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Status Report

Archean Evolution of the Bastar Craton-present Status

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Introduction

As cratons have remained tectonically stable for a prolonged time since the Archean Eon (>2420 Ma) they would be expected to preserve the record of over 1.6 Gyr duration of evolution of the continental crust as well as evidence for the formation of vast tonalite-trondhjemite-granodiorite (TTG) suite(s) and associated supracrustal rocks (termed as greenstone belts). The Bastar Craton in central India (Fig. 1) is one such craton with preservation of all three basic components of a craton which include the TTG suite, greenstone belts and late Archean sedimentary basins. Recent geochronological evidence, from a large swath of crust comprising the southwest Bastar craton, has placed its earliest formed crust to be as old as the Paleoarchean (~3.6 Ga, Sarkar *et al*., 1993; Ghosh 2004; Rajesh *et al*., 2009) and thus making it one of the oldest regions of the Indian Peninsula, and a potential target to search for older Paleoarchean crust (defining the Paleo-Mesoarchean transition at 3490 Ma). The cratonic block is bounded by two mobile belts, the Central Indian Tectonic Zone to its North and Northwest and the Eastern Ghats Belt (EGB) to the Southeast, and by two Palaeozoic rifts, the Mahanadi rift to its Northeast and the Pranhita-Godavari rift to its Southwest. The ubiquitous rock types in the craton include older gneissic enclaves of deformed TTG and belts of supracrustal rocks, younger supracrustals and K-feldspar rich granitoids. The above sequences have been intruded by Proterozoic mafic dykes and are covered by Neoarchean volcanosedimentary basins and Meso- to Neoproterozoic (Purana) sedimentary basins.

Geologic Status

The Sukma, Bengpal and Amgaon groups consist of the oldest gneisses and supracrustals in the Bastar craton. In the geological succession presented by Crookshank (1963) no clear dividing line could be traced between the Sukma and Bengpal Groups, an interpretation supported by later workers, whereas Ramakrishnan (1990) showed an unconformity separating these Groups. The Bengpal Group, by virtue of its local diverse litho-association, complex deformation and high-grade metamorphism was reclassified by Ramachandra *et al*., (2001) into the Chandernar-Tulsidongar Mobile Belt (CTB), which consists of a sequence of older high-grade gneissic supracrustals (Sukma Group) along with (putative younger) lower metamorphic grade supracrustals characterized by an association of metabasalt, conglomerate and sandstone reclassified as the Bengpal Group. They have proposed that the CTB terrane represents intracratonic reworking with the two sequences of different metamorphic grade being separated by a tectonized unconformable contact, with structural conformity as a result of intense deformation. Neoarchean deformation and migmatization, for the CTB, has been proposed based on a Rb-Sr whole rock age of 2530 ± 89 Ma for migmatitic gneiss and granite components (Bandyopadhyay *et al*., 1990).

The major units of the Archean craton are discussed below starting from units that are older up to the youngest Neoarchean and the synoptic view is given in Table 1.

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Table 1: Chronostratigraphy of Archean units in the Bastar craton#

		Bastar Craton	CITZ
Palaeoproterozoic Era	Siderian Period	Sonakhan Greenstone Belt [2390 ± 100 [1]]	
----2420Ma----			
Neoarchaean Era			
----2630Ma----		Dongargarh granitoid[2465 ± 22 [2]]Malanjkhand granitoid [2490 ± 8 to 2455 ± 8[3]]	Sakoli Group
		Kotri-Dongargarh Group [2525 ± 15 to 2506 ± 4[5], 2530[6]] = Nandgaon Group [2503 ± 35[7]]	B42D
		Chandernar-Tulsidongar Belt [2530 ± 89[13]]	Group II zircon [2530 ± 3[12]]
		Abujhmarh group [2490 ± 48[4]] Bailadila Group [2725 ± 7[8]]	Group I zircon [2556 ± 8 [12]]
----2780Ma----	Methanian Period		
Mesoarchaean Era			
-----3490Ma----			
Palaeoarchaean Era			
----3810Ma----			
----4030Ma----		Trondhjemitic gneiss [3509 +14-7 [9]] KLB-2 Tonalitic gneiss [3561 ± 11 [10]] D9 True granite [3583 ± 4 [11]]	B42D Group I zircon [3398 ± 15 , 3584 ± 3 [12]]
——4030Ma——			

#[1] Rb-Sr on metarhyolites (Ghosh et al., 1995); [2]Rb-Sr (Krishnamurthy et al., 1990); [3] Re-Os method on molybdenite (Stein et al., 2006); [4] Basaltic andesite – andesite (Sarkar and Gupta 1991); [5] Ghosh (2006); [6] U-Pb single crystal zircon dating of oldest rhyolite (Ghosh 2004); [7]Rb-Sr (Krishnamurthy et al., 1990); [8] Detrital zircons from basal arenites (Mukhopadhyay et al., 2014); [9] U-Pb zircon age (Sarkar et al., 1993); [10] U-Pb zircon age (Ghosh 2004); [11] U-Pb zircon age (Rajesh et al., 2009); [12] U-Pb zircon age (Bhowmik et al., 2014)

The oldest Paleoarchaean dates have been reported from the TTG gneisses occurring as basement inliers/enclaves within younger supracrustal belts. Sarkar *et al*., (1993) dated trondhjemitic gneisses from Markampara to yield a zircon U-Pb age of 3509 ± 4 Ma, which is considered to be the age of primary crystallization. Ghosh (2004) reported a zircon U-Pb tonalite crystallization date of 3561±11 Ma (upper intercept and a single zircon grain concordia date of 3562±2 Ma) from around Kapsi. This tonalite sample represents the basement to the 2.5 Ga Kotri Linear Belt (Ghosh and Pillay, 2003). Rajesh *et al*., (2009) reported a concordia date of 3582.6±4 Ma and upper intercept date of 3585±10 Ma for the oldest true K-feldspar bearing granite from south of Dalli-Rajhara.

The Kondagaon Granulite Belt (KGB) situated in the central-eastern part of the craton contains amphibolite facies enclaves of Sukma gneiss-supracrustals metamorphosed to granulite facies conditions. The western and northern contacts of the granulite belt are intruded by coarse porphyritic granite which contains enclaves of granulite facies rocks, even far away from the contact. The eastern margin is bordered by younger granite associated with pillowed metabasalt of the Bengpal Group (Ramachandra *et al*., 2001). The margins of the granulite belt with younger granitoids are intrusive rather than tectonic and this screen of granitoids separates the Kondagaon Granulite Belt from the Eastern Ghats Belt (EGB) (Ramachandra and Roy, 2014). The 2.5 Ga Kondagaon Granulite Belt does not record deformation and metamorphic reworking related to amalgamation of Bastar craton with EGB. Rb-Sr whole rock age of 2610 ± 43 Ma and 2409 Ma (Sarkar *et al*., 1990) for fine grained granite and pegmatite granite has been recorded from KGB. The origin of a cratonal granulite belt is highly debatable; whether the KGB is a klippe of the EGB or not. Geochronological studies need to be conducted on the rocks of the KGB to find out the exact age of crystallization and metamorphism to granulite facies conditions.

One of the advances in understanding the tectonic setting of the Sonakhan greenstone belt has been proposed by Manu Prasanth *et al*., (2018), in an island arc setting deciphered from mineral chemistry of chromite and trace element geochemistry of siliceous high-Mg basalt (SHMB). Although based on the Rb-Sr whole rock data on metarhyolite, Ghosh *et al*., (1995) proposed that the Sonakhan greenstone belt formed at 2390 ± 100 Ma, but as this isotope systematic would record mostly time of deformation and metamorphism, the eruptive age would be older, likely around 2.7 Ga, a time period that marks global peak development (and preservation) of crust and coeval with several such greenstone belts in the Eastern Dharwar craton. Detailed geochronology of this belt is awaited.

The late Archean sedimentary successions, unique to Indian cratons comprise the Dongargarh Group (Sensarma and Mukhopadhyay, 2014) with different volcanic units being parts of a continuous volcanic sequence; the Kotri Belt is the southern continuation of the Dongargarh Group (Mishra *et al*., 1988). Due to intrusive relations, Sensarma and Mukhopadhyay (2014) have stratigraphically placed the Dongargarh granite as younger than the Dongargarh Group, but more precise geochronological data is awaited (discussed below).

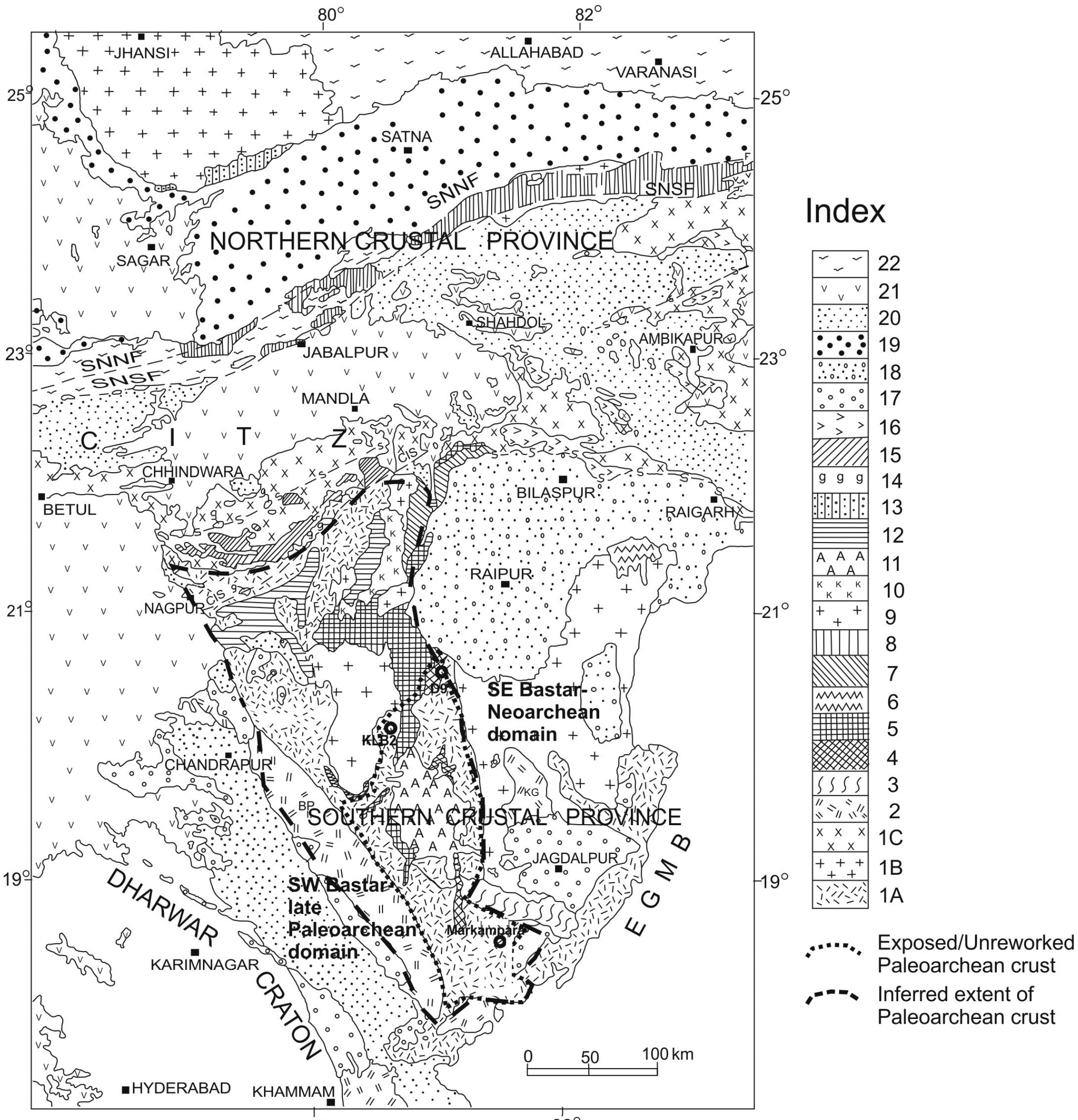
Of the late Archean sedimentary successions, the Bailadila Group is a Neoarchaean Superior-type BIF formation which is unconformably overlain by the Kotri volcanics/Bijli rhyolites near the Dalli-Rajhara area. Mukhopadhyay *et al*. (2014) reported the maximum age of the Bailadila Group from the $^{207}Pb/^{206}Pb$ SHRIMP age of 2725 ± 7 Ma from the youngest detrital zircons of the basal arenites. As the oldest Dongargarh Group of volcanic rocks erupted around 2525 Ma ago, the Bailadila Group would have been deposited between 2725 Ma and 2525 Ma, and probably being a potential site for identifying a likely GSSP for the base of the Methanian Period of the Neoarchean Era (2630 Ma being the time boundary of the Methanian from the younger Siderian Period marked by deposition of BIF units).

The younger, reclassified Dongargarh Group (merging the Nandgaon and Khairagarh Groups) components comprise the basal Bijli rhyolites overlain by the Pitepani volcanics; the formed yielded Rb-Sr isochron age of 2503 ± 35 Ma (Krishnamurthy *et al*., 1990) (Sr_i = 0.7035 ± 0.0017). According to Ghosh (2006), the deposition of the Kotri Group started with the extrusion of the Pachangi rhyolite at 2525 ± 15 Ma and ended with the deposition of the upper part of the Kurse-Korhi formation at 2506 ± 4 Ma, with the TTG of the Hanker Group, dated at ~3552 Ma, as its basement. Ghosh (2004) dated the oldest rhyolite in the Kotri belt by U-Pb single-crystal zircon dating and reported an emplacement age of ~2530Ma.

In contrast, the intrusive Dongargarh granite gives a Rb-Sr isochron age of 2465 ± 22 Ma (with low Sr_i = 0.7010 ± 0.0042) (Krishnamurthy *et al*., 1990). Madenbera granite, a possible equivalent or extension of the Dongargarh granite in the Kotri basin, yielded a $^{207}Pb/^{206}Pb$ age of ~2470 Ma (Ghosh 2006). Stein *et al*. (2006) reported Re-Os ages of 2490 ± 8 Ma to 2455 ± 8 Ma on molybdenite samples collected from the Malanjkhand granitoid. Therefore, it is clear that the plutonic, intrusive hases post-date the development of rift-related late Archean volcano-sedimentary successions of the Bastar craton.

From the northern segment of the Bastar craton, the Bhandara-Balaghat Granulite Belt, which is interpreted as the exhumed lower crust of the Bastar Craton, Bhowmik *et al*. (2014) have dated psammo-pelitic granulites from. U-Pb concordia studies of core regions within detrital zircon grains give an age range of 3584 ± 3 Ma, whereas there are zircons with younger ages of 2530 ± 3 Ma. This clearly suggests presence of Paleoarchean crust, which was affected by Neoarchean reworking, and is typical of the Bastar craton so far observed even from the southwestern segment.

Another line of application of temporal constraints on craton-wide cryptic thermal events is from the detrital zircon age spectra from sedimentary rocks that have been shown to be deposited proximal or over the Bastar cratonic rocks. One such succession is the Somanpalli Group in the Pranhita-Godavari rift basin, and from one of the basal sandstone, yielded detrital zircon grains with an age spectra having peaks at ~3480 Ma, ~2470 Ma and



1A-Sukma and Amgaon TTG with enclaves, 1B-Younger granitoids (and Bundelkhand cratonic rocks), 1C-Gneiss of CITZ, 2-Granulite belt, 3-Bengpal mobile belt, 4- Bailadila Gp, 5. Nandgaon Gp, Sonakhan Greenstone, 7-Chilpi Gp, 8-Mahakoshal Gp, 9-Dongargarh and Malanjkhand granitoid, 10-Khairagarh Gp,,11- Abujmar Gp, 12-Sakoli Gp, 13-Bijawar Gp, 14-Younger granulite, 15- Sausar Gp, 16-Betul-Bilaspur-Raigarh-Surguja belt, 17Indravati/Pakhal/Albaka Gps, 18-Chhatisgarh SpGp, 19-Vindhyan SpGp, 20-Gondwana SpGp, 21-Deccan Volcanic province, 22-Quaternary.
SNNF-Son-Narmada North Fault, SNSF-Son-Narmada South Fault
O - Locations of oldest TTG dated ~3.5-3.6 Ga

Fig. 1: Geological map of the Bastar craton after Ramachandra *et al.* (2001). Paleoproterozoic dykes swarms are not shown. The SW Bastar late Paleoarchan domain likely represents the older nucleus around which the Neoarchean evolution occurred due to accretionarytectonics

~1620 Ma; minor age peaks in the Paleoarchaean (~3.8 Ga) and at ~2750 Ma (Amarsinghe *et al*., 2015). This again reflects provenance suggesting presence of eroded early Mesoroterozoic crust and the typical late Neoarchean growth.

Conclusion

The Bastar craton plutonic TTG units have been constrained as belonging to the largest continuous area of Paleoarchean crust in India. Significantly, there is an absence of crust developed during the

Mesoarchean and early Neoarchean; such an age pattern is also seen from major peaks in most detrital zircon age spectra. The nominal interpretation is a bimodal growth in crust during Paleoarchean and apparently reflect a major episode of crustal growth by accretion during the terminal Neoarachean; the ~2.7 Ga Sonakhan belt is one of the only recognized greenstone belts akin to those developed in the Eastern Dharwar craton.

From the older supracrustal successions, significant is the paucity of ages as well as the context of development with respect to the two major pulses of TTG growth.

Uncertainties and Future Research

One of the most significant observations from this review is that rock units of dominantly Mesoarchaean age have not been reported from the Bastar Craton. There is insufficient geochronological data on the Sonakhan Greenstone Belt and its precise age is yet to be determined, although its tectonic setting as having formed in an arc has been recently proposed by Prashanth *et al*. (2017). The source of the detrital zircons in the basal arenites of the Bailadila Group is not known. From the psammo-pelitic granulite of the Amgaon Group rocks, inherited zircon as old as 3.5 Ga could have been sourced from the TTG of the Paleoarchean craton, suggesting their proximity. Rajesh *et al*. (2009) have proposed intracrustal melting to explain genesis of the 3.6 Ga true granite which they ascribe to formation due to collisional tectonics. This leaves open several questions related to the petrogenesis and tectonic setting of the 3.5 Ga TTG suite rocks and their relation to the Palaeoarchean true granite. Detrital (magmatic) zircons within sandstones of the Somanpalli Group were likely sourced from the Paleoarchean TTG crust of the Bastar Craton and a high-resolution U-Pb age and Hf-isotope study of these detrital zircons could be used to test their provenance. Migmatitic gneisses are common in the craton and migmatisation likely has formed these magmatic zircons. Therefore there are younger metamorphic events which are yet to be identified and dated to understand the complete crustal evolution of the Bastar Craton. Details of geochronologic studies of the TTG gneisses and greenstone belts are warranted to unravel the geological evolution of the Indian Precambrian shield and also to test the equivalence of the Bastar and Singhbhum cratons at least till the Palaeoarchaean.

References

Amarasinghe U, Chaudhuri A, Collins A S, Deb G and Patranabis-Deb S (2015) Evolving provenance in the Proterozoic Pranhita-Godavari Basin, India *Geoscience Frontiers* **6** 453-463

Bandyopadhyay B K, Bhoskar K G, Ramachandra H M, Roy A, Khadse V K, Mohan M, Sreeramachandra Rao K, Ray Barman T, Bishui P K and Gupta S N (1990) Recent geochronological studies in parts of the Precambrian of Central India *Geological Survey of India Special Publication* **28** 199-211

Bhowmik S K, Wilde S A, Bhandari A and Sarbadhikari A B (2014) Zoned monazite and zircon as monitors for the thermal history of granulite terranes: an example from the Central Indian Tectonic Zone *Journal of Petrology* **55** 585-621

Ghosh J G (2004) 3.56 Ga tonalite in the central part of the Bastar Craton, India: oldest Indian date *Journal of Asian Earth Sciences* **23** 359-364

Ghosh J G (2006) Geochronological constraints in the evolution of the Kotri Linear Belt and its basement *Records Geological Survey of India* **138** 24-26

Ghosh J G and Pillay K R (2003) Late Archean Rifting of Early Archean Bastar Craton: Geology and Preliminary U–Pb Zircon Ages from the Kotri Linear Belt of Central India. Indian Society for Mass Spectrometry (ISMAS) Silver Jubilee Symposium on Mass Spectrometry, Dona Paula, Goa (India), 654-660

Ghosh S, Rajajaiya V and Ashiya I D (1995) Rb-Sr dating of components from the Sonakhan granite-greenstone belt, Raipur district M. P., *Records Geological Survey of India* **128** 11-13

Krishnamurthy P, Sinha D K, Rai A K, Seth D K and Singh S N (1990) Magmatic rocks of the Dongargarh Supergroup, Central India – their petrological evolution and implications on metallogeny *Geological Survey of India Special Publication* **28** 303-319

Mukhopadhyay J, Beukes N J and Armstrong R A (2014) Depositional setting and New Age Constraints of the Bailadila Group, Bastar Craton: Implications for the Oldest

‘Superior Type’ Iron Formation in India and its Economic Potential *Gondwana Geological Magazine* **16** 213-214

Manu Prasanth M P, Hari K R, N V Chalapathi Rao, Hou G and Pandit D (2018) An island-arc tectonic setting for the Neoarchean Sonakhan Greenstone Belt, Bastar Craton, Central India: Insights from the chromite mineral chemistry and geochemistry of the siliceous high-Mg basalts (SHMB). *Geological Journal* DOI: 10.1002/gj.2971

Rajesh H M, Mukhopadhyay J, Beukes N J, Gutzmer J, Belyanin G A and Armstrong R A (2009) Evidence for an early Archaean granite from Bastar craton, India *Journal of the Geological Society, London* **166** 193-196

Ramachandra H M and Roy A (2014) A Review of Evolutionary Characteristics of Bastar Craton, Central India *Gondwana Geological Magazine Special Volume* **16** 1-16

Ramachandra H M, Roy A, Mishra V P and Dutta N K (2001) A Critical Review of the Tectonothermal Evolution of the Bastar Craton *Geological Survey of India Special Publication* **55** 161-180

Sarkar G, Corfu F, Paul D K, McNaughton N J, Gupta S N and Bishui P K (1993) Early Archean crust in Bastar Craton, Central India – A geochemical and isotopic study *Precambrian Research* **62** 127-137

Sarkar G, Paul D K, McNaughton N J, DeLaeter J R and Mishra V P (1990) A geochemical and Pb, Sr isotopic study of the evolution of the granite gneisses from the Bastar Craton, Central India *Journal of Geological Society of India* **35** 480-496

Sensarma S and Mukhopadhyay D (2003) New Insight on the stratigraphy and volcanic history of the Dongargarh Belt, Central India *Gondwana Geological Magazine Special Volume* **7** 129-136

Sensarma S and Mukhopadhyay D (2014) Stratigraphy of ~2.5 Ga Dongargarh Belt, Central India: Key Observations and Suggested Revisions *Gondwana Geological Magazine Special Volume* **16** 41-48

Stein H J, Judith J, Zimmerman A and Markey R (2006) Mineralization and deformation of the Malanjkhand terrane (2,490-2,440 Ma) along the southern margin of the Central Indian Tectonic Zone, *Mineral Deposita* **40** 755-765.