of clustering together, which is truly unknown.

Tectonic Divisions of the Indian Shield

The earliest proposal on the broad tectonic division of the Indian Shield (should read Peninsular Indian Shield) was by Fermor (1936) who divided it into two broad tectono-metamorphic domains: Charnockitic and Non-charnockitic regions.

Since Fermor's (1936) division of the Indian Shield into two exclusive terranes, a number of reports came up indicating occurrence of charnockite and granulite facies rocks from different parts of the Indian Shield outside the Fermor's 'Charnokite Line'. Yet, Fermor's proposal deserves consideration as it provides an important clue to differentiate the Precambrian rocks of Indian Peninsula into two basic crustal types having distinctly different tectonic evolutionary history.

A feature of great significance is the cross-cutting relationship between the Charnockitic and the Non-Charnockitic terranes indicated in the geological Map of India published by Geological Survey of India (1993), especially in the case of the Eastern Ghats Granulite Belt which lies astride the structural grains of the three Precambrian crustal blocks (Dharwar, Bastar and Singhbhum) occurring on its western side. The cross-cutting relationship is most obvious especially in the domain north of the Pranhita-Godavari (PG) Valley. According to Ramakrishnan et al. (1998) the Eastern Ghats Granulite Belt represent a zone of westerly directed thrust slices abutting against the Precambrian block of Bastar. Based on this, the western margin of the Eastern Ghats belt has been interpreted as an ancient Suture

Zone resulting from continental collision very much like the Himalayan collisional tectonics. Quoting Gupta et al. (2005), Leelanandam et al. (2006), and Ramakrishnan and Vaidyanadhan (2008) interpreted the occurrences of ‘deformed alkaline rocks and carbonatites’ along the western margin of the Eastern Ghats belt as a marker of an ancient Suture Zone. The interpretation has a strong support from multidisciplinary studies of Gupta et al. (2000) and Bhadra et al. (2004).

Regarding the tectonic status of the western margin of the Eastern Ghats Belt south of Godavari (P-G) Valley, a little elaboration is necessary in view of some studies made in recent years, especially on tectonostratigraphic status of the Nellore-Kammam schist Belt and associated ensembles. Based on critical evaluation of the existing geological and isotopic data, Dobmeir and Reith (2003) suggested inclusion of the Nellore-Kammam Schist Belt into the domain of the Eastern Ghats (orogenic) Belt. The revision implies not only a change in the original concept of Fermor’s ‘Charnockite Line’, but also the shifting of ‘Line’ further to the west coinciding with the eastern sheared margin of the Cuddapah Basin. In the structural relationship shown in the schematic map (Fig. 3), the western margin of the Eastern Ghats Belt is drawn along eastern margin of the Cuddapah-Kurnool

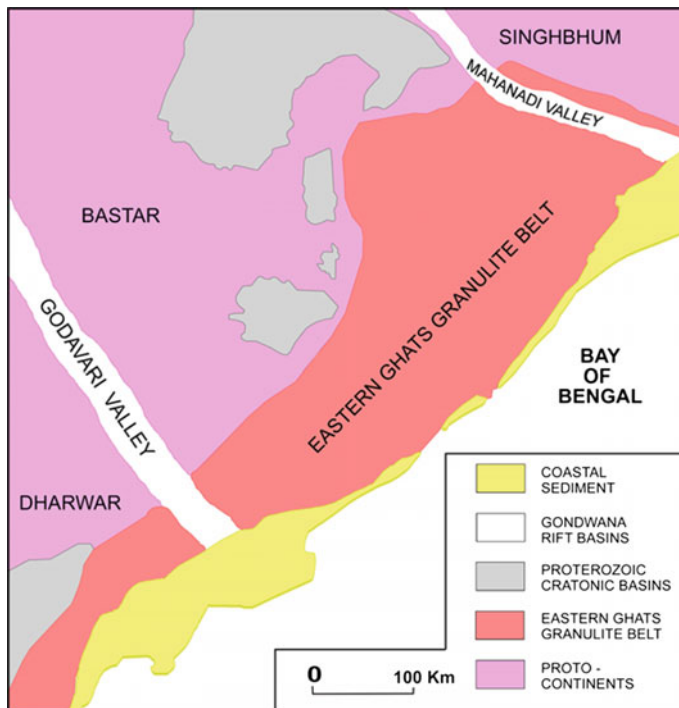


Fig. 3 Geological map showing extent of the Eastern Ghats Belt (with the redefined western boundary in the south), truncating the structural grains of Dharwar, Bastar and Singhbhum Protocontinents

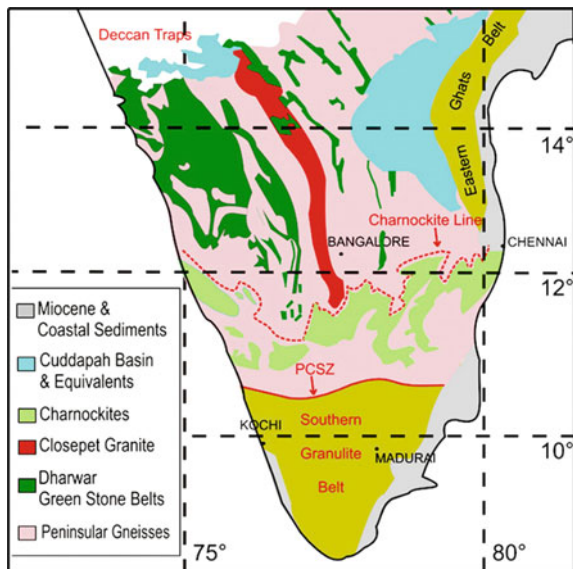
outcrop following the tectonostratigraphic reinterpretation of rock ensembles discussed above.

In the southern part of the (Peninsular) Indian Shield, recent studies indicated continuity of the Dharwar belt further south of the Charnockite Line. Confirmation of the southward continuity of the Dharwarian rocks comes from the reports of end-Archaean ages ranging between 2500 and 2900 Ma both in the charnockitic granulites as also in the Peninsular gneisses further south of the Fermor’s Charnockite Line (Rama Rao 1940; Venkatasubramanian 1975; Friend 1981; Janardhan 1983; Friend and Nutman 1992; Jayananda and Peucat 1996). The field and geochronologic studies indicated continuity of the Dharwarian rocks up to the Palghat-Cauvery Shear Zone, (PCSZ) (Fig. 4). South of the PCSZ occur a crustal block which is tectonically different from the indubitably Archaean granulite terrane in the north. The new tectonic model received weighty support of Drury and Holt (1980) and Drury et al. (1984) based on their studies on Satellite Imagery.

The geochronological support for the concept of the two diverse terranes comes from the reports of ‘younger’ Pan-African tectono-thermal reconstitution ages centring around 500 ± 50 Ma from the granulites and associated rocks from the south of the PCSZ (Harris et al. 1994; Chaudhary et al. 1992; Bartlett et al. 1995; Unnikrishnan-Warrier et al. 1995; Santosh et al. 1992, 2003; Shabeer et al. 2004; Collins et al. 2007). The two juxtaposed terranes across the PCSZ are named as the Northern Granulite Terrain bearing signatures of Archaean evolutionary history in the north, and the Southern Granulite Terrain showing evidence of strong Pan-African tectonothermal reconstitution south of the PCSZ (Srikantappa 1993).

Naming the southern terrane (south of the PCSZ) as SGT may be misleading in view of the fact that the same nomenclature is also in use for the entire granulite

Fig. 4 Lithotectonic map of the southern part of the Peninsular Indian Shield showing major tectonic features. PCSZ = Palghat Cauvery Shear Zone



terrane south of the Fermor's Charnockite Line. Possibly because of that Ramakrishnan (1988) introduced a new term 'Pandyan Mobile Belt' for the southernmost granulite terrane. However, this new nomenclature though appears quite rational did not find general acceptance in literatures (Sharma 2010). In the present paper, therefore, the traditionally accepted nomenclature is used, but after changing the geographic term 'terrain' by the nondescript word 'belt', and with a rider to constrain its northern limit to the south of the PCSZ.

The PCSZ which acts as a tectonic divide between two distinctive terranes is also considered a Suture Zone marking accretion (or welding) of diverse crustal blocks. Some authors advocate that the accretion was caused during collision (of the Dharwar crustal block) with the cratonic blocks of Africa or Antarctica (Ramakrishnan 2003; Sharma 2010).

The rocks of the redefined Southern Granulite Belt show many similarities in lithologic and metamorphic character with those of the Eastern Ghats Belt. Both the belts show Archaean-Palaeoproterozoic protolith ages of the gneisses and granulites, but have undergone significant reconstitution (under granulite facies condition) by the late-Proterozoic tectonothermal events. This could be the reason for mapping the entire charnockite terrane in Peninsular India (*sensu* Fermor 1936) as the 'Eastern Ghats' (Subramanyam 1983). Based on their geographic disposition, these are named the Coastal Granulite Terrain (Eastern Ghats domain *sensu stricto*) and the 'Southern Granulite Terrane' (for the granulite province south of Fermor's Charnockite Line in south India). The combined terranes are known to have their counterparts outside the domain of the Indian Peninsula. Apart from the possibility of their being 'Exotic' or 'Suspect Terranes' (Radhakrishna 1989), the granulite and other high-grade metamorphic rocks comprising the Eastern Ghats and the Southern Granulite Belt (even considering the revised boundaries) appear distinctly different from the components of the Non-charnockite belt in terms of their litho-stratigraphic character, tectono-metamorphic evolutionary history, geochronologic framework, and metallogenic traits. Characterization of the charnockite belts as Exotic or Suspect Terranes implies that the Non-charnockitic domain constituted the primary crustal block or 'Proto-India' (Dobmeir and Raith 2003), the frontiers of which was enlarged because of the subsequent accretion of Charnockite terranes. The concept is ingrained in the thought Mahadevan (1994) who conceived of a 'central core region' as the primary crustal block constituting the Peninsular Indian Shield to which the granulite belts were exhumed. In the present description, however, the term Proto-India is preferred as it appears a little more evocative in describing the framework of the Indian Shield.

Following the suggestion of the early geologists of late nineteenth century of the Geological Survey of India (Medlicott and Blanford 1879–81), the Proto-India comprising components of Fermor's (1936) Non-Charnockitic terrane can be divided into a northern Aravalli-Bundelkhand domain and a southern Gondwana domain. The two domains are physiographically separated by the Narmada-Son River Valley (Basin), which today is better known as the Narmada-Son Lineament (Mahadevan 1994).

The Aravalli-Bundelkhand domain can be further sub-divided into eastern Bundelkhand Mass and western Aravalli Mountains (including part of the western sandy plain of Thar Desert). In spite of many similarities, the emerging thought is that these two Precambrian crustal blocks have evolved more or less contemporaneously but under two different tectonic settings. The Archaean Crust of the Aravalli Mountains enlarged its dimension through stabilization (=cratonization) of three successive Mobile belts during Palaeoproterozoic-early Neoproterozoic. The Bundelkhand Mass, on the other hand portrays a different picture of late-Archaean cratonization with the deposition of Paleo-Mesoproterozoic sedimentary-volcanic succession under stable platformal condition. The difference between the two is also reflected in some way in the lithological character, tectonic pattern and the metallogenic behaviour (Roy and Jakhar 2002). Considering all these, it may be logical to subdivide the northern domain into two fundamental nuclei, the Bundelkhand and Aravalli Protocontinents respectively, separated by the Great Boundary Fault.

Southern Gondwana domain can be subdivided into a number of separate 'fundamental nuclei' or Protocontinents, which are separated by narrow belts 'Gondwana rift basins' (Fig. 5). For example, the Gondwana rift basin of the Godavari Valley (Basin) divides the Dharwar from the Bastar Protocontinents, whereas the Mahanadi Valley (Basin) separates the Bastar from the Singhbhum Protocontinent. In the present description the nondescript term 'Join' (hiring the term from Rogers 1986) is used as markers separating the primary crustal blocks described as Protocontinents. Very little is known about these zones along which Joins are traced except these represent the antique of rift zones over which the Gondwana basins evolved (Naqvi et al. 1974). In the Godavari Valley which marks the Join between the Dharwar and Bastar Protocontinents, the cratonic platformal Proterozoic sediments form the basement for the Gondwana Rift Basins. In other instances, the Gondwana Rift Basin (marking Joins) overlie the unclassified Precambrian granite and gneisses.

The proposed scheme of dividing the Gondwana domain by Joins marked by the Gondwana rift basins would imply delimitation of the Singhbhum Protocontinent by Gondwana Rift Basin of the Damodar Valley in the north. This leaves a small region between the Son-Narmada Lineament in the northwest and the Damaodar valley Gondwana basins in the south. If we accept the poorly exposed, north-south trending Rajmahal coal occurrences as remnant of a Gondwana basin, then the extent of this continental nucleus would be the small triangular area bounded by the Son-Narmada Lineament in the northwest and the Damodar valley Gondwana basins in the south, and the Rajmahal coal occurrences in the east. On the other hand, the reported presence of Gondwan rift basins in the northern Bengal Basin under the thick cover of 'Cenozoic to Recent' sediments in the 'Garo-Rajmahal Gap' (in Bangladesh) across the N-S lying outcrops of the Rajmahal Traps strongly the continuity of the Damodar Valley coal basins further east (Khan et al. 1994). Thus, if we neglect the Rajmahal coal belts as misidentified '*freak*' occurrence, then there lies the possibility of extension of this northern Precambrian nuclei further east across the Bengal basin into the Precambrian blocks of Shillong Plateau and its eastern continuity. We may tentatively describe this poorly defined crustal block as

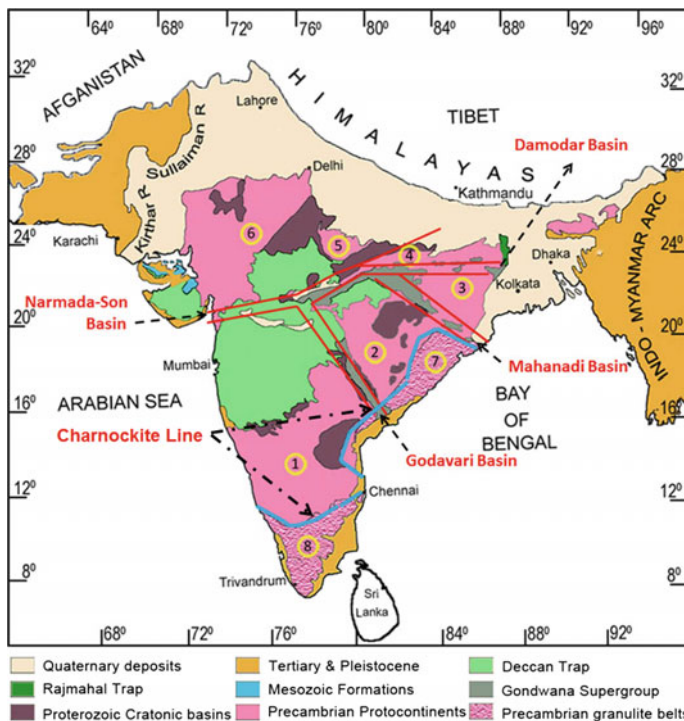


Fig. 5 Geological Map of Indian Subcontinent showing different tectono-stratigraphic features like, the Protocontinents and the accreted exotic blocks, rift basins represented by the river valleys, and the Charnockite Line (marked by blue line). Protocontinents: 1 Dharwar, 2. Bastar, 3. Singhbhum, 4. Rajmahal, 5. Bundelkhand, and 6. Aravalli. Accreted exotic block: 7. Eastern Ghats Granulite Belt, 8. Southern Granulite Belt. Modified after Geological Survey of India Map, 1993

the Rajmahal Protocontinent. The limit of the Rajmahal Protocontinent in the east is virtually unknown because of the occurrence of thick younger Cenozoic sediments forming the Bengal Basin. It is possible that Protocontinent continues further east joining the Precambrian rocks of the Shillong Palteau.

Some Gondwana type coal basins are known from different parts of the eastern Himalayas. However, because of the highly dismembered and tectonised state of these Gondwana basin bodies, it is hard even to guess their geological significance.

Summary and Concluding Remarks

Evolving entirely during the Precambrian, the pristine Indian Shield (or Greater India) had undergone several successive changes in the aerial extent during the Jurassic break-up of the Gondwana Land; and subsequently during successive

Table 1 Table showing crustal evolutionary trends, age of cratonization and metallogenic character of the different Protocontinents

Protocontinents	Dharwar	Bastar	Singhbhum	Bundelkhand	Aravalli
Archaean Crustal evolution	Evolution of granite-gneiss basement followed by greenstone belts	Evolution of granite-gneiss basement followed by greenstone belts	Evolution of Archaean granite-gneiss greenstone belt	Evolution of granite-gneiss basement	Evolution of granite-gneiss basement
Proterozoic crustal growth	Platformal Proterozoic cratonic basins	Development of Proterozoic fold-thrust belt	Development of Proterozoic fold belts	Platformal Proterozoic cratonic basins	Development successive Proterozoic fold belts
Cratonization (Ga)	~2.5	~1.8	~1.65	~2.5	8.5
Metallogeny	Gold, Copper, BIF, Chromite, and Diamond	Gold, Copper, BIF Manganese Diamond	Copper-uranium, BIF, Chromite nickel, Platinum	Diamond	Rock phosphate, Lead-zinc copper, Uranium

Note Geological information of Rajmahal Protocontinent is not included in the Table because of lack of available information

Plume impingement-related reconstitution and fragmentation events. Relying on the information from the Peninsular India it is possible to divide this Precambrian crustal block into two major tectonic blocks comprising the Precambrian Continental Core or Proto-India and the accreted charnockitic terranes. The Proto-India can be further sub-divided into six fundamental nuclei or Protocontinents separated by Joins. These are: (1) Dharwar, (2) Bastar, (3) Singhbhum, (4) Rajmahal, (5) Bundelkhand, and (6) Aravalli. The two accreted terranes which were added subsequently include the Eastern Ghats Granulite Belt and the Southern Granulite Belt. The combined Precambrian crustal blocks of Proto-India and the accreted terrains constitute the Indian Shield.

Geological history of each individual Protocontinent suggests a very distinctive history of crustal growth, tectonic evolution, ages of cratonization and metallogenic traits (Table 1). The disparate character of each of the Protocontinents makes them individually inimitable suggesting independent growth and evolution of the Protocontinent favouring an independent growth of the Protocontinent without any outside influence or interference. Under such a tectonic situation, it is hard to conceive of operation of any larger scale or global scale process responsible for the growth and evolution of these fundamental nuclei analogous to the modern Plate Tectonics.

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