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The Central Indian Tectonic Zone: A Rodinia supercontinent-forming collisional zone and analogy with the Grenville and Sveconorwegian orogens

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ABSTRACT

In the paleogeographic reconstructions of the Rodinia supercontinent, the circum-global 1.1–0.9 Ga collisional belt is speculated to skirt the SE coast of India, incorporating the Rodinian-age Eastern Ghats Province. But the Eastern Ghats Province may not have welded with the Indian landmass until 550–500 Ma. Instead, the ~1500-km-long, E-striking Central Indian Tectonic Zone provides an alternate option for linking the 1.1–0.9 Ga circum-global collisional belt through India. The highly tectonized Central Indian Tectonic Zone formed due to the early Neoproterozoic collision of the North India and the South India blocks. Based on a summary of the recent findings in the different crustal domains within the Central Indian Tectonic Zone, we demonstrate that the 1.03–0.93 Ga collision involved thrusting that resulted in the emplacement of low-grade metamorphosed allochthonous units above the high-grade basement rocks; the development of crustal-scale, steeply dipping, orogen-parallel transpressional shear zones; syn-collisional felsic magmatism; and the degeneration of orogenesis by extensional exhumation. The features are analogous to those reported in the broadly coeval Grenville and Sveconorwegian orogens. We suggest that the 1.1–0.9 Ga circum-global collisional belt in Rodinia swings westward from the Australo-Antarctic landmass and passes centrally through the Greater India landmass, which for the most part welded at 1.0–0.9 Ga. It follows that the paleogeographic positions of India obtained from paleomagnetic data older than 1.1–0.9 Ga are likely to correspond to the positions of the North and South India blocks, respectively, and not to the Greater India landmass in its entirety.

■ 1. INTRODUCTION

The paleogeographic positions of fragmented and drifted crustal domains/continents are combined with the inherent characteristics of collisional orogens to reassemble past supercontinents (Pisarevsky et al., 2003; Evans, 2009; Collins et al., 2011; Martin et al., 2020, among others). In this study, collisional orogens are considered to form due to the welding of fragments of the continental lithosphere, and as a result are located in the interiors of the assembled continental mass. These orogens are distinct from accretionary orogens that result from oceanic plate subduction, and as a consequence they occupy peripheral parts of the continental fragments (Cawood et al., 2009; Collins et al., 2011; Martin et al., 2020; Spencer et al., 2013). Accretionary orogens consist of accretionary wedges, ophiolite sequences, arc-related magmatic rocks, clastic sedimentary basins, old continental blocks, post-tectonic felsic rocks, and even paired metamorphic belts (Cawood et al., 2009). The late Mesoproterozoic and early Neoproterozoic eras (1.1–0.9 Ga; herein referred to as Rodinian-aged) witnessed amalgamations of older crustal domains that resulted in a series of collisional events and related magmato-metamorphic episodes that culminated in the assembly of the Rodinia supercontinent (Hoffman, 1991; Li et al., 2008).

Several attempts have been made to recreate a circum-global, Rodinian-aged (1.1–0.90 Ga) collisional orogen along which older crustal fragments were welded following the breakup of the Columbia supercontinent (Fig. 1). The reconstructions can be divided into two groups: those that exclude India from Rodinia and those that incorporate India in Rodinia. In several reconstructions (Pisarevsky et al., 2003; Evans, 2009; Spencer et al., 2013), the Greater India landmass is inferred to be located in or close to the polar region during 1.0–0.9 Ga and not part of the Rodinia supercontinent positioned at lower latitudes. In the recent ca. 1.0 Ga reconstruction of Rodinia proposed by Merdith et al. (2021), India is separated, albeit westward, from the main mass (dominated by Laurentia, Baltica, Amazonia, Antarctica, Austral-Antarctica, the North and South Australian cratons, the Western Australia Craton, and the North China Craton) by a divergent boundary and a transform fault boundary, but both India and Rodinia are placed at similar lower latitudes (Fig. 1A). In other reconstructions, however, the Greater India landmass is positioned at the western periphery of the Rodinia supercontinent, near the equator, and in close proximity to Antarctica and Australia (Fig. 1).

In these reconstructions, the 1.1–0.9 Ga orogen is located along the eastern coast of India (Figs. 1B–1E) and extends along the western margin of the Rodinian-age Eastern Ghats Province (Dobmeier and Raith, 2003) of the Eastern

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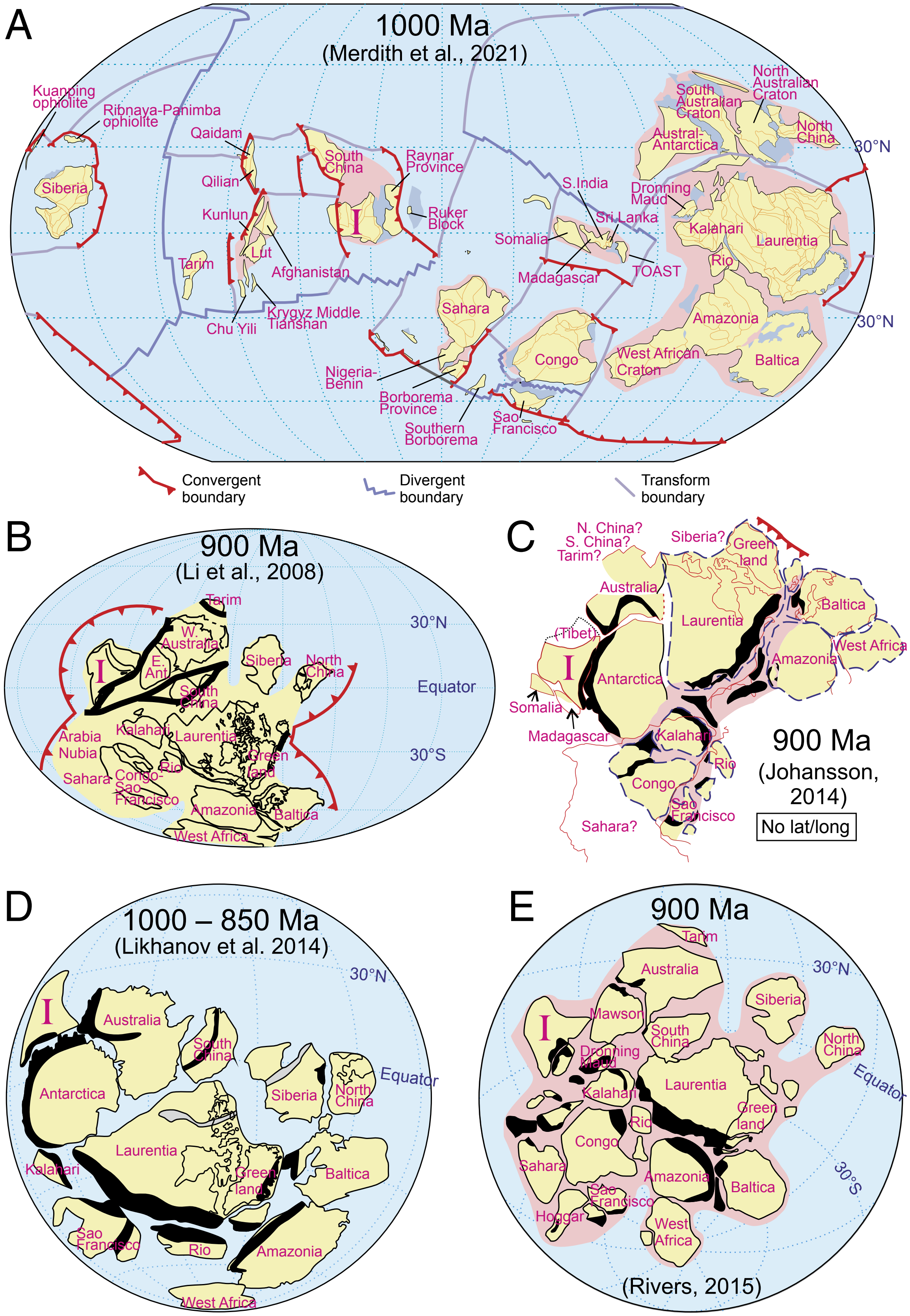

Figure 1. Reconstructions of the Rodinia supercontinent showing the position of India after (A) Merdith et al. (2021), (B) Li et al. (2008), (C) Johansson (2014), (D) Likhanov et al. (2014), and (E) Rivers (2015). In panel A, India (I) and Sri Lanka are distal from the main mass of the Rodinia supercontinent. In the other figures, India is placed alongside the western periphery of Rodinia. TOAST refers to the Stenian–Tonian juvenile arc system present in Western Dronning Maud Land in East Antarctica. (B–E) In the reconstructions, the circum-global 1.1–0.9 Ga collisional orogen (thick black line) extends along the SE coast of India to encompass the Eastern Ghats Province.

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Ghats Belt. The Eastern Ghats Province comprises an ensemble of ultrahigh-*T* granulites (Sengupta et al., 1999, and references therein), foliated blastoporphyritic felsic intrusives (commonly garnet-bearing, foliated charnockite-enderbite, and granite; Mukhopadhyay and Bhattacharya, 1997) and mantle-derived intrusives such as anorthosite massifs (Maji et al., 1997; Bhattacharya et al., 1998; Nasipuri et al., 2011) and silica under-saturated syenites (Ganguly and Chatterjee, 2020). The ensemble of the Rodinian-age Eastern Ghats Prince lithologies is juxtaposed with the cratonic footwall. Several authors (Black et al., 1987; Mezger and Cosca, 1999; Bose et al., 2016; Padmaja et al., 2022) have suggested that the welding of the Eastern Ghats Prince with the Greater India landmass to the west is Rodinian in age. If true, the cratonic footwall adjacent to the Eastern Ghats Prince is expected to record the Rodinian-age collisional event. Nasipuri et al. (2018) demonstrated that the Late Archean to Paleoproterozoic cratonic footwall adjacent to the Eastern Ghats Prince does not record any evidence of the early Neoproterozoic collision. Instead, the thrusting of the Rodinian-age Eastern Ghats Prince and syn-tectonic anatexis in the footwall (Bhadra et al., 2007) of the early Paleoproterozoic cratonic granites is Pan-African in age (U-Pb zircon and monazite dates of 550–500 Ma; Nasipuri et al., 2018). Earlier, based on analysis of mesoscale structures and U-Pb zircon geochronology, Biswal et al. (2007) concluded that the nappe structures and overprinted, steeply dipping mylonite zones characterized by transpressional kinematics at the interface between the Bastar Craton and the granulites of the Eastern Ghats Belt formed due to the collision of the craton and the Eastern Ghats Mobile Belt between 617 ± 85 Ma and 517 Ma. In other words, the early Neoproterozoic domain (Eastern Ghats Prince) of the Eastern Ghats Belt is unlikely to have accreted with the Indian landmass until the Pan-African (Biswal et al., 2007; Nasipuri et al., 2018). In such a case, the Eastern Ghats Prince could not have been a part of the Rodinian-age collisional orogen located along the southeastern part of India. As it stands, whether collision of the Eastern Ghats Prince and the cratonic nucleus of the Greater India landmass occurred at 600–500 Ma versus 1000–900 Ma continues to be debated.

In the last decade, a large body of robust data on the structural, chronological, petrological, and geochemical aspects has accumulated for the ensemble of anatectic basement gneisses, foliated granitoids, and allochthonous low-grade meta-supracrustal rocks in the Central Indian Tectonic Zone. The zone extends for more than 1500 km in the north-central part of the Indian Peninsula (Figs. 2A and 2B; Banerjee et al., 2021) and encompasses the late Mesoproterozoic to early Neoproterozoic crustal domains of the Chottanagpur Gneiss Complex of Eastern India (Sequeira and Bhattacharya, 2020; Sequeira et al., 2020), the southern and central parts of the Satpura Mobile Belt (bound between the Gavilgarh-Tan Shear Zone and the Central Indian Shear Zone; Banerjee et al., 2021) in Central India (Bhowmik et al., 2012; Chattopadhyay et al., 2017), and extends westward up to the Godhra–Chhota–Udepur sector of Western India (Figs. 2A and 2B; Banerjee et al., 2021, 2022a, 2022b). The eastern and central segments of the Central Indian Tectonic Zone are welded between the North India and South India blocks. In the western part, the NNE-striking Aravalli-Delhi Fold Belt juxtaposed between the North India Block and the Marwar Craton terminates against the Central Indian Tectonic Zone (Fig. 2A). A review of available data (Banerjee et al., 2021) and recent work (Bhattacharya et al., 2019; Sequeira and Bhattacharya, 2021; Banerjee et al., 2022a, 2022b, 2022c) demonstrates that the Central Indian Tectonic Zone was the zone of late Mesoproterozoic to early Neoproterozoic amalgamation of the North and South India blocks. In the existing reconstructions of the Rodinia supercontinent, this important Neoproterozoic (1.03–0.93 Ga; Banerjee et al., 2021, 2022a, 2022b, 2022c) collisional zone is not mentioned (Fig. 1). In the present study, we highlight the record of major events in the Central Indian Tectonic Zone, compare the events with those in the Grenvillian and the Sveconorwegian orogens, and argue that the Central Indian Tectonic Zone and the Grenvillian orogens share a mostly analogous history. Hence, we suggest the need to integrate the Central Indian Tectonic Zone into the circum-global 1.1–0.9 Ga orogen, along which the major crustal blocks welded to form the Rodinia supercontinent. At this time, a dominant part of the Greater India landmass came into existence.

Several studies (Van Kranendonk, 1996; Condie, 2007; Anderson et al., 2018; Granseth et al., 2020) emphasize that the structural, metamorphic, and igneous evolution in different domains within a collisional orogen typically varies in time and space due to variations in the contractional stress fields, the thermal state of the domains, and the rheology and dimensions of the domains wedged within the colliding crustal blocks. Thus, as a first step, we attempt to correlate the first-order characteristics of the crustal domains within the Central Indian Tectonic Zone. These characteristics are compared with the common aspects of Grenville-Sveconorwegian orogens that are deemed to be parts of a continuous collisional zone; however, the two orogens differ in minute details. In this paper, subtle divergences in the evolution of the different domains within Central Indian Tectonic Zone are ignored.

2. TECTONIC EVENTS IN THE CENTRAL INDIAN TECTONIC ZONE: A SUMMARY

Banerjee et al. (2021) reviewed the chronological aspects of major deformational, magmatic, and metamorphic events in the Chottanagpur Gneiss Complex, south and central Satpura Mobile Belt, and the Godhra–Chhota Udepur sectors of the Central Indian Tectonic Zone. More recently, Banerjee et al. (2022a, 2022b, 2022c) provided new structural, magmatic, and metamorphic data and robust chronological constraints based on laser ablation–inductively coupled plasma–mass spectrometric (LA-ICP-MS) analyses of U-Pb in zircon in the hitherto poorly documented Godhra–Chhota Udepur sector at the western extremity of the Central Indian Tectonic Zone (Fig. 2). In this section, we highlight the most striking features of the Central Indian Tectonic Zone that are analogous to those of the Grenville and Sveconorwegian orogens. The Central Indian Tectonic Zone comprises multiple deformed late Paleoproterozoic to early Mesoproterozoic anatectic basement gneisses, mafic granulites, and charnockites (Acharyya, 2003; Maji et al., 2008; Karmakar et al., 2011; Mukherjee et al., 2018a, 2018b; Sequeira and Bhattacharya, 2021; Sequeira et

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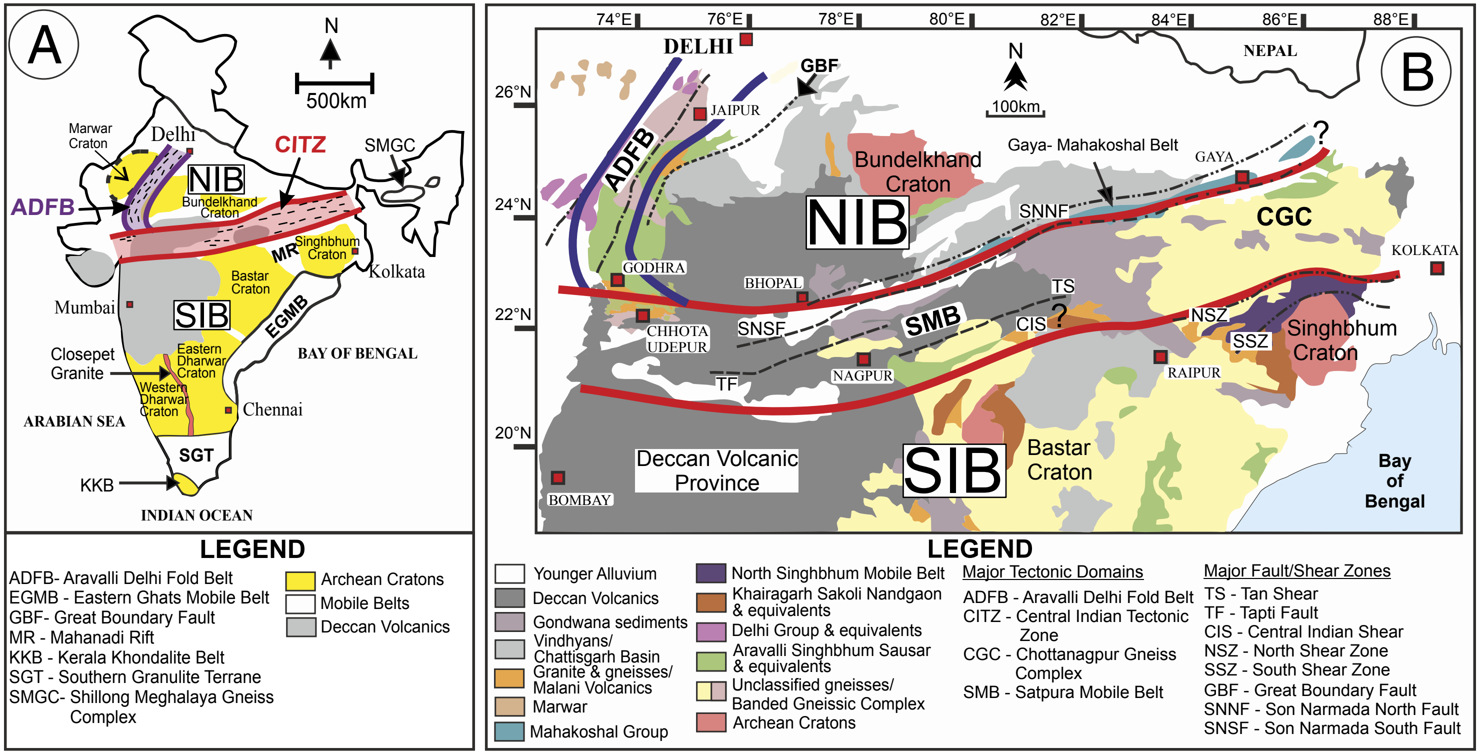

Figure 2. (A) Map of India showing the location of the Central Indian Tectonic Zone (CITZ). The NNE-striking Aravalli Delhi Fold Belt (ADFB) is slightly curved at its southern tip, where it is juxtaposed against the E-striking CITZ. (B) Generalized geological map of the CITZ and its three crustal domains, the Chottanagpur Gneiss Complex (CGC), the central and southern domains of the Satpura Mobile Belt (SMB), and the Godhra–Chhota–Udepur sector (GC sector) in the westernmost part. The Archean Bundelkhand Craton (Saha et al., 2011, and reference therein) forms a part of the North India Block (NIB); the Archean cratons of Singhbhum (Prabhakar and Bhattacharya, 2013, and references therein), the Bastar Craton (Sarkar et al., 1993; Ghosh, 2004), and the Dharwar Craton (Patra et al., 2021; further to the south, not shown) are parts of the South India Block (SIB).

al., 2021; Banerjee et al., 2022a, 2022b); early, middle, and late Mesoproterozoic to early Neoproterozoic foliated granitoids (Mukherjee et al., 2018a, 2018b; Dey et al., 2019; Sequeira et al., 2021); massif anorthosites (Chatterjee et al., 2008); nepheline syenites (Chakrabarty et al., 2013); carbonatite complexes of unknown age (Basu and Bhattacharyya, 2014); and belts of early Neoproterozoic amphibolite/epidote–amphibolite-facies supracrustal rocks that occur as E-striking hill ranges (Sequeira and Bhattacharya, 2020, 2021; Sequeira et al., 2020). Ultramafic rocks in the Central Indian Tectonic Zone—deemed to be obducted slices of oceanic lithosphere—are restricted to the southern margin of the Chottanagpur Gneiss Complex (Bhattacharya et al., 2019) and the northern margin of the Godhra-Chhota Udepur sector (Banerjee et al., 2022c) in the Central Indian Tectonic Zone.

In the discussions that follow, the Precambrian crustal domain of the Assam-Meghalaya Gneiss Complex of NE India (Chatterjee et al., 2007, 2011; Kumar et al., 2017; Borah et al., 2019), which lies farther to the east across the extensive sediments of the Ganga-Brahmaputra Rivers in northern Bangladesh, is excluded for three reasons. (1) The structural, magmatic, and geochronological evolution of the West Garo Hills (westernmost Assam) is wholly lacking, and this impedes a precise correlation between the Precambrian rocks of the Assam-Meghalaya Gneiss Complex and the adjoining Chottanagpur Gneiss Complex. (2) Based on robust age dating of basement rock drill cores in Northern Bangladesh, which are straddled by the two Precambrian terranes, correlation of the two crustal domains is contentious. Hossain et al. (2007, 2018) consider the two domains to be continuous, whereas Ameen et al. (2022) opine that the Assam-Meghlaya

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Gneiss Complex is an exotic block that is different from the Chottanagpur Gneiss Complex. (3) It is unknown whether the westward extension of the collateral effect of Pan-African collisional tectonics extended eastward within the Assam Meghalaya Gneiss Complex (Chatterjee et al., 2007, 2011).

First, in recent times, the erosional remnants of extensive, hitherto undocumented tracts of shallow-dipping foliations (dip <30°) in granitoid mylonites, and recumbent to gently inclined folds in high-grade basement gneisses and allochthonous meta-supracrustal rocks of low metamorphic grade, have been found in the Chottanagpur Gneiss Complex (Sequeira and Bhattacharya, 2020, 2021; Sequeira et al., 2020, 2021), the southern and central Satpura Mobile Belt (Chattopadhyay and Khashdeo, 2011; Chattopadhyay et al., 2017; Mohanty, 2010), and the Godhra–Chhota Udepur sector (Banerjee et al., 2022a, 2022b, 2022c). These shallow-dipping domains (D2 deformation) are part of an eroded carapace (similar to the "orogenic lid" of Rivers, 2008) that formed due to top-to-the-north thrusting in the Chottanagpur Gneiss Complex (Sequeira and Bhattacharya, 2020, 2021) and top-to-the-south thrusting in the Satpura Mobile Belt (Chattopadhyay and Khashdeo, 2011; Chattopadhyay et al., 2017) and in the Godhra–Chhota Udepur sector (Banerjee et al., 2021, 2022a, 2022b; Figs. 3A and 3B). The existence of crustal-scale thrusting manifested by eroded nappe structures in the Chottanagpur Gneiss Complex (Sequeira and Bhattacharya, 2020; Sequeira et al., 2020, 2021), the Satpura Mobile Belt (Chattopadhyay and Khashdeo, 2011; Chattopadhyay et al., 2017), and the Godhra–Chhota Udepur sector (Banerjee et al., 2022a, 2022b, 2022c) remained unidentified until recently. Underlying the carapace, in the deeply eroded parts of the Chottanagpur Gneiss Complex, the ensemble of basement anatectic gneisses with steeply dipping and sinuous N-striking, high-*T* deformational fabrics (D1a–D1b) intruded by granites (post-D1b and pre-D2) are exposed (Figs. 3A and 3B; Sequeira and Bhattacharya, 2020, 2021; Sequeira et al., 2020, 2021). The basement rocks comprise 1.65–1.50 Ga anatectic gneisses that evolved along clockwise granulite-facies *P-T* paths contemporaneous with D1a–D1b deformations (summary in Banerjee et al., 2021), steeply-dipping and foliated 1.35–1.45 Ga granitoids (Mukherjee et al., 2017, 2018a; Sequeira et al., 2021), and 1.03–0.93 Ga granitoids in the Godhra–Chhota Udepur sector (Banerjee et al., 2022c).

The 1.85–1.75 Ga undeformed to weakly deformed granites and low-grade mica schists in the northern part of the Chottanagpur Gneiss Complex (neighboring Gaya; Chatterjee and Ghose, 2011; Sequeira and Bhattacharya, 2021; Saikia et al., 2017), and in the Mahakoshal Belt (Deshmukh et al., 2017) in the northern section of the Satpura Mobile Belt (Fig. 2B), are not considered to be parts of the Central Indian Tectonic Zone. If these lithologies were a part of the Central Indian Tectonic Zone prior to 1.65 Ga, it was impossible for the >1.7 Ga rocks to escape the younger 1.65–1.50 Ga granulite-facies metamorphism in the Central Indian Tectonic Zone. Therefore, the northern collar of the Gaya-Mahakoshal Belt must have accreted with the Central Indian Tectonic Zone later (cf. Banerjee et al., 2021). Sequeira and Bhattacharya (2021) argue that the belt of >1.7 Ga lithologies constitutes a separate crustal domain (Gaya-Mahakoshal Belt) that accreted with the <1.7 Ga Central Indian Tectonic Zone at ca. 1.0 Ga. The same

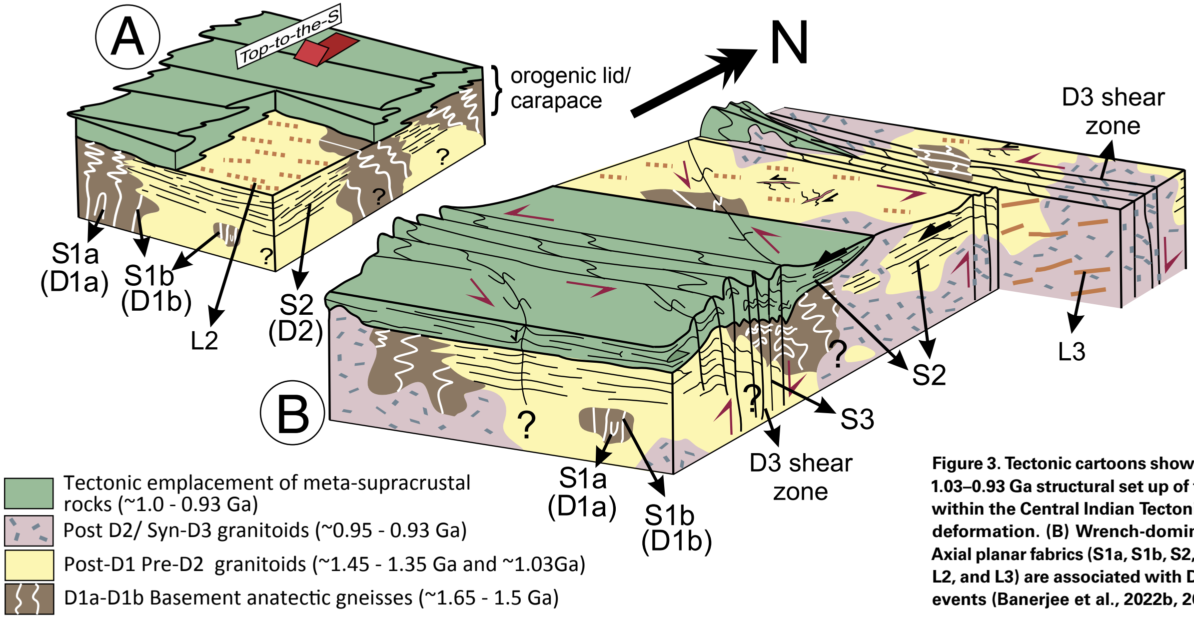

Figure 3. Tectonic cartoons showing three-dimensional views of the 1.03–0.93 Ga structural set up of the Chottanagpur Gneiss Complex within the Central Indian Tectonic Zone. (A) Thrust-dominated (D2) deformation. (B) Wrench-dominated (D3) deformational features. Axial planar fabrics (S1a, S1b, S2, and S3) and linear fabrics (L1a, L1b, L2, and L3) are associated with D1a, D1b, D2, and D3 deformational events (Banerjee et al., 2022b, 2022c).

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argument applies to the recent findings of Chakrabarty et al. (2023) in the Markohar granulite belt of the northern part of the Central Indian Tectonic Zone.

Second, the meta-supracrustal rocks in the shallowly dipping D2 thrust sheets characterized by early Neoproterozoic (1.0–0.93 Ga), clockwise *P*-*T* paths at amphibolite/epidote–amphibolite-facies metamorphic conditions (Sequeira et al., 2021; Banerjee et al., 2022c) are intimately associated with the older anatectic gneisses that describe open to E-striking, D3 tight, upright to steeply inclined and subhorizontal to gently plunging folds (Chattopadhyay and Khashdeo, 2011; Chattopadhyay et al., 2017; Sequeira and Bhattacharya, 2021; Sequeira et al., 2021; Banerjee et al., 2021, 2022a; Fig. 3B). The axes of these D3 folds are broadly collinear with the orogen-parallel stretching lineations. The tightness of the D3 folds increases closer to the network of the E-striking, steeply dipping transpressional D3 shear zones with left-lateral and dominantly N-down kinematics (Fig. 3B). Within these D3 shear zones, the shallowly dipping (thrust-induced) D2 fabrics are steepened and transposed parallel to the WNW-striking axial planes of folds related to the steeply dipping, dominantly left-lateral transpressional D3 shear zones (Fig. 4A).

Third, the youngest granitoids in the different crustal domains within the Central Indian Tectonic Zone are early Neoproterozoic (0.95–0.93 Ga) emplacements (Fig. 5A). These granitoids postdate the regional-scale D2 thrusting (shallowly dipping carapace) and are pre/syn-tectonic with the nucleation of the network of steeply dipping transpressional D3 shear zones. The broad contemporaneity between N–S shortening and granitoid emplacements is manifested by magmatic flow textures defined by tiling, and trains of K-feldspar (microcline) phenocrysts. Chessboard-patterned subgrain structures in quartz (Mamtani and Greiling, 2005; Mamtani et al., 2000; Banerjee et al., 2021, 2022a) in the syn-D3 granitoids also attest to a broad contemporaneity between crustal shortening and high-*T* subsolidus deformation in the post-D2 granitoids.

Fourth, in the north of the Godhra–Chhota Udepur sector, 2.5–2.4 Ga granitoids have emplacement ages identical to those of granitoids in the banded gneissic complex (BGC-I and -II) of the Aravalli Delhi Fold Belt (Roy and Kröner, 1996; Wiedenbeck et al., 1996a, 1996b; Sivaraman and Odom, 1982; Kaur et al., 2019). The 2.5–2.4 Ga granitoids in the Godhra–Chhota Udepur sector are juxtaposed with the 1.65–1.50 Ga anatectic gneisses in the Central Indian Tectonic Zone, but these granitoids do not record the 1.65–1.50 Ga high-grade metamorphic event in the gneisses (Banerjee et al., 2022a, 2022b). However, both of the lithodemic units record the 0.95–0.93 Ga granite emplacement and metamorphic ages in the interleaved anatectic gneisses and the meta-supracrustal rocks in the shallowly dipping carapace (Banerjee et al., 2022a, 2022b).

Finally, the early Neoproterozoic (1.03–0.93 Ga) tectonism involving progressive deformation that is thrust-dominated (formation of shallow-dipping carapace) and then wrench-dominated (Casas et al., 2001; Tikoff et al., 2004), leading to the nucleation of steeply dipping shear zones and broadly contemporaneous granitoid emplacement, is correlated with N–S crustal shortening (Banerjee et al., 2022b, 2022c; Sequeira et al., 2020, 2021; Sequeira and Bhattacharya, 2020). The progressive shortening is correlated with the convergence of the North India and South India blocks (Figs. 2A and 2B). The interleaving of the Late Archean/early Paleoproterozoic crustal domains with the late Paleoproterozoic/early Mesoproterozoic anatectic gneisses of the Central Indian Tectonic Zone is attributed to tectonic juxtaposition induced by this N–S convergence (Fig. 4A). The Neoproterozoic collisional orogeny was associated with clockwise *P*-*T* paths at low temperature (~500 °C) and high pressure, 10–12 kbar, which led to the stabilization of phengite–garnet–clinozoisite–quartz assemblages in the allochthonous mica schists of the Godhra–Chhota Udepur sector (Banerjee et al., 2022c). The crustal shortening was followed by steep decompression (Banerjee et al., 2022c); however, shallowly dipping extensional structures postdating thrusting are not common.

To summarize, in the Chottanagpur Gneiss Complex, where the Central Indian Tectonic Zone is at its widest (~200 km), the regionally sinuous N/NNE-striking D1b, low-*P*, high-*T* fabric, and the isoclinal folds on the anatectic D1a fabric in basement gneisses are synchronous with late Paleoproterozoic to early Mesoproterozoic E–W compression. In the western, central, and eastern domains of the Central Indian Tectonic Zone, these 1.65–1.55 Ga basement anatectic gneisses were intruded by mid-Mesoproterozoic (1.45–1.35 Ga) anorogenic granitoids derived from partial melting of the basement quartzofeldspathic gneisses. The voluminous mid-Proterozoic felsic magmatism in the Central Indian Tectonic Zone is linked to the breakup of the Columbia supercontinent, which comprised the lithosphere of the Central Indian Tectonic Zone. The youngest (1.03–0.93 Ga) events in the Central Indian Tectonic Zone are marked by expansive nappe formation and thrusting (D2 deformation). The breakup led to crustal thickening of up to 40 km in the Godhra–Chhota Udepur sector; the nucleation of regional-scale, E-striking, steeply dipping transpressional D3 shear zones (Fig. 3); and the formation of metamorphic core complexes that have been identified in the Chottanagpur Gneiss Complex. This Rodinian-aged collision related to the N–S convergence of the North India and South India blocks involved coeval pre-D2 and pre/syn-D3 felsic magmatism (1.03–0.93 Ga) and low-*T*, medium- to high-*P* greenschist/epidote–amphibolite-facies metamorphism (ca. 0.95 Ga) along clockwise *P*-*T* paths at the orogen margin, and mid-crustal prograde heating at the core of the orogen. Pods of distended ultramafic rocks locally occurring along the southern (Bhattacharya et al., 2019) and northern margins (Banerjee et al., 2022b, 2022c) of the doubly verging Central Indian Tectonic Zone (Fig. 4A) are possible remnants of an obducted oceanic crust caught up during the collisional event.

3. SUMMARY OF MAJOR TECTONIC EVENTS IN THE GRENVILLE AND SVECONORWEGIAN OROGENS

The Central Indian Tectonic Zone, or crustal domain portions thereof, is thought to be continuous with several Proterozoic orogens in neighboring continents (Fig. 4B), such as the Albany-Fraser Orogen (Harris, 1993; Harris and Beeson, 1993) and the Capricorn Orogen (Mohanty, 2012) in Western Australia, and the Trans–North China Craton (Zhao et al., 2003; Santosh, 2012). In subsequent years, these trans-continental correlations were thought to be untenable

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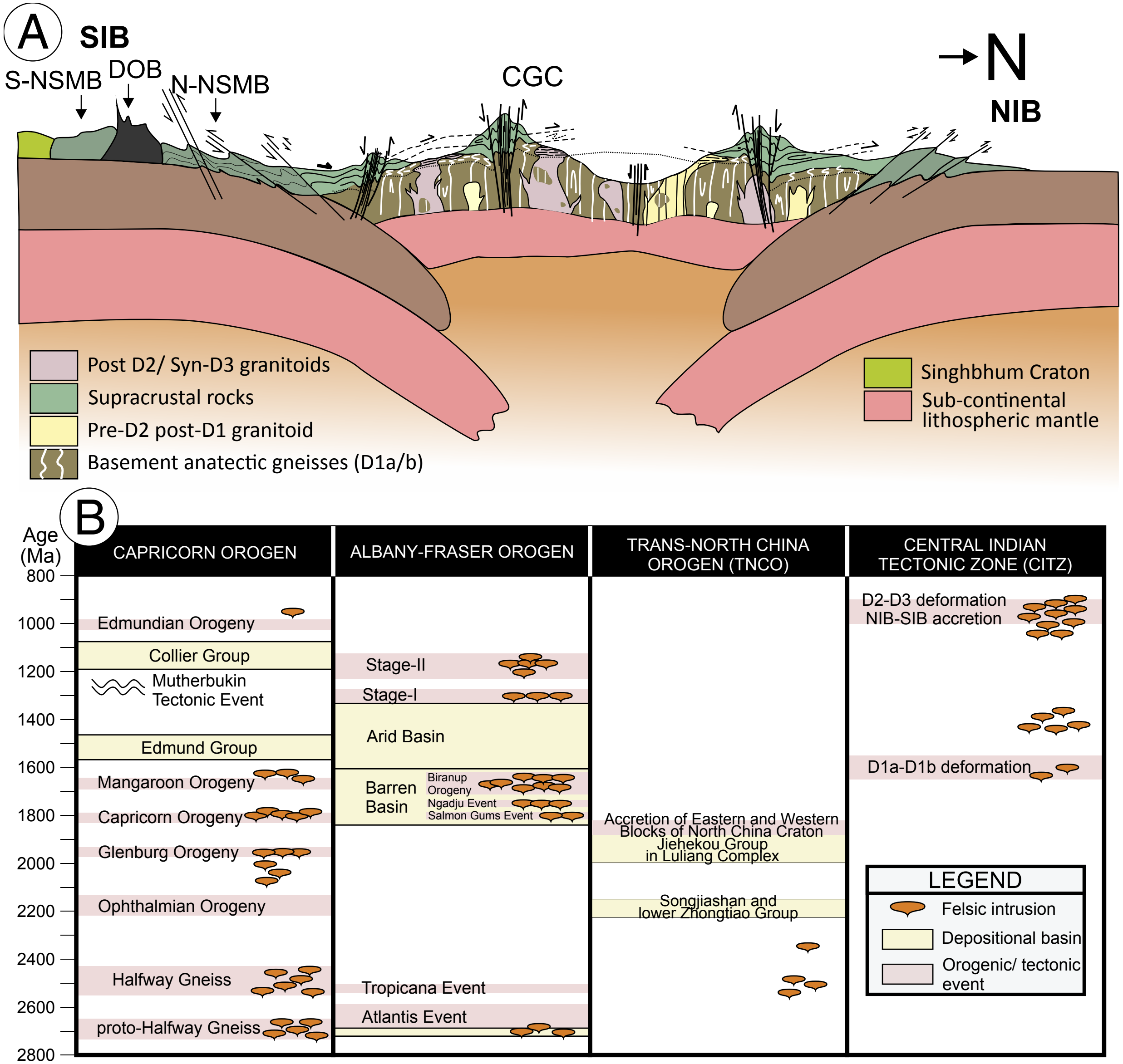

Figure 4. (A) Cartoon showing the tectonic features of the Chottanagpur Gneiss Complex (CGC) sandwiched between the South India Block (SIB) and the North India Block (NIB). The Mesoproterozoic southern domain of the North Singhbhum Mobile Belt (S-NSMB; Mahato et al., 2008; Rekha et al., 2011) and the Neo- to Paleoarchean Singhbhum Craton (Prabhakar and Bhattacharya, 2013; Prabhakar, 2013) are shown as part of the SIB. Also shown is the Dalma Ophiolite Belt (DOB; broken line) separating the northern and southern domains of the North Singhbhum Mobile Belt (NSMB; Rekha et al., 2011). The mesoscale structures and the timing of the felsic intrusives are identical to those in Figure 3. (B) Major geologic events of the Central Indian Tectonic Zone are compared with those in the Capricorn and Albany-Fraser orogens in Western Australia (modified from Sequeira and Bhattacharya, 2021) and the Trans-North China Craton (based on data compiled by Deshmukh et al., 2017).

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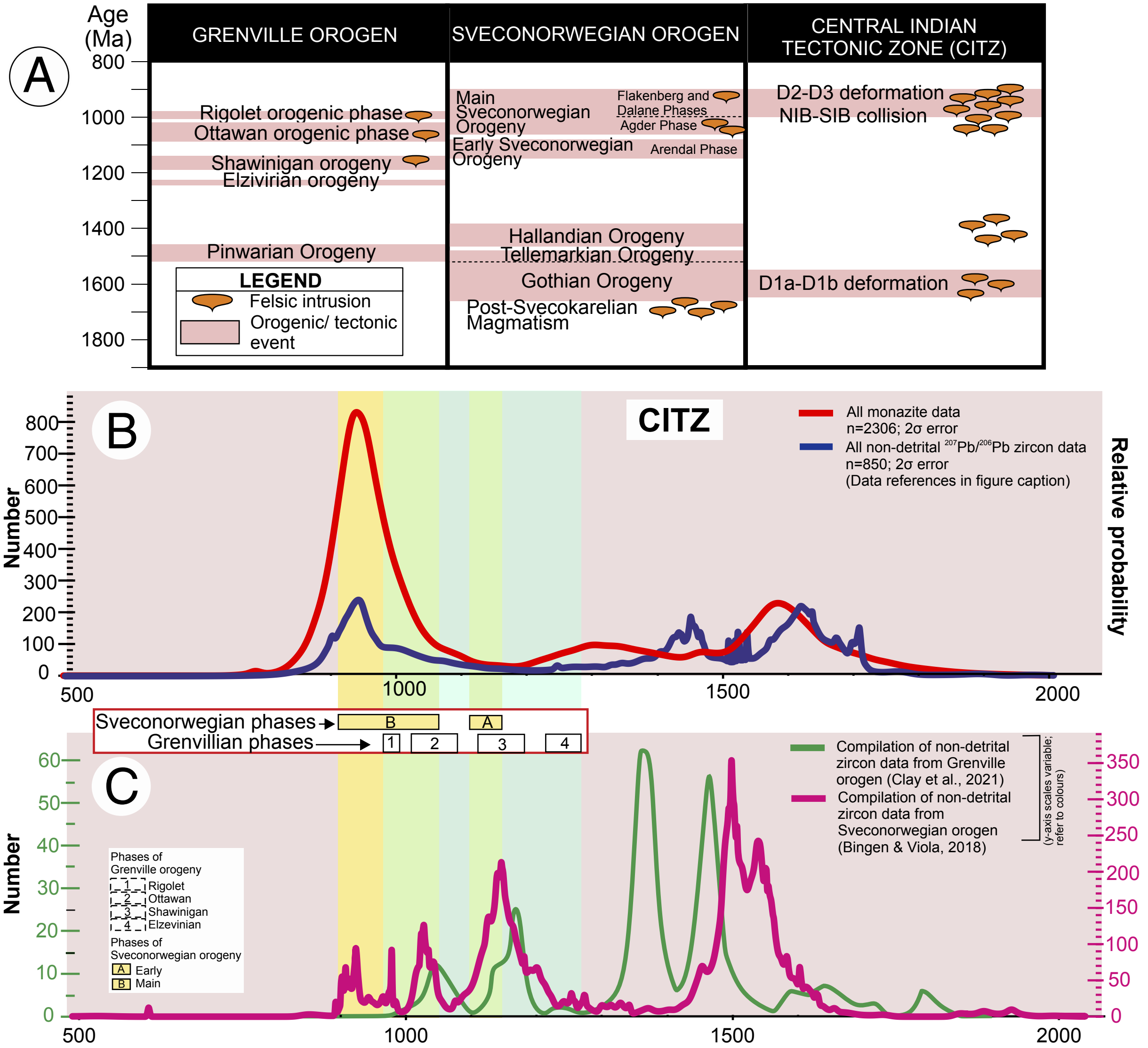

Figure 5. (A) Major geologic events of the Central Indian Tectonic Zone are compared with those in the Grenville and the Sveconorwegian orogens. Bar diagrams for the two orogens are adopted from Rivers (2021) and compiled from Bingen et al. (2021), respectively. (B) Probability-density plots of existing non-detrital Pb-Pb (zircon) dates and monazite chemical dates in the Central Indian Tectonic Zone (data source: Mukherjee et al., 2017, 2018a, 2018b; Sequeira et al., 2021; Banerjee et al., 2022a, 2022b). Pb-Pb zircon dates with <2% discordance were included in U-Pb plots. Dates from detrital zircon were excluded. Data are from Rekha et al. (2011), Chatterjee et al. (2008, 2010), Chatterjee and Ghose (2011), Chowdhury and Lentz (2011), Karmakar et al. (2011), Mukherjee et al. (2017, 2018a, 2018b, 2019), Hazarika et al. (2017), Chakraborty et al. (2019), Bhattacharya et al. (2019), Dey et al. (2017, 2019), Sequeira and Bhattacharya (2020, 2021), Sequeira et al. (2020, 2021), Bhandari et al. (2011), Chattopadhyay et al. (2015, 2017), Bhowmik et al. (2011, 2012, 2014), and Banerjee et al. (2022a, 2022b). Data set (n) in the probability-density plots refers to the number of measurements (spot ages). (C) Probability-density plots of available dates in the Grenville Orogen and the Sveconorwegian Orogen, modified after Clay et al. (2021) and Bingen and Viola (2018), respectively.

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(Fitzsimons, 2003; Dey, 2013; Rekha and Bhattacharya, 2014; Deshmukh et al., 2017; Sequeira and Bhattacharya, 2021) due to the availability of robust geochronological data (primarily U-Pb zircon dates) of geological events (reviewed by Banerjee et al., 2021), a rigorous delineation of the southern and northern margins of the Central Indian Tectonic Zone (Bhattacharya et al., 2019; Banerjee et al., 2021; Sequeira and Bhattacharya, 2021), and a clearer elucidation of the structure, petrology, and geochemistry of the lithodemic units in the Central Indian Tectonic Zone (Banerjee et al., 2021, 2022a, 2022b, 2022c). In view of these developments, and in proposing the Central Indian Tectonic Zone as a Rodinia-forming collisional zone between the South and North India blocks, we compare the geologic features of the Central Indian Tectonic Zone with those of the Grenville Orogen along the present-day eastern margin of North America (Rivers, 2015, and references therein) and the Sveconorwegian Orogen (Bingen and Viola, 2018; Slagstad et al., 2020; Wang et al., 2021, and references therein) of present-day southern Scandinavia (southwestern margin of Proto-Baltica; Fig. 5). These two orogens (Fig. 6) stand out as classic examples of the tectonic events characterizing the circum-global late Mesoproterozoic to early Neoproterozoic (1.1–0.9 Ga), Rodinia-forming collisional belt. However, we do not intend to discuss the finer differences of the tectonic events of the two collisional orogens.

3.1 The Grenville Orogen

The Grenville Orogen (Fig. 6A) is a product of a "large, hot, long-duration orogeny" (Beaumont et al., 2010; Rivers, 2008) spanning 1090–950 Ma that resulted from the collision and final amalgamation of the Laurentian and Amazonian plates in the Rodinia supercontinent (Hynes and Rivers, 2010). The orogen, which is dominated by ortho/para-gneisses and felsic igneous rocks, is categorized into three domains (Carr et al., 2000): (1) "pre-Grenvillian Laurentia and its margin," with ca. 1740 Ma and 1450 Ma continental arc plutons and associated meta-supracrustal rocks; (2) the "Composite Arc Belt," which comprises ca. 1300–1250 Ma volcanic arcs and sedimentary rocks; and (3) the "Frontenac-Adirondack Belt," which is composed of meta-supracrustal and granitoid rocks, and anorthosites, of uncertain affinity that represent a distinctive part of the Composite Arc Belt or an exotic (micro)continent. The overall structure of the Grenville Orogen comprises the Grenville Front (northwestern margin), a para-autochthonous belt that is followed to the southeast by a broad, southeast-dipping ductile shear zone (the Allochthon Boundary Thrust), and a thin-skinned fold-and-thrust belt that involves a stack of overlying allochthonous rocks that were transported from the southeastern hinterland during

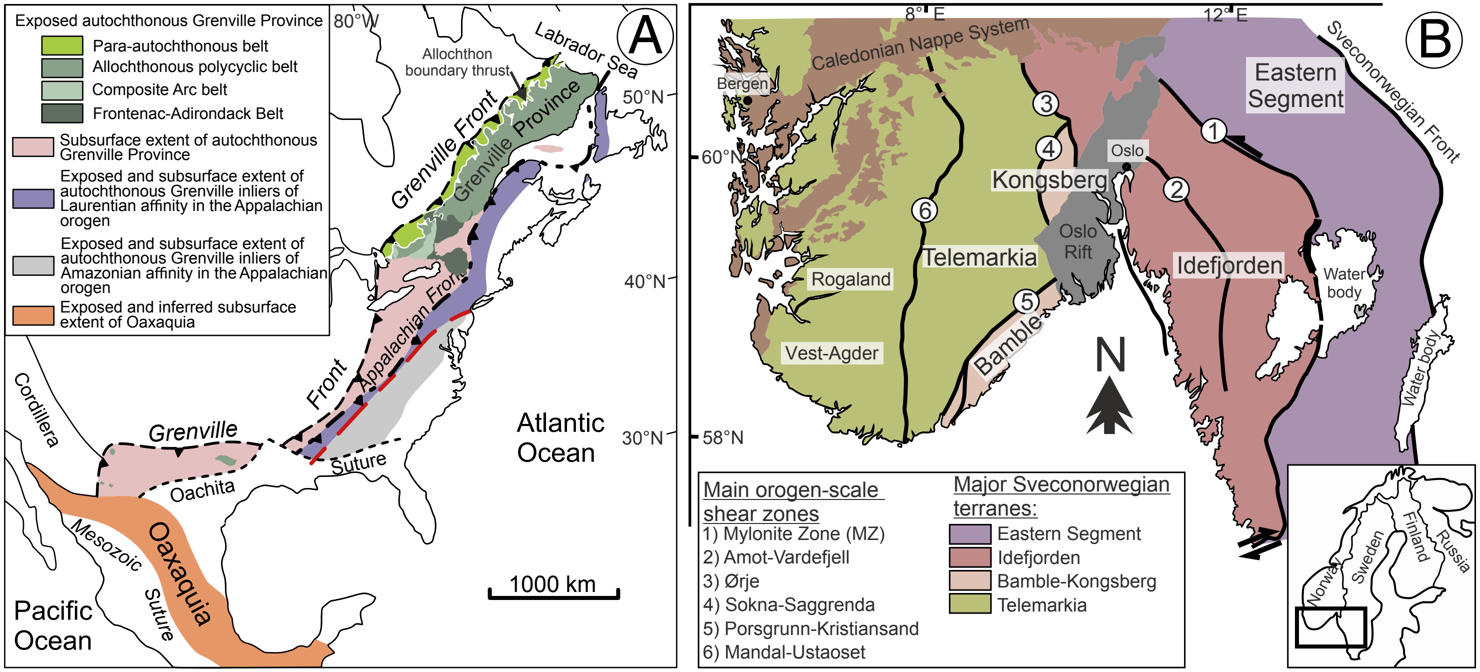

Figure 6. Generalized tectonic maps of (A) the Grenville Orogen (simplified after Rivers, 2015) showing first-order tectonic divisions in the Grenville province (modified after Carr et al., 2000; Hynes and Rivers, 2010) and (B) the Sveconorwegian Orogen (simplified after Viola et al., 2011).

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the Grenvillian orogeny (Rivers et al., 1993; van Gool et al., 2008; Fig. 6A). The Grenville Front is a moderately dipping, compressional–transpressional shear zone with variably developed mylonitic fabrics, but with no profound lithological boundary separating the para-autochthonous rocks (Rivers, 2008). By contrast, the Allochthon Boundary Thrust is a gently dipping, high-grade shear zone with an early phase of compression followed by later extension (cf. Ketchum et al., 1998). The Mesoproterozoic rocks in the SE-dipping Grenville Orogen were intensely reworked at amphibolite–granulite-facies conditions during the two-phase Grenvillian orogeny, namely the Ottawan phase (1070–1020 Ma) and the Rigolet phase (1020–980 Ma; Fig. 5B; Rivers, 1997; Rivers et al., 2002; Hynes and Rivers, 2010). Together, the Ottawan and Rigolet phases constitute the main phase of continent–continent collision (1070–980 Ma) in the Grenville Orogen (Rivers, 2021). An older (1140–1070 Ma) Shawingian phase (Rivers et al., 2002) is no longer considered to be a part of the Grenvillian cycle (Hynes and Rivers, 2010). The Composite Arc and the Frontenac-Adirondack Belt were welded at ca. 1160 Ma, and the welded composite was thrust top-to-the-west (Tollo et al., 2004; Hynes and Rivers, 2010) over Laurentia during the Ottawan and Rigolet orogenic phases, and subsequently dissected and exhumed by normal faults of <1040 Ma in age (Carr et al., 2000). The phases of thrusting and metamorphism were discontinuous and punctuated by periods of quiescence and extension during which the late Mesoproterozoic anorthosite–mangerite–charnockite–granite suites were emplaced (Tollo et al., 2004). The maximum crustal thickening recorded during the Ottawan phase (1080 Ma and ca. 1045 Ma) is inferred to be 60 km (Brudner et al., 2021), i.e., >20 km thicker than in the phengite schists (Banerjee et al., 2022c) in the Godhra–Chhota Udepur sector of the Central Indian Tectonic Zone. Structural analysis of the thin-skinned fold-and-thrust belt (Carizzo Mountain Belt; Grimes and Mosher, 2003) beyond the Allochthon Boundary Thrust reveals signatures of oblique, dextral transpression. Compressional tectonics were prevalent during the Ottawan phase (Ketchum and Krogh, 1997, 1998; Wodicka et al., 2000), whereas extensional reworking occurred during the Rigolet phase (Culshaw et al., 1997, Carr et al., 2000; Indares et al., 2000). This led to reactivation of the compressional shear zones throughout the Grenville Orogen and the formation of core complexes in the Adirondack Highlands (Bickford et al., 2008). Sinistral strike-slip shear zones associated with the collision of Amazonia and Laurentia during the Grenvillian orogeny are better developed and exposed in the Amazonian Block than in the Grenville Orogen, which indicates an orogenic asymmetry and a deeper crustal section being exposed in the Grenville Orogen (Tohver et al., 2006).

3.2 The Sveconorwegian Orogen

The 500-km-long, N-trending Sveconorwegian Orogen (1140–900 Ma; Möller, 1999; Bingen et al., 2021; Slagstad et al., 2017, 2020; Wang et al., 2021; Stephens and Wahlgren, 2020, and references therein) comprises a collage of orogen-parallel, N-trending crustal blocks (Fig. 6B), e.g., the lithospheric units/terranes of Telemarkia, Bamble, Kongsberg, and Idefjorden that were accreted due to the SE–NW collision of Fennoscandia in the east and an unknown block to the west that is suggested to be Amazonia. The Sveconorwegian Orogen is considered to be the result of a hot and lengthy continental collision that occurred during 1140–900 Ma and was broadly similar to the Grenville Orogen. The Sveconorwegian crustal blocks—separated by crustal-scale, steeply dipping ductile zones (Bingen et al., 2021)—are limited in the east by the Transscandinavian Igneous Belt, which is composed of 1810–1650 Ma plutonic and volcanic rocks that intrude an older crust (1920–1810 Ma) of low metamorphic grade. This belt, also known as the Hallandian lithospheric unit, or the Eastern Segment, is analogous with the para-autochthonous rocks in the Grenville Orogen. In the west, the Silurian–Devonian Caledonide nappes (Fig. 6B) overlie the Paleo- to Mesoproterozoic lithologies that were tectonically reworked (see below) at amphibolite–granulite-facies conditions during the late Mesoproterozoic to early Neoproterozoic Sveconorwegian orogeny.

The high-grade lithologies of the Idefjorden Terrane were thrust top-to-the-SE over the lower-grade metamorphic lithologies of the Eastern Segment (Park et al., 1991; Viola and Henderson, 2010). These east-verging thrust stacks were subsequently superposed by networks of N-striking, steeply dipping transpressional shear zones that dissected the 1.7–1.2 Ga basement gneisses and 1.1 Ga supracrustal rocks (Park et al., 1991; Stephens et al., 1996; Viola and Henderson, 2010). The Mylonite Zone separating the Hallandian and Idefjorden terranes seemingly formed at greenschist-facies conditions (Stephens et al., 1996). Westward, along the Kongsberg-Telemarkia boundary ductile shear zone, however, the movement was top-to-the-west; this high-temperature thrusting event was reactivated by sinistral transpressive movement along steep shear zones in both the Kongsberg and Telemarkia terranes (Scheiber et al., 2015).

The Idefjorden, Kongsberg, and Bamble domains comprise metasediments and metavolcanics of amphibolite to granulite facies. The Telemarkia region hosts low-grade supracrustal rocks preserved in synclines that overlie the amphibolite- to granulite-facies gneiss and mark a major litho-tectonic boundary. Structurally, these litho-tectonic units consist of a steep to subvertical foliation, isoclinal and highly transposed folds, and a penetrative tectonic layering (Bingen and Viola, 2018; Slagstad et al., 2020; Starmer, 1985, 1991) that developed during the oblique syn-metamorphic shortening during the Sveconorwegian orogeny (Bingen and Viola, 2018). The Telemarkia domain also hosts several magmatic belts comprising foliated granitic batholiths interleaved with gneissic enclaves and non-foliated to weakly foliated large plutons with distinct ferroan geochemical characteristics, e.g., the Sirdal magmatic belt is “magnesian” and the >900 Ma granite plutons are “ferroan” (Bingen et al., 2021). This belt is considered to represent syn-collisional magmatism based on the ages of the rocks (Andersen et al., 2001; Granseth et al., 2020; Van der Auwera et al., 2011; Bingen et al., 2015; Bingen and van Breemen, 1998; Coint et al., 2015; Möller et al., 2002; Slagstad et al., 2018, 2013) and their structural disposition (Bingen et al., 2021). The crustal-scale shear zones (EUGENO-S Working Group, 1988) that separate the different litho-tectonic units are steep, largely westerly dipping, and exhibit greenschist–upper amphibolite-facies mylonite

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fabric (Bingen et al., 2021). They essentially constitute nappe structures along which the thrust blocks have been transported in transpressional settings (Stephens et al., 1996; Viola and Henderson, 2010; Viola et al., 2011; Park et al., 1991; Wahlgren et al., 2016). Rocks in these zones are characterized by a steep to subvertical foliation, isoclinal and highly transposed folds, and penetrative tectonic layering (Bingen and Viola, 2018; Slagstad et al., 2020; Starmer, 1985, 1991). These features were the result of syn-metamorphic shortening, with a component of near-vertical stretching, and a component of sinistral strike-slip shearing that postdates the orthogonal shortening (Scheiber et al., 2015). The shear zones were reactivated by extension, which led to the exhumation of the high-grade footwall rocks during the waning phase of the Sveconorwegian orogeny (Viola and Henderson, 2010; Viola et al., 2011).

Overall, the Sveconorwegian orogeny is divided into four distinct tectonic phases (Bingen et al., 2008a, 2008b): the Arendal phase (1140–1080 Ma), the Agder phase (1065–1000 Ma), the Falkenberg phase (1000–970 Ma), and the Dalane phase (970–900 Ma). The Arendal phase is correlated with tectonic wedging of the Bamble and Kongsberg terranes that was induced by collision of the Idefjorden and Telemarkia terranes. This phase involved granulite-facies metamorphism and deformation in the Bamble and Kongsberg terranes, and thrusting of the Bamble Terrane onto the Telemarkia Terrane. The Agder phase involved oblique collision that resulted in under-thrusting and burial of the Idefjorden Terrane at high-pressure, followed by exhumation and protracted granite magmatism and granulite-facies metamorphism that is best manifested in the Rogaland–Vest Agder sector. The Falkenberg phase marks the final phase of convergence, which is manifested by foreland propagation of the orogeny that led to underthrusting of the Eastern Segment at eclogite-facies conditions and was followed by the initiation of crustal extension. Slagstad et al. (2017) suggested a time-space variation of events within the orogen. The oldest events (1140–1080 Ma) of thrusting and high-grade metamorphism in the central parts of the orogen were followed successively by arc-related magmatism and ultrahigh-*T* metamorphism (1060–920 Ma) in the western parts, and in the eastern part crustal thickening and high-*P* metamorphism occurred at ca. 1050 Ma and ca. 980 Ma in two different terranes. The Dalane phase was marked by gravitational collapse of the belt; post-collisional magmatism that was dominant westward; formation of anorthosite–mangerite–charnockite complexes; nucleation of core complexes in the southern part of the Eastern Segment and gneiss doming in the Telemarkia Terrane; and low-*P*, high-*T* granulite-facies metamorphism in the Rogaland sector.

4. COLLISIONAL OROGENY IN THE CENTRAL INDIAN TECTONIC ZONE: AN ANALOGUE OF THE 1.1–0.9 GA GRENVILLIAN OROGENY?

In this section, we compare the major features of the Central Indian Tectonic Zone vis-a-vis the Rodinian-age Grenville and Sveconorwegian orogens (1080–920 Ma) in North America and Fennoscandia, respectively.

First, both the Grenville and Sveconorwegian orogens are far wider than the maximum exposed width (~200 km) of the Chottanagpur Gneiss Complex in the eastern Central Indian Tectonic Zone. Also, the two orogens are examples of long-lived (ca. 150 Ma) high-*T* orogens that may have evolved by collision and re-amalgamation of fragmented crustal blocks (Slagstad et al., 2017). By contrast, the Rodinia-aged (1030–930 Ma) metamorphism in the Central Indian Tectonic Zone occurred at greenschist/epidote–amphibolite-facies conditions, with the highest pressure (10–12 kbar) recorded in the Godhra–Chhota Udepur sector (Banerjee et al., 2022b, 2022c).

Second, in recent years, the most remarkable but hitherto undocumented feature identified in the different domains of the Central Indian Tectonic Zone is the presence of large tracts of a gently dipping carapace of granitoid mylonites and recumbent to gently inclined folds in the older anatectic basement gneisses and the allochthonous meta-supracrustal rocks (Figs. 3A and 3B) metamorphosed at amphibolite/epidote–amphibolite-facies conditions. In the Chottanagpur Gneiss Complex, this carapace is demonstrably atop the steeply dipping basement gneisses (Sequeira and Bhattacharya, 2020; Sequeira et al., 2021), and it is intruded by the 1.02–0.90 Ga granitoids emplaced synchronously with the N–S convergence of the North India and South India blocks (Fig. 4A). The thrusting occurred between 1.03 Ga and 0.93 Ga. This age of crustal convergence is ~50–100 m.y. younger than the peak thrusting events in the Grenville Orogen (the Ottawan phase; 1070–1020 Ma) and in the Sveconorwegian Orogen encompassing the Arendal (1140–1080 Ma) and the Agder (1065–1000 Ma) phases (Figs. 5A and 5C).

Third, the thrusting with orogen-parallel stretching in the Central Indian Tectonic Zone occurred at mid-crustal amphibolite-facies conditions and resulted in clockwise *P*-*T* paths recorded in the allochthonous meta-supracrustal rocks. By contrast, collision-related thrusting occurred at higher temperatures (amphibolite/granulite facies) in the Grenville Orogen; in the Sveconorwegian Orogen, metamorphism varied in time and space, e.g., at high *T* (central part, 1060–920 Ma), at ultrahigh *T* in the western part (1020 Ma and 920 Ma), and at high *P* in the eastern part (ca. 1050 Ma and ca. 980 Ma).

Fourth, the continued N–S convergence across the Central Indian Tectonic Zone (Figs. 3 and 4A) is manifested by the networks of orogen-parallel, steeply inclined, basement-piercing, left-lateral transpressional shear zones with dominantly N-down (dominant) and S-down (rare) kinematics, and gentle to moderately plunging orogen-parallel stretching lineations throughout the Central Indian Tectonic Zone. Steeply dipping stretching lineations are noted along the southern margin and locally in the central part of the Chottanagpur Gneiss Complex, and in the southern part of the Satpura Mobile Belt. These shear zones may be correlated with the steeply dipping, sinistral transpressional shear zones in the central and western parts of the Idefjorden Terrane (Park et al., 1991), the Mylonite Zone (Stephens et al., 1996), and the Kongsberg–Telemarkia boundary shear zone (Scheiber et al., 2015) in the Sveconorwegian Orogen. In the Grenville Orogen, the steeply dipping transpressional shear zones overprinting early crustal-scale recumbent folds are reported in the southern Adirondacks (Chiarenzelli et al., 2000) and the Black Lake Shear Zone (Wong et al., 2011).

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Fifth, extensive S-type, weakly peraluminous and ferroan granitoids (1.0–0.93 Ga) in the different segments of the Central Indian Tectonic Zone are dominantly post-thrusting. These emplacements intruded the 1.65–1.55 Ga granulite-facies basement gneisses and 1.45–1.35 Ga granitoids prior to and during the formation of the orogen-parallel, steeply dipping transpressional shear zones. In the granitoids, the E-striking linear trails/imbrications of euhedral K-feldspar grains and chessboard subgrain structures (T > 650 °C, Kruhl, 1996) in the quartz grains (Banerjee et al., 2021, 2022a, 2022b, and references therein) wrapped around feldspar clasts indicate that the oblique convergence (D3 deformation) was broadly contemporaneous with, but outlasted, solidification of the post-D2 granitoids, as they were still hot. In both the Grenville (Rivers, 2008, 2015) and Sveconorwegian orogens (Bingen and Viola, 2018; Bingen et al., 2008b, 2021; Slagstad et al., 2020), the emplacement ages of S-type and A-type granitoids either overlap or postdate the collisional events, although most granitoid emplacements are suggested to have occurred during periods of tectonic quiescence.

Sixth, in the Central Indian Tectonic Zone, physical evidence of extensional tectonism—such as low-angle normal faults or fold hinges and stretching lineations at high angle (>45°) to the strike of the orogen—are lacking, unlike in the early Neoproterozoic low-*T* normal faults of the Grenville and Sveconorwegian orogens. However, the steep decompression sectors in *P*-*T* paths recorded in the early Neoproterozoic meta-supracrustal rocks (Banerjee et al., 2022c) in the Godhra–Chhota Udepur sector and granite mylonites (Sequeira and Bhattacharya, 2021) in the Chottanagpur Gneiss Complex, and the occurrence of syn-orogenic early Neoproterozoic metamorphic core complexes in the Chottanagpur Gneiss Complex (Sequeira et al., 2021), point to crustal extension as the likely cause for tectonic denudation in the Central Indian Tectonic Zone.

Finally, the range of the pre-collisional ages (1.03–0.93 Ga) of the basement rocks in the Central Indian Tectonic Zone (1.65–1.35 Ga) largely overlaps with the pre-Grenvillian dates estimated in the lithodemic units of the Grenville Orogen (1.7–1.25 Ga; Rivers, 1997; Karlstrom et al., 2001; Tohver et al., 2006) and the Sveconorwegian Orogen (1620–1235 Ma; Heaman and Smalley, 1994; Andersen et al., 2004a, 2004b; Engvik et al., 2016; Bingen et al., 2008a, 2008b; Fig. 5C). The overlap in the pre-Grenvillian dates in the Central Indian Tectonic Zone and those in North America and Fennoscandia does not appear to be fortuitous in spite of the great differences in distances separating the orogens in the Rodinia supercontinent (Fig. 1). Instead, the contemporaneity may suggest a close connection in the evolutionary histories of the Central Indian Tectonic Zone and the North American and Fennoscandian orogens.

To summarize, it appears, barring subtle differences in the ages of tectonic events, that the Central Indian Tectonic Zone and the Grenville-Sveconorwegian orogens share fundamental similarities, e.g., in the long-lived (1.1–0.9 Ga) nature of the collisional orogeny that involved crustal shortening primarily accommodated by large-scale thrusting and the formation of nappe structures; the development of crustal-scale, steeply dipping transpressional shear zones; expansive felsic magmatism synchronous with crustal convergence; and the final decay of orogenesis via extensional exhumation and the erosion of thrust slices (Rivers, 2015; Bingen and Viola, 2018; Slagstad et al., 2020; Wang et al., 2021). These events caused profound reworking of broadly contemporaneous pre-Grenvillian protoliths in the Central Indian Tectonic Zone as well as in the Grenville-Sveconorwegian orogens.

5. CENTRAL INDIAN TECTONIC ZONE AND THE CIRCUM-GLOBAL 1.1–0.9 GA COLLISIONAL BELT: A DISCUSSION

Paleogeographic reconstructions between 1.1 Ga and 0.9 Ga place the Greater Indian landmass at the polar region (Li et al., 2008; Pisarevsky et al., 2003) as well as close to the equator (Li et al., 2008; Merdith et al., 2021, and references therein). Within this time range, little consensus exists regarding the position of the Indian landmass with respect to the position of the Rodinia supercontinent. We provide a twofold explanation for the possible sources of the inconsistencies in the manifold locations of the Indian landmass between 1.1 Ga and 0.9 Ga.

First, the Precambrian crust of the Greater India landmass (Fig. 2A) is traversed by multiple regional-scale collisional orogens, e.g., the 1.03–0.93 Ga Central Indian Tectonic Zone collisional zone (this study, and references therein); the 820–800 Ma Phulad ophiolite belt, NW India (Chatterjee et al., 2017, 2020); the Pan-African (Ediacaran: 638–539 Ma) collisional zones along the western margin of the Eastern Ghats Prince (Biswal et al., 2007; Nasipuri et al., 2018); the collisional Achankovil Shear Zone that welded the Kerala Khondalite Belt with the Madurai Block in the southern tip of India (Praharaj et al., 2021, and references therein); and the Garo-Goalpara Block with the Sonapahar Block in the Assam-Meghalaya Gneiss Complex, NE India (Chatterjee et al., 2007, 2011). More recently, a regional-scale 820–700 Ma transpressional shear zone that hosts arc-related 800–750 Ma (U-Pb zircon age; Deeju et al., 2016) felsic intrusions has been proposed at the interface (Moyar-Bhavali Shear Zone) between the Western Dharwar Craton and the Southern Granulite Terrane. It appears that the time-space aggregation history of the Greater Indian landmass is yet to be worked out in detail. This is crucial, because the paleogeographic location is relevant to the age of formation of the crustal domain to which the rock belongs. But the location does not necessarily reflect the position of the Greater India landmass as a whole unless the crustal domain is proven to be part of the Indian landmass prior to the estimated age.

Second, paleomagnetic data spanning the assembly and breakup ages of the Rodinia supercontinent were obtained from three crustal domains in India: (1) the Marwar Craton, NW India: the Malani Igneous Suite with 786–750 Ma emplacement ages (Torsvik et al., 2001; Gregory et al., 2009; Pradhan et al., 2009; Meert et al., 2013); (2) the Western Dharwar Craton, South India: 1200–1000 Ma kimberlites from Wajrakarur (Miller and Hargraves, 1994), 1192 ± 10 Ma dikes in swarms (U-Pb zircon concordant age) in the Harohalli-Bangalore region (Pradhan et al., 2008), and 1027 ± 13 Ma mafic dikes in the Anantapur area (Pradhan et al., 2009); and (3) the Bundelkhand Craton, North India: 1073 ± 13 Ma (^{40}Ar/^{39}Ar ages on phlogopite separates) Majhgawan brecciated kimberlite in

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the Upper Vindhyan (Bhander-Rewa) sequence (Malone et al., 2008; Gregory et al., 2006) and the 1113 ± 7 Ma (mean ^{207}Pb/^{206}Pb age) Mahoba suite of ENE-striking dikes (Pradhan et al., 2012). Several of these ages are not without uncertainties and ambiguities (Malone et al., 2008).

Finally, different researchers have used various combinations of age data to reconstruct the position of India, and this could potentially affect the eventual results. Barring the age data from the Anantapur mafic dikes in the Western Dharwar Craton (Pradhan et al., 2009), most of the dates obtained from zircon and phlogopite in mafic/ultramafic rocks in the Dharwar and Bundelkhand cratons and the detrital zircon grains in the Upper Vindhyan sediments predate the age of collision of the North and South India blocks along the Central Indian Tectonic Zone. Thus, most of the older dates provide the global positions of the Dharwar Craton (South India Block) and the Bundelkhand Craton (North India Block) separately prior to their collision along the Central Indian Tectonic Zone. On the other hand, new evidence suggests that the Marwar Craton, which hosts the Malani Igneous Suite, welded with the Indian landmass along the Phulad Shear Zone at 820–810 Ma (Chatterjee et al., 2017, 2020). Therefore, the paleogeographic reconstruction of the Greater India landmass based on the age data from the Malani Igneous Suite (NW India) postdates the Central Indian Tectonic Zone collision. Clearly, there is a need to obtain the paleogeographic coordinates of the Dharwar and Bundelkhand cratons or the welded part of the Indian landmass in lithologies between 1.03 Ga and 0.93 Ga. Until the two conditions stated above are established, the locations of the Greater India landmass vis-à-vis the configuration of the Rodinia supercontinent are likely to be speculative.

In spite of these issues, several authors (Li et al., 2008; Johansson, 2014; Likhanov et al., 2014; Rivers, 2015) position India as part of the Rodinia Supercontinent and close to Australia and Eastern Antarctica (Fig. 1). We suggest that the circum-global 1.1–0.9 Ga collisional zone swung westward from East Antarctica along the Central Indian Tectonic Zone in north-central India (Fig. 7) and did not extend along the eastern coast of India (Fig. 1), since the ca. 1.0 Ga Eastern Ghats Prince possibly welded with the Greater Indian landmass 400 m.y. later in the Pan-African age (Biswal et al., 2007; Nasipuri et al., 2018). It follows that the 1.03–0.93 Ga collisional event in the Central Indian Tectonic Zone amalgamated the North India Block with the South India Block within the Rodinia supercontinent (Fig. 4). It stands to reason, therefore, that the positions reconstructed from paleomagnetic studies in rocks older than 1.03–0.93 Ga are unlikely to represent the location of the Greater India landmass, for the landmass in its entirety did not exist prior to that age. Instead, the paleogeographic positions >1.03 Ga should correspond with the positions of the separate North and the South India blocks.

Figure 7. Reconstructions of the Rodinia supercontinent (after Johansson, 2014) showing the 1.1–0.9 Ga circum-global orogen extending across the Greater Indian landmass as the Central Indian Tectonic Zone (CITZ; in black). Note the difference with Figure 1C, in which the circum-global 1.1–0.9 Ga collisional orogen incorporated the Eastern Ghats Province along the SE coast of India (I).

6. CONCLUDING REMARKS

In past interpretations, the Eastern Ghats Prince, along the SE coast of India, was regarded as the main segment of the circum-global 1.1–0.9 Ga collisional belt suturing Greater India into the Rodinia supercontinent. In this study, we suggest an alternate option, namely that the circum-global Rodinia-age collisional zone may have extended for ~1500 km across the Greater India landmass along the E-striking Central Indian Tectonic Zone. We demonstrate that the 1.03–0.93 Ga collision in the Central Indian Tectonic Zone involved thrusting that resulted in the emplacement of low-grade (high-pressure, low-temperature) metamorphic allochthonous rocks above the late Paleoproterozoic/early Mesoproterozoic (1.65–1.55 Ga) high-grade (low-*P*, high-*T*) basement gneisses intruded by mid-Mesoproterozoic (1.45–1.35 Ga) granitoids. The collision also involved the nucleation of crustal-scale steeply dipping, orogen-parallel transpressional shear zones; syn-collisional (1.03–0.95 Ga) felsic magmatism; and the decay of orogenesis by extensional exhumation. The features are broadly similar to those reported in the Grenville and Sveconorwegian orogens, although notable differences exist. For example, in the Sveconorwegian Orogen, the lithosphere is progressively younger toward the hinterland, multiple metamorphic episodes of high-*T* to locally ultrahigh-*T*, low-*P* to medium-*P* metamorphism span 150 Ma, and increasingly younger high-*P* granulite- and eclogite-facies metamorphism and orogenic magmatism occur toward the foreland. We suggest that the Rodinia-age (1.1–0.9 Ga) circum-global collisional belt swings westward from the Australo-Antarctic landmass and passes centrally within the Greater Indian landmass along the Central Indian Tectonic Zone, i.e., the zone of collision between the North India and South India blocks. It follows that the paleogeographic positions of India

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obtained from 1.1–0.9 Ga paleomagnetic data in the Bundelkhand Craton and the Dharwar Craton correspond to the positions of the North and South India blocks, respectively, exclusive of each other, and not to the Greater India landmass in its entirety. Furthermore, based on the findings of Chatterjee et al. (2017, 2020), the paleographic position of India retrieved from the Marwar Craton does not reflect the position of the Greater India landmass, because the craton welded with India ~100 m.y. later, between 800 Ma and 820 Ma.

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