



# Bundelkhand and Dharwar Cratons (Indian Shield): Comparison of Crustal Evolution in Archean Time



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## Abstract

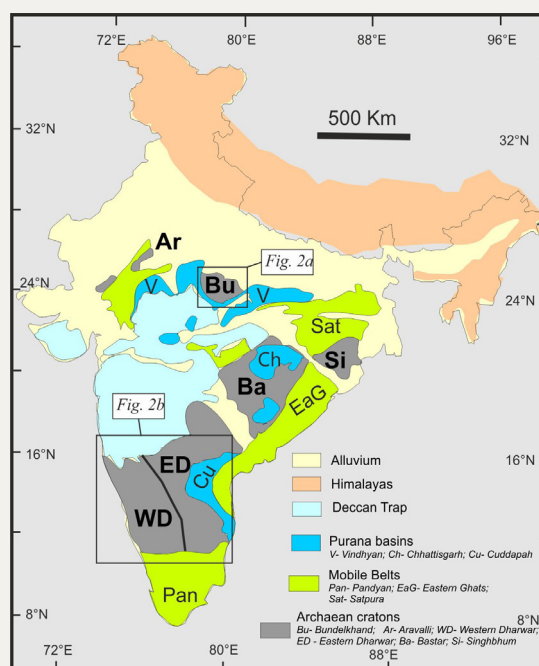
Comparison of the Meso-Neoproterozoic crustal evolution of the Bundelkhand, Western and Eastern Dharwar cratons shows that geodynamic mechanisms, similar to modern plate-tectonic and mantle-plume mechanisms, were active in that period. Each of the cratons displays its own crust formation pattern. It seems that in Archean time the Bundelkhand craton and the Western and Eastern Dharwar cratons were the various parts of the Kenorland Supercontinent, rather than one block.

**Keywords:** Archean; Crustal evolution; Geodynamics; Indian shield; Bundelkhand craton; Western Dharwar craton; Eastern dharwar craton

## Introduction

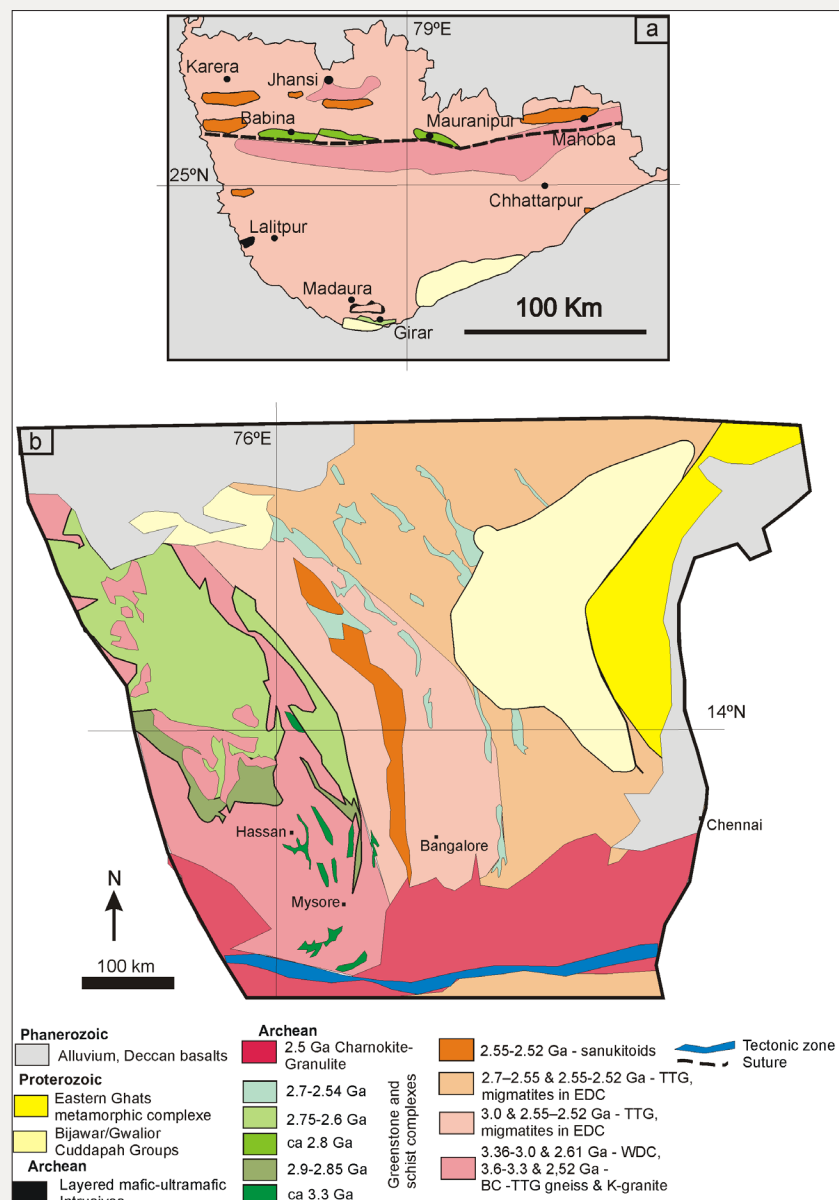
Archean rocks in the Indian Shield (Figure 1) [1] are exposed in the Bundelkhand and Aravalli cratons to the north and in the Dharwar (Western and Eastern), Singhbhum and Bastar cratons to the south respectively to the E-W trending Central Indian tectonic zone [1,2]. The Western and Eastern Dharwar cratons are one of

the well-known in the world [1,3-6] and can use as standard. TTG, supracrustal (greenstone and schist), sanukitoid and other typical Archean complexes were identified in the Bundelkhand craton, based on the data obtained in the past few years [7-13]. The goal of the present study is to correlate the crustal evolution of the above two cratons.



**Figure 1:** Main tectonic division of Indian shield [1].

## Geology and Crustal Evolution of the Bundelkhand Craton



**Figure 2a:** Geological maps of the Bundelkhand craton [after, 8-10].

**Figure 2b:** Western Dharwar and Eastern Dharwar cratons [after, 4-6].

The Bundelkhand craton consists of an Archean TTG-gneisses, granitoids (K-granites, diorites, sanukitoids), greenstone and schist/metasedimentary complexes and mafic-ultramafic layered intrusion, (Figure 2a) [9,10,13-18] and Paleoproterozoic mafic dykes, and huge quartz veins [19,20]. Granite-greenstone terrains form a basement for the deposition of Paleoproterozoic sedimentary rocks (Gwalior basin in the northwestern part of craton and Bijawar basin in the southern to southeastern part of the craton). The Paleoproterozoic doleritic dykes exhibit an NNW-SSE to NW-SE trend and are generally regarded as undeformed basic magmatic activity in the craton [19,21]. Highly jointed Paleoproterozoic (1.9-1.8Ga) quartz veins generally display a NE-SW trend and indicate the last endogenic activity [20,22]. Meso- to

Neoproterozoic (Vindhyan Supergroup) rocks was also deposited to the southeast, south, southwest and western part of the craton (Figure 1 & 2a) [1,19].

The oldest TTG-gneissic rocks are dated at 3.6-3.2Ga in the craton [7,8,23,24]. The TTG-gneisses generally strike ESE-WNW. There are Central and the Southern Bundelkhand supracrustal (greenstone and schist) complexes in the craton [9,10,14,17]. The Central Bundelkhand Greenstone Complex forms the Babina and Mauranipur Greenstone Belts (GBs) generally show an E-W linear trend (Figure 2a). This complex consists of an early (Mesoarchean) assemblage, which contains basic-ultrabasic, felsic volcanics ( $2810 \pm 13$ Ma) and BIF rocks, and a late (ca 2.54Ga-Neoproterozoic)

assemblage composed of felsic volcanic rocks. The Babina GB contains three stratotectonic associations:

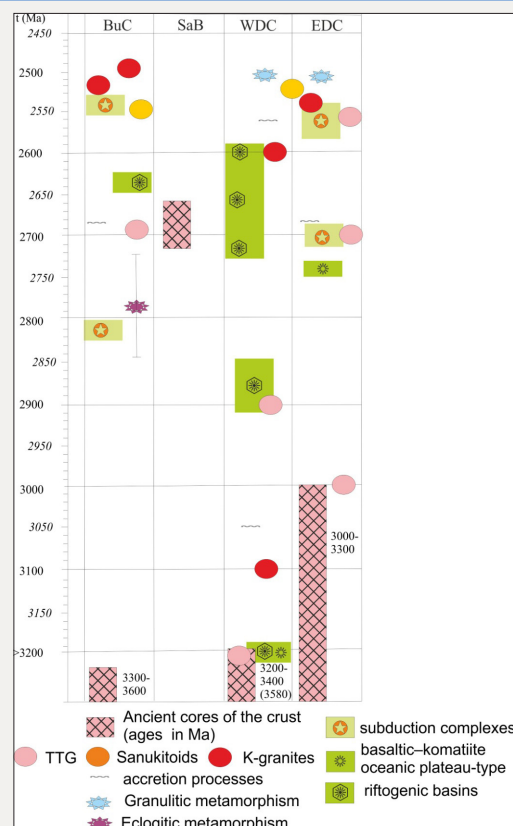
1. A basalt-ultramafic association (with preserved small lens-shaped schistose-structured bodies).
2. An iron formation association (BIF).
3. A dacite-rhyolite association (felsic volcanics).

The first two associations constitute an early assemblage and the third one a late assemblage. The boundaries between the assemblages extend as mélanges along the tectonic contact. The high-P metamorphism (ca 18-20kbar, 620-640 °C) reveal in northern part of Babina belt during 2780±60Ma [25]. At the northern and southern margins of the Central Bundelkhand Greenstone Complex, a series of Neoarchean (2.54-2.56Ga) sanukitoid massifs were revealed [18]. Towards the southern flank of the Babina greenstone belt, at contact zone with TTG granitoids, a metamorphic process dated from monazite at 2733±30Ma, were active [25]. Furthermore, late metamorphic events, dated at ca. 2.5Ga (2467±24Ma), occurred in this belt. Late- to post-kinematic Neoarchean (2.53-2.51Ga) granites are most common in the craton [13] and form during accretions after TTG partial melting.

The Southern Bundelkhand schist/metasedimentary complex formed the Girar belt (Figure 2a). This schist belt consists of two groups of rocks [10]: quartzite, BIFs and dolomitic marble and chlorite schist lenses near the quartzite/BIF boundary. U-Pb zircon

data from Girar belt quartzites give an older age of 3.43Ga and a younger age of 3.25Ga, suggesting that 3.25Ga is the minimum age of the source for the sediments [17]. The foliated rocks of the Girar metasedimentary belt are covered by gently dipping undeformed Paleoproterozoic (ca 1800Ma) rocks of the Bijawar Group. This is indirect evidence for older, most probably Archean, quartzite and BIF rocks of the Girar belt. The field relations of Ikauna Archean peridotite-gabbro-diorite layered intrusive rocks, the pink granite and lesser TTG, which occur north of the Girar metasedimentary belt, are demarcated by a tectonic boundary.

Available data from supracrustal rocks of Bundelkhand craton are consistent enough to propose that the Central Bundelkhand Greenstone Complex is a collage of two assemblages. The early assemblage formed in the Mesoarchean, as indicated by the age of felsic volcanics (2810±13Ma) in Mauranipur GB. The formation of the basic-ultrabasic constituent of this assemblage, which comprises boninite-like varieties [26], is attributed to subduction processes in the oceanic island-arc system (Figure 3). This volcanism is followed by island-arc dacitic-rhyolitic volcanism. The 2810Ma felsic volcanic are contaminated by old crustal matter, as they contain the 3.2Ga xenogenic zircons. This evidence suggests the emergence of an old crust fragment at the base of the island-arc [11]. This could be a microcontinent similar in composition to 3.6-3.2Ga TTG complexes in the northern part of the Bundelkhand craton [7,8,24], which approached the subduction zone and became part of a supra subduction zone.



**Figure 3:** The scheme of correlation of Archean geodynamic processes in the Bundelkhand (BuC), Western Dharwar (WDC), Eastern Dharwar (EDC) cratons and SaB - Satpura Mobile Belt.

BIFs developed in the second-stage island-arc system in the basins. As BIFs of the Mauranipur belt formed in back-arc basin whereas BIFs of the Babina belt form in a fore-arc basin. The Archean ( $\sim 2780 \pm 60$  Ma) eclogite facies metamorphism and island-arc dacitic-rhyolitic volcanism ( $\sim 2810 \pm 13$  Ma) have relatives (within analytical uncertainty) similar age. This fact is the important argument in favour of subductional nature of an early assemblage of Central Bundelkhand Greenstone Complex [12]. At about 2.7 Ga the arc complex accreted to the southern continental block (Figure 3). This event is marked by the formation of thrust faults and  $2687 \pm 17$  Ma metamorphic processes, as indication in the Mauranipur belt [11] and  $2730 \pm 33$  Ma processes in the Babina belt [25]. The youngest ( $2669.3 \pm 7.4$  Ma) TTG formed here in this time too [13] and similar age ( $2684 \pm 8$  Ma) TTG rocks are recognize in Western Dharwar craton [27].

Important events in the crustal evolution of the Bundelkhand craton took place in the Neoproterozoic (Figure 3), when the southern continental block was affected by a mantle plume, which was responsible for the formation of a sedimentary basin, in which the quartzites and BIFs of the South Bundelkhand schist (metasedimentary) complex were formed [10,17]. A new stage in the subduction processes began at 2.56-2.54 Ga. A spreading zone seems to have existed in the ocean which separated these blocks. However, the rate of its opening was lower than the rate of subduction at periphery. At the southern margin of the northern block (it is Babina belt in the modern coordinate system) subduction occurred in an active continental margin regime, as indicated by Neoproterozoic (2542 Ma) [9], felsic volcanics of the Babina belt and sanukitoid massif similar in age (2560-2559 Ma) [18]. At the northern flank of the southern continental block this stage is marked by Neoproterozoic (2557 Ma) dacites of Mauranipur belt [11] and a sanukitoid massif [18]. The closure of the ocean and an accretion stage in the evolution of the greenstone took place at about 2.53 Ga, after the youngest 2542 Ma volcanics and prior to the formation of the earliest post-kinematic granites -2531 Ma [13]. At this stage its Meso- and Neoproterozoic constituents are combined to form one greenstone complex. The melting of large volumes of granitoids in the period 2.53-2.51 Ga is associated with post-accretionary processes in the crust. The craton is stabilized at around 2.5 Ga.

## Geology and Crustal Evolution of the Western and Eastern Dharwar Craton

The Dharwar craton has been divided lately into two cratons: Western and Eastern, based on their evolution patterns and crustal structures. Each of them is 3-4 times the size of the Bundelkhand craton (Figure 2). The Western Dharwar craton consists of Paleoproterozoic (3.36 (3.58)-3.2) TTG gneisses (Peninsular gneisses), three generations of greenstone complexes (Sargur, Bababudan and Chitradurga Groups) and several granitoid massifs [4,6]. The Sargur greenstone belt is composed of mafic-ultramafic rocks (metabasalts, komatiites and their intrusive conglomerates and meta anorthosites), which often predominate, and metasediments (kyanite/sillimanite-staurolite-biotite gneisses, quartzites, BIF,

local marble, calc-silicate rocks, bedded barite); felsic volcanic are scarce. The age of the complex is estimated at 3.1-3.3 Ga, based on the Sm-Nd whole-rock isochron age of komatiites of  $3352 \pm 110$  Ma [28] and the U-Pb age of zircon from felsic volcanics of  $3298 \pm 7$  Ma [29]. It forms small greenstone belts, both belts dominated by mafics-ultramafics (e.g. Ghatti Hosahalli, Krishnarajapet and Nagamangala) and those with abundant sediments (e.g. Sargur and Hole Narasipura). The Sargur greenstone complex was formed presumably in both rift-related structures on an early continental crust (3.58-3.23 Ga zircons in quartzites have been found, suggesting the existence of an older crust) and an oceanic plateau-type setting. The occurrence of 3.2 Ga TTGs in the region suggests subduction processes of that age. A second generation of greenstone complexes in the Western Dharwar craton is the Meso-Neoproterozoic Bababudan Group at the base of the Dharwar Supergroup in Bababudan, Chitradurga schist belts. The base of the Bababudan Group sequence consists of cross-bedded quartz conglomerates with ripple marks (Kalasapura Formation). These sediments rest with angular unconformity on Peninsular gneisses Sargur Group rocks. In addition to quartz conglomerates, the Sargur Group comprises phyllites and BIF. Mafic (metabasalts and gabbroic rocks) and ultramafic bodies seem to occur among them as sills. Felsic volcanics, occurring as part of the Santaveri Formation, are scarce. The mafics-ultramafics are dated at 2.9-2.85 Ga (Sm-Nd whole rock isochron ages are  $2911 \pm 49$  and  $2848 \pm 70$  Ma, [30]). The formation of the Bababudan greenstone complex was associated with plume activity and took place in an intracontinental basin.

A third greenstone/schist complex of the craton corresponds with the Chitradurga Group of the Dharwar Supergroup, which makes up the largest Shimoga and Chitradurga groups. This Group consists dominantly of sediments (quartz and polymictic conglomerates containing TTG and Bababudan Group rock fragments, chert-phyllite, manganese and iron formation and stromatolitic carbonates) with pillow basalt and lesser felsic volcanic intercalations. The complex is dated at 2.75-2.58 Ga: the Sm-Nd whole rock isochron age is  $2747 \pm 15$ , [30]; the U-Pb age of zircon from the felsic volcanic is  $2677 \pm 2$  to  $2576 \pm 20$  [6]. The sedimentation basin of the Chitradurga Group [31] seems to have been controlled by mantle plume activity.

The Eastern Dharwar craton is separated from the Western Dharwar craton by a large fault, the Chitradurga shear zone, and differs from the latter in deep structure (a thinner earth crust) [32] and the compositions and ages of Archean granitoid and greenstone complexes [33,34]. The craton consists dominantly of commonly migmatized TTG granitoids, but, in contrast to the Eastern Dharwar craton, they are dominated by 2.7-2.55 Ga rocks with minor fragments of 3.0-3.38 Ga crust [6]. Moreover, the contribution of old matter to granitoid composition decreases markedly (Nd TDM up to 2.8-3.0 Ga in the eastern part [35], but 2.56-2.5 Ga juvenile ( $\epsilon_{\text{Nd}} = +3.3$ ) calc-alkaline to potassic granitoids are widespread here. Occurring in the western part of the craton is the 2.51-2.53 Ga sanukitoid-like Closepet Granite batholiths, which cross-cuts the entire craton. The greenstone belts of the Eastern Dharwar



craton are small narrow N-S and NW-SE trending linear structures, e.g. Kolar, Hutti, Kushtagi etc.). They consist mainly of metabasalts (often pillowed) associated with komatiites and BIF; felsic volcanics, associated with greywacke and polymictic conglomerates (Kolar GB), are common; metasediments, occurring as schists, are less common. An early association (beginning probably with 2.75, but mainly at ca. 2.7Ga) of basalts and komatiites was formed in an oceanic setting under the influence of plumes, i.e. oceanic plateaus), but this stage was also terminated by subduction processes (Sangur GB). However, the main episode in the subduction processes, which gave rise to a continental crust, occurred at 2.58-2.52Ga, when felsic volcanics and various granitoids (including sanukitoids) originated. Ca 2.5Ga granulite-facies metamorphism, widespread in the southern part of the Eastern and Western Dharwar cratons, was associated with accretion-collision processes.

## Conclusion

Western Dharwar, Eastern Dharwar, and Bundelkhand cratons of the Indian Shield compared each other which reveal its own structural and evolutionary characteristics. First of all, it should be noted that the Bundelkhand craton is much smaller than the Western and Eastern Dharwar cratons. However, it comprises TTG, greenstone/schist and sanukitoid complexes most typical of Archean cratons. The old cores of all the cratons commonly consist of Paleoproterozoic TTG. The oldest (3.6-3.2Ga) TTG occur in the central Bundelkhand craton, but they seem to have been more common. The Western Dharwar craton is dominated by 3.36-3.2Ga TTG, but they probably comprised even older (up to 3.58Ga) constituents, which have survived only as zircons in sedimentary rocks. It should also be noted that the formation of the Paleoproterozoic (3.3-3.2Ga) Sargur greenstone complex is similar in age to TTG. The Eastern Dharwar craton displays a somewhat different distribution and age of old TTG: fragments of 3.3-3.0Ga TTG occur here as part of migmatized gneisses in the western part of the craton, while its eastern portion consists of juvenile Neoproterozoic (2.7-2.55Ga) granitoids, including TTG. The Meso-Neoproterozoic (2.9-2.6Ga) evolution of the Western Dharwar craton was affected by mantle plumes. As a result, intraplate sedimentary basins, exhibiting bimodal magmatism, were derived. The intrusion of 2.61Ga potassium-granites stabilized the craton.

The processes occurring in the Eastern Dharwar craton were entirely different: the formation of a juvenile continental crust took place here mainly in Neoproterozoic time, beginning at 2.75-2.7Ga, but dominantly at 2.58-2.54 (2.51)Ga. The leading role was played by subduction processes, which terminated by the accretion of the newly-formed crust to the Western Dharwar craton, which had stabilized earlier. The crustal evolution of the Bundelkhand craton differs substantially from those described above. One of the essential differences is that in Mesoarchean time (ca. 2.81Ga) a new continental crust was formed during subduction here and in the Karelian craton [36,37], but it was not transformed by plumes as in the Western Dharwar craton. The Neoproterozoic evolution of the central portion of the Bundelkhand craton differed from that of the southern portion of Bundelkhand craton.

The former was an area where the ocean, dividing the northern and southern terrains, was closed. Subduction processes were active here at ca.2.7Ga but were most vigorous at 2.56-2.54Ga and were terminated by accretion-collision events and the formation of 2.53-2.5Ga potassium-granites. Crust formation in the central Bundelkhand craton is similar in time and geodynamic pattern with the Eastern Dharwar craton, but there are some essential differences. Subduction processes in the Eastern Dharwar craton occurred in an island-arc regime and those in the Bundelkhand craton in an active continent margin regime. The earth crust of the southern Bundelkhand craton, where presumably Neoproterozoic layered intrusions and a sedimentary basin (Girar greenstone/schist belt) were revealed, which was formed in a different manner. The effect of a mantle plume is felt here and in the Western Dharwar craton.

In the late Neoproterozoic (ca. 2.5Ga) the Western and Eastern Dharwar cratons were involved as one structure in an accretion-collision process, which gave rise to southern Dharwar craton granulites. Thus, correlation of the Meso-Neoproterozoic crustal evolution of the Bundelkhand, Western and Eastern Dharwar cratons shows that geodynamic mechanisms, similar to modern plate-tectonic and mantle-plume mechanisms, were active in that period. Each of the cratons displays its own crust formation pattern. It seems that in Archean time the Bundelkhand craton and the Western and Eastern Dharwar cratons were the various parts of the Kenorland Supercontinent, rather than one block [38,39].

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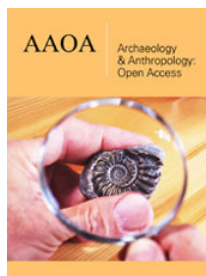
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