# Archean granitoids of India: windows into early Earth tectonics – an introduction

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**Abstract:** Granitoids form the dominant component of Archean cratons. They are generated by partial melting of diverse crustal and mantle sources and subsequent differentiation of the primary magmas, and are formed through a variety of geodynamic processes. Granitoids, therefore, are important archives for early Earth lithospheric evolution. Peninsular India comprises five cratonic blocks bordered by mobile belts. The cratons that stabilized during the Paleoarchean–Mesoarchean (Singhbhum and Western Dharwar) recorded mostly diapirism or sagduction tectonics. Conversely, cratons that stabilized during the late Neoarchean (Eastern Dharwar, Bundelkhand, Bastar and Aravalli) show evidence consistent with terrane accretion–collision in a convergent setting. Thus, the Indian cratons provide testimony to a transition from a dominantly pre-plate tectonic regime in the Paleoarchean–Mesoarchean to a plate-tectonic-like regime in the late Neoarchean. Despite this diversity, all five cratons had a similar petrological evolution with a long period (250–850 myr) of episodic tonalite–trondhjemite–granodiorite (TTG) magmatism followed by a shorter period (30–100 myr) of granitoid diversification (sanukitoid, K-rich anatectic granite and A-type granite) with signatures of input from both mantle and crust. The contributions of this Special Publication cover diverse granitoid-related themes, highlighting the potential of Indian cratons in addressing global issues of Archean crustal evolution.

Granitoids constitute a major part of the Archean cratons, and originate from partial melting of a variety of crustal and mantle sources in a wide range of tectonic settings (Martin *et al.* 2005; Halla *et al.* 2017; **Moyen 2020**). Granitoids, therefore, act as windows into the early Earth's geodynamic processes and the secular changes thereof. The Indian cratons (Fig. 1) are rich archives Archean crustal growth, and comparable, in many respects, to other well-studied cratons such as Superior, Pilbara, Yilgarn, Kaapvaal, North China and Karelia (Champion & Sheraton 1997; Zhao *et al.* 2003; Holtta *et al.* 2012; Percival *et al.* 2012; Dey 2013; Champion & Smithies 2019; Chaudhuri 2020; **Moyen 2020**). During the last few decades, a significant amount of structural, geochemical, isotope and geochronological data have been gathered on the diverse types of Archean granitoids occurring in the Indian cratons. Many of these granitoids are also linked to important mineralizations. However, the information is fragmentary, locality specific and often not readily accessible to international readers.

The contributions of this Special Publication synthesize the available information on Archean granitoids from each Indian craton and highlight their potential in understanding evolution of early Earth. The papers discuss a broad spectrum of themes related to granitoid typology, emplacement mechanism, petrogenesis, phase-equilibria modelling, temporal distribution, tectonic setting, and their roles in fluid evolution, metal delivery and mineralizations. The volume presents a broader picture incorporating regional- to craton-scale comparisons, implications for Archean geodynamic processes and secular changes thereof. We hope that this volume will generate interest among researchers, teachers, students and exploration geologists interested in early Earth processes, and foster future international collaborative research.

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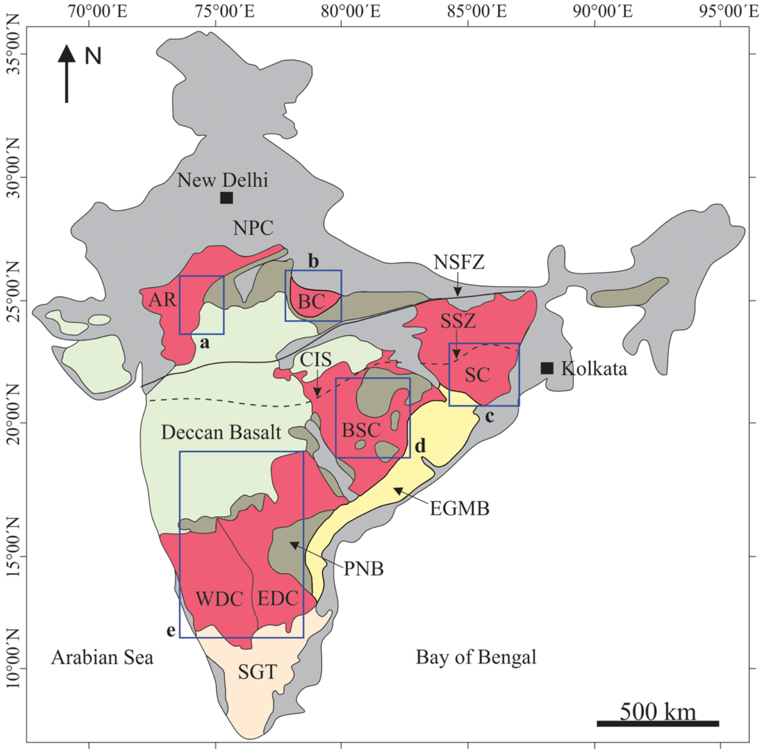


**Fig.1.** Geological sketch map of India, showing the location of Archean cratonic blocks and mobile belts. The Central Indian Tectonic Zone lies between the Narmada–Son Fault Zone and Central Indian Shear Zone. Modified after a compilation by French *et al.* (2008). AR, Aravalli Craton (including the Aravalli–Delhi Fold Belt), CIS, Central Indian Shear Zone; EDC, Eastern Dharwar Craton; EGMB, Eastern Ghats Mobile Belt; BC, Bundelkhand Craton, BSC, Bastar Craton; NPC, Neoproterozoic–Phanerozoic Cover (including the Himalayan Orogen); NSFZ, Narmada–Son Fault Zone; PNB, Paleoproterozoic–Neoproterozoic Basin; SC, Singhbhum Craton; SGT. Southern Granulite Terrain; SSZ, Singhbhum Shear Zone; WDC, Western Dharwar Craton. Letters a–e indicate the locations of the map areas shown in Figure 2a–e.

## Indian cratons

Peninsular India comprises five cratonic blocks (Dharwar, Singhbhum, Bastar, Bundelkhand and Aravalli) bordered by mobile belts (Eastern Ghats Mobile Belt, Southern Granulite Terrain and Central Indian Tectonic Zone) (Fig. 1) (Jain *et al.* 2020; Jayananda *et al.* 2020*b*). The Indian cratons have distinct evolutionary histories marked by multiple cycles of basin formation, sedimentation, magmatism, deformation, metamorphism and mineralization (Sarkar & Gupta 2012; Jain *et al.* 2020; Jayananda *et al.* 2020*b*). We provide a short description of granitoid formation events within the Indian cratons for the international readership interested in Indian Archean geology. For a more detailed description, readers are referred to the individual papers in this volume.

The Aravalli Craton is composed of Archean gneisses and granitoids which form the basement for the Proterozoic sediments of the adjacent Proterozoic Aravalli–Delhi Fold belt (ADFB) (Fig. 2a) (**Ahmad *et al.* 2020**; Fareeduddin & Banerjee 2020; Jain *et al.* 2020). The basement, conventionally known as the Banded Gneissic Complex (BGC), constitutes an ensemble of amphibolites-facies polyphase (*c.* 3.31 and 2.56–2.55 Ga) tonalite–trondhjemite–granodiorite (TTG) gneisses and migmatites containing enclaves of metasedimentary and mafic–ultramafic meta-igneous rocks (Kaur *et al.* 2019; **Ahmad *et al.* 2020**). Some workers consider the enclaves as dismembered bodies of Archean greenstone belts (Sinha-Roy 1985). Some of the gneisses also show a transitional TTG character (**Ahmad *et al.* 2020**). During 2.55–2.49 Ga, sanukitoids and K-rich anatectic granites intruded the BGC, marking the stabilization of the craton (Kaur *et al.* 2019; **Ahmad *et al.* 2020**). The ADFB comprises *c.* 1.8–1.0 Ga sedimentary and volcanic rocks which have undergone polyphase deformation and metamorphism, and intrusion of Proterozoic granitoids (Fareeduddin & Banerjee 2020). The relationship between the BGC and the ADFB has been debated for decades, although the recognition of unconformities and, in places, palaeosols (Roy & Jakhar 2002) suggests that the BGC formed the basement for the supracrustal rocks of the ADFB.

The Bundelkhand Craton is exposed over a triangular area of *c.* 26 000 km$^2$ (Fig. 2b). TTG magma emplaced episodically within the craton over a period from 3.55 to 2.70 Ga (Fig. 3) (Joshi *et al.* 2016; Kaur *et al.* 2016; **Singh *et al.* 2020**). During 2.58–2.50 Ga, diverse types of crust- and mantle-derived granitoids intruded the craton, including sanukitoids, Closepet-type granitoids, anatectic K-rich granites and A-type granites, marking the stabilization of the craton. These granitoids indicate widespread crust–mantle interaction and reworking of older crust (Joshi *et al.* 2016; Kaur *et al.* 2016). Greenstone belts containing mafic–ultramafic and felsic volcanic rocks, banded iron formations (BIFs) and quartzites, which range in age from the Mesoarchean to the Neoarchean, occur within the granitoids (Singh & Slabunov 2016). The volcanic rock associations and their geochemical signatures have been interpreted to reflect a range of tectonic settings, including plume, arc and mid-oceanic ridge settings (Singh & Slabunov 2016; Raza & Mondal 2019).

The Singhbhum Craton, exposed over *c.* 50 000 km$^2$, is made up of a Paleoarchean granitoid core surrounded by Paleoarchean–Paleoproterozoic volcano-sedimentary/greenstone belts (Fig. 2c). The granitoids are divided into two suites: the 3.47–3.40 Ga Champua Suite (TTG gneisses) and the 3.37–3.25 Ga Singhbhum Suite (TTGs, transitional TTGs and K-rich anatectic granites) (Nelson *et al.* 2014; Pandey *et al.* 2019; Dey *et al.* 2017*b*, 2019) (Fig. 3). The greenstone assemblages include *c.* 3.5–3.2 Ga greenschist–amphibolite-facies metasediments (BIF, shale, chert) and mafic–ultramafic volcanic rocks (basalt, komatiite) which form synformal keels surrounding the domal Paleoarchean granitoid bodies. These greenstone belts host Fe, Mn, Au and Cr deposits. The recent discovery of Hadean and early Eoarchean xenocrystic zircons within granitoids, and detrital zircons from the Singhbhum Craton, indicate the antiquity of the crust formation (Chaudhuri *et al.* 2018; Sreenivas *et al.* 2019). The craton stabilized at *c.* 3.25 Ga, followed by A-type granitoid magmatism at 3.1 and 2.8 Ga, episodic mafic dyke emplacement during *c.* 2.80–1.76 Ga, and formation of several cover sedimentary/volcano-sedimentary sequences during the Mesoarchean–Paleoproterozoic (Ghosh & Bose 2020; Mukhopadhyay & Matin 2020).

The Bastar Craton, occupying *c.* 130 000 km$^2$, is the least studied among the Indian cratons (Fig. 2d). A vast tract of granitoids is well exposed in the craton containing 3.56–3.50 and *c.* 3.0 Ga TTG gneisses, *c.* 3.51 Ga transitional TTGs, and 2.50–2.48 Ga K-rich anatectic and A-type granites (Sarkar *et al.* 1990, 1993; Narayana *et al.* 2000; **Mondal *et al.* 2020**; Santosh *et al.* 2020) (Fig. 3). Interestingly, Rajesh *et al.* (2009) reported a 3.58 Ga granite from the Bastar Craton, which is the oldest known K-rich granite in the world. Several generations of Paleoarchean–Paleoproterozoic supracrustal/greenstone belts are exposed within the craton hosting important Fe and Au resources. The craton stabilized during the early Paleoproterozoic concurrently with intrusion of voluminous, K-rich granitoids (although some are sodic), which contain the Malanjkhand Cu (+Mo) deposit and rare-metal (Nb, Ta, Be, Sn and Li) pegmatites (Ramesh Babu 1999; **Pandit *et al.* 2020**).

The Dharwar Craton, occupying an area of *c.* 350 000 km$^2$, is divided into western and eastern blocks (Fig. 2e). The western block or Western Dharwar Craton (WDC) is composed of 3.42–3.2 Ga TTG gneisses, 3.35–3.15 Ga transitional TTGs and 3.20–3.00 Ga K-rich anatectic granites (Jayananda *et al.* 2020*b*, ***c***; Ranjan *et al.* 2020*a*) (Fig. 3). The granitoids are interleaved with the Paleoarchean–Mesoarchean greenstone belts of the Sargur Group. The craton stabilized at *c.* 3.0 Ga. Subsequently, the younger (2.9–2.6 Ga) Dharwar Supergroup greenstone successions were formed, which host Fe, Mn and Cu deposits (Bhaskar Rao *et al.* 2020). At 2.6 Ga, K-rich granites intruded the WDC, marking a second stage of cratonization. On the other hand, the eastern block or Eastern Dharwar Craton (EDC) is composed mainly of 2.7–2.5 Ga linear north–south-trending granitoid–greenstone belts with small remnants of Paleoarchean–Mesoarchean (3.3–3.0 Ga) TTG gneisses. The Neoarchean granitoids of the EDC have a wide range of compositions, including TTG, transitional TTG, sanukitoid (+Closepet-type granitoid), K-rich anatectic granite and A-type granite (+syenites) (Fig. 3) (Moyen *et al.* 2003; Dey *et al.* 2017*a*; Jayananda *et al.* 2020*a*). Some researchers consider the EDC as a Neoarchean hot orogen characterized by a lateral constrictional flow of soft and ductile lower crust against the older and rigid WDC in a convergent set up (Chardon *et al.* 2011). The EDC stabilized at 2.5 Ga, concomitant with the formation of granulites in the lower crust and gold mineralization within the granite–greenstone belts (Peucat *et al.* 2013; **Pandit *et al.* 2020**).

## Towards a unifying scenario?

Recent petrological and isotope studies suggest that each Indian craton has a unique evolution pattern

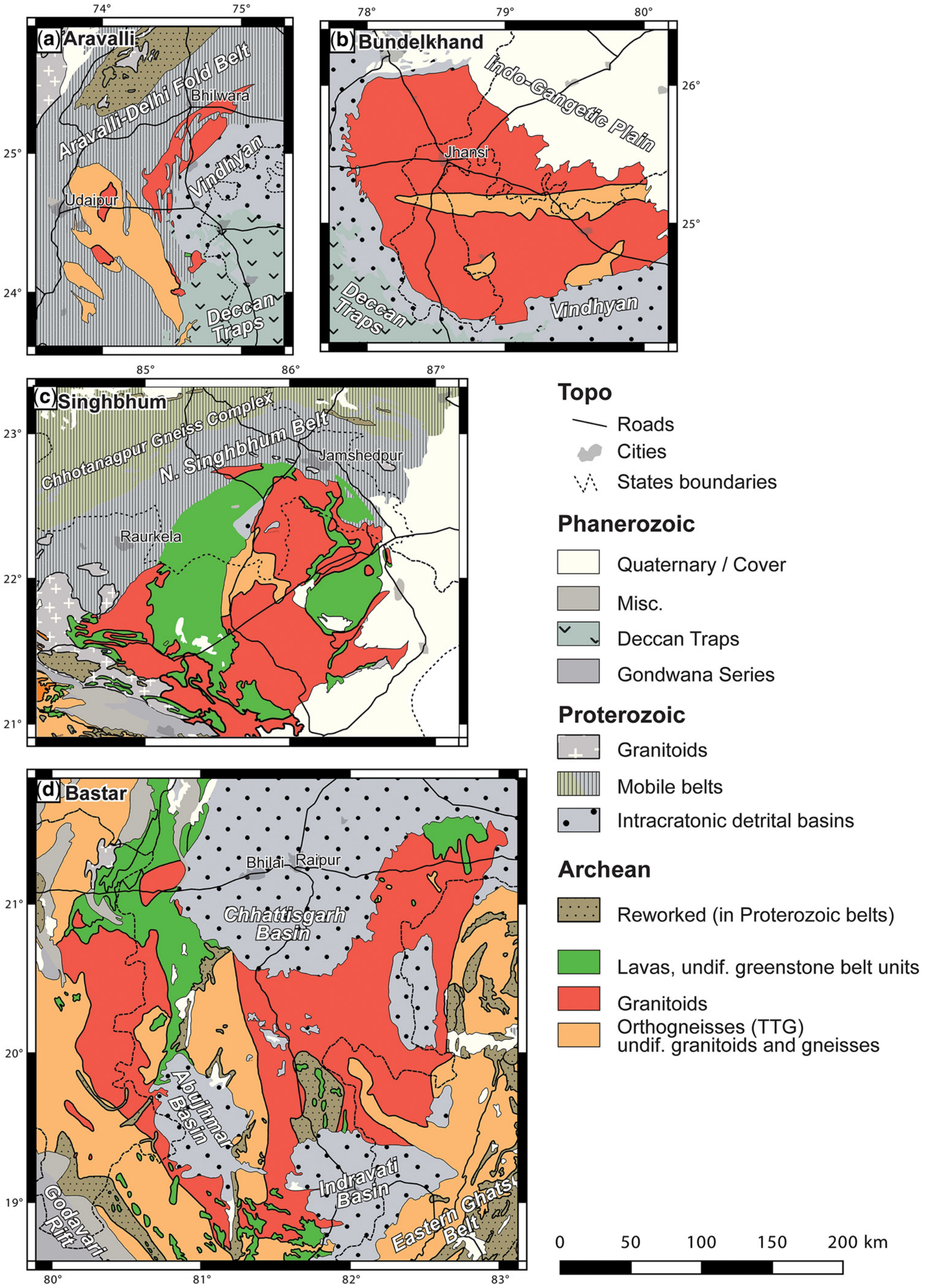
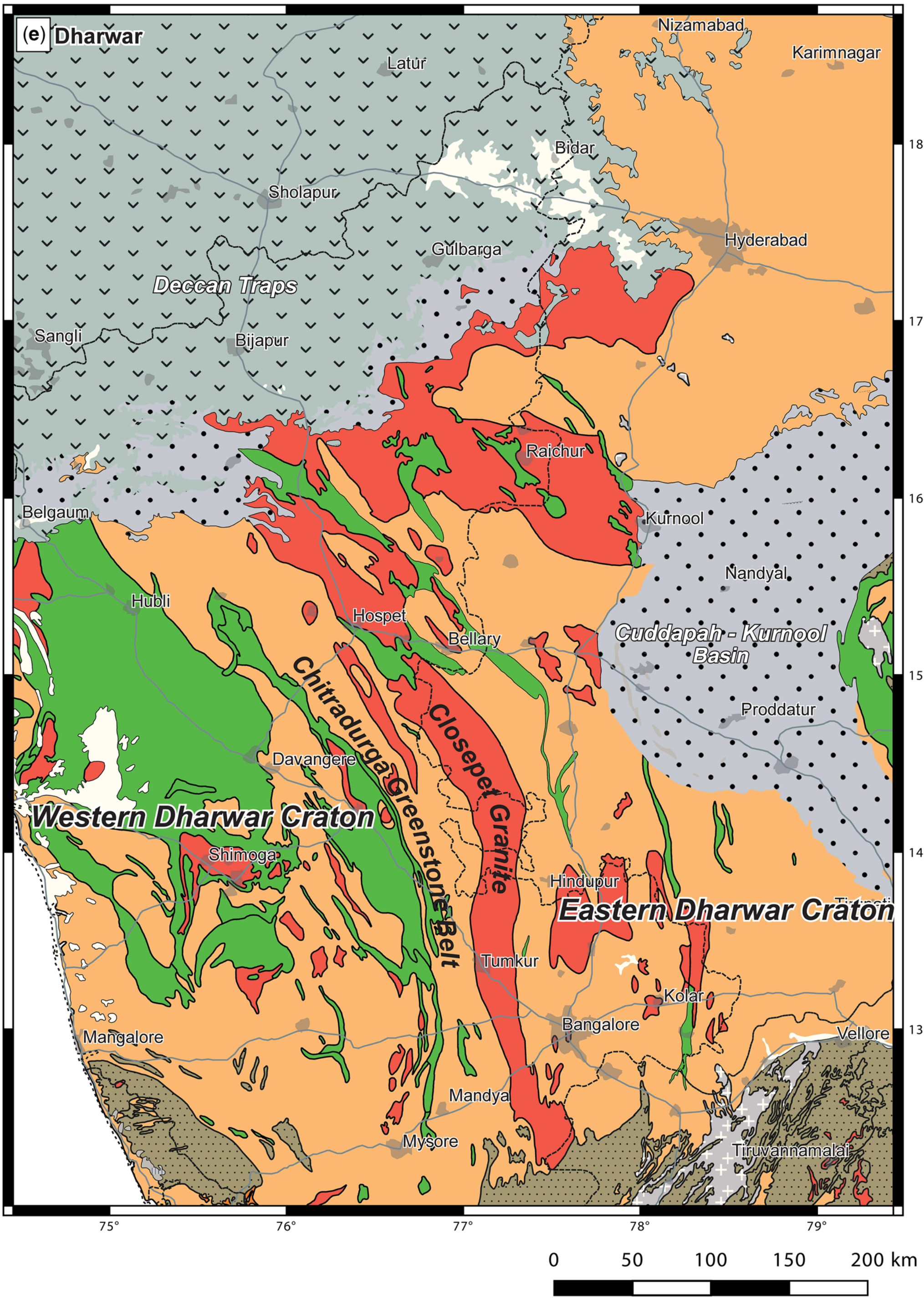


**Fig. 2.** Geological maps of the Archean cratons of India, redrawn after OneGeology portal (http://portal.onegeology.org/OnegeologyGlobal/). All maps are at the same scale. Topography from Natural Earth (https://www.naturalearthdata.com). When applicable, the units have been reinterpreted based on Jain *et al.* (2020). The map from onePortal is compiled (by the Geological Survey of India) at a scale of 1:2 500 000, and is therefore not very detailed, more detailed maps of each craton appear in the relevant chapters in this volume. In these maps, some earliest Proterozoic (*c.* 2.5 Ga) units are depicted as Archean, even though they are technically on the Proterozoic side of the border, when they clearly belong to the Archean evolution of their region.



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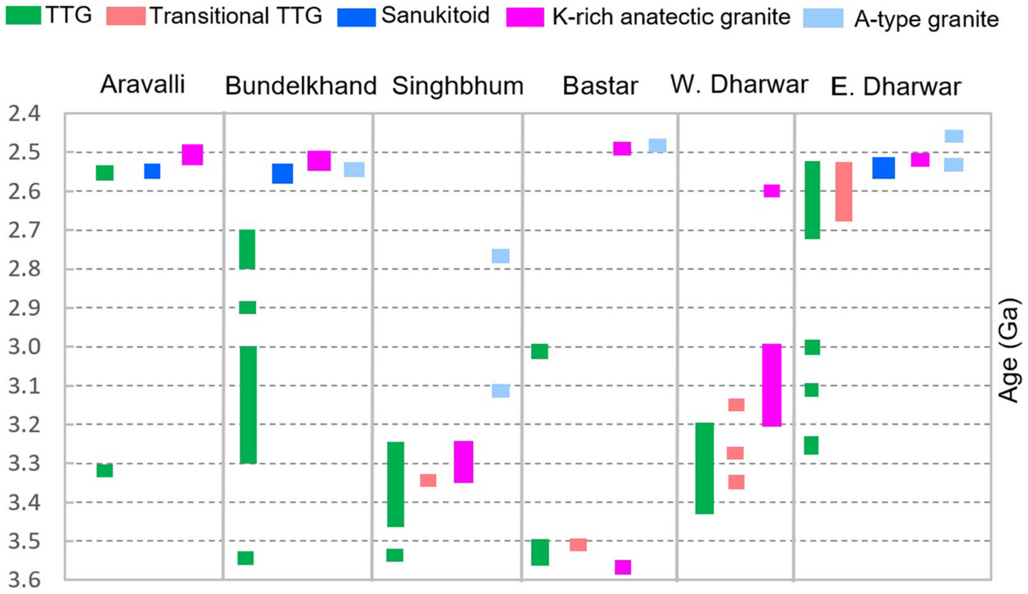

**Fig. 3.** Distribution of ages (mostly zircon U–Pb) of different types of granitoids in the Indian cratons. The available data from Bastar and Aravalli cratons are limited. Data source: Aravalli: Kaur *et al.* (2019). Bundelkhand: Joshi *et al.* (2016) and Kaur *et al.* (2016). Singhbhum: Nelson *et al.* (2014), Dey *et al.* (2019, **2020**), Mitra *et al.* (2019) and Pandey *et al.* (2019). Bastar: Sarkar *et al.* (1990, 1993), Ghosh (2004), Panigrahi *et al.* (2004), Rajesh *et al.* (2009) and Manikyamba *et al.* (2016). Dharwar: Dey *et al.* (2017*a*), Jayananda *et al.* (2020*a*, ***c***) and Ranjan *et al.* (2020*a*).

in terms of juvenile crust formation, crustal reworking and crust–mantle interaction events (Fig. 4), and probably evolved as independent entity up to the end of the Neoarchean (Dey *et al.* 2019; Kaur *et al.* 2019; Mitra *et al.* 2019; Santosh *et al.* 2020). For example, a zircon U–Pb age v. $\varepsilon_{\mathrm{Hf}}(t)$ plot shows that crust formation in the Singhbhum Craton started in the Hadean which was reworked up to 3.6 Ga. During 3.50–3.25 Ga, the craton underwent continuous addition of juvenile crust and its immediate reworking. The WDC evolved through juvenile magma input until 3.25 Ga, followed by significant reworking of older crust during 3.25–3.00 Ga. The craton recorded another event of juvenile crust formation and reworking of older crust during late Neoarchean (2.7–2.5 Ga). The detrital zircon archive in the EDC reflects the 3.6–3.2 Ga addition of juvenile crust, followed by continuous reworking of older crust up to 2.5 Ga. The craton hosts predominantly Neoarchean rocks which show a wide range of zircon $\varepsilon_{\mathrm{Hf}}(t)$ values, suggesting both juvenile crustal addition and reworking of older crust. The 3.3 Ga rocks of the Aravalli Craton shows near-chondritic zircon $\varepsilon_{\mathrm{Hf}}(t)$ values, whereas the 2.55–2.50 Ga rocks predominantly record the reworking of significant older crust with the addition of some juvenile crust. The Buldelkhand Craton shows the addition of juvenile crust at 3.58 Ga, followed by reworking of older crust during 3.55–3.10 Ga. No data are available for Neoarchean rocks of the craton. The Bastar Craton also lacks data on Paleoarchean–Mesoarchean rocks. Limited data suggest 2.8–2.7 Ga reworking of older crust, succeeded by both juvenile magma input and crustal reworking at *c.* 2.5 Ga. In general, crustal formation in the Indian cratons started with a relatively restricted range of zircon $\varepsilon_{\mathrm{Hf}}(t)$ values, eventually showing a wider span at the end stage of cratonization (Fig. 4) indicating effective crust–mantle interaction, a flare-up of juvenile magmatism and the reworking of older crust.

Notably, the Singhbhum Craton and the WDC stabilized relatively early (at *c.* 3.25 and *c.* 3.00 Ga, respectively), and display diapirism or sagduction tectonics characterized by the sinking of the denser greenstone belts and the rising of granitoid domes (Bouhallier *et al.* 1995; Prabhakar & Bhattacharya 2013). The presence of Mesoarchean–early Neoarchean terrestrial to marginal-marine mature clastic sediments, deposited over the cratonic basement, mark the attainment of early crustal stability and the subaerial emergence of the two cratons (Srinivasan & Ojakangas 1986; Mukhopadhyay *et al.* 2016). The Eastern Dharwar (EDC), Bastar, Bundelkhand and Aravalli cratons, on the other hand, have significant Neoarchean crust (granitoid–greenstone belts) and more diversified granitoid types (**Ahmad**

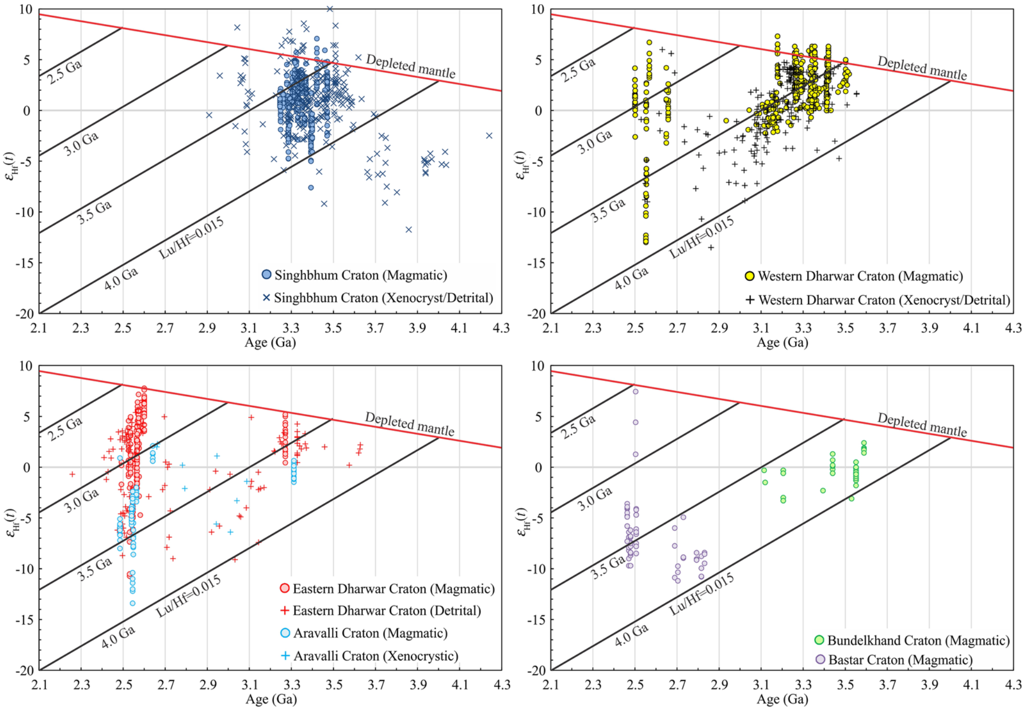

**Fig. 4.** Zircon $\varepsilon_{\mathrm{Hf}}(t)$ vs. age plot for Indian cratons suggesting that these cratons have distinct evolutionary histories (marked by the addition of juvenile crust, reworking of older crust and crust–mantle interaction events). Data sources: Bundelkhand Craton: Kaur *et al.* (2014, 2016) and Saha *et al.* (2016). Western Dharwar Craton: Mohan *et al.* (2014), Lancaster *et al.* (2015), Ishwar-Kumar *et al.* (2016), Maibam *et al.* (2016), Guitreau *et al.* (2017), Roberts & Santosh (2018) and Ranjan *et al.* (2020*a*). Eastern Dharwar Craton: Lancaster *et al.* (2015), Yang & Santosh (2015), Maibam *et al.* (2016) and Jayananda *et al.* (2020*a*). Singhbhum Craton: Dey *et al.* (2017*b*, 2019, **2020**), Chaudhuri *et al.* (2018), Miller *et al.* (2018), Mitra *et al.* (2019), Pandey *et al.* (2019), Sreenivas *et al.* (2019) and Ranjan *et al.* (2020*b*). Aravalli Craton: Kaur *et al.* (2019). Bastar Craton: Manikyamba *et al.* (2016) and Santosh *et al.* (2020).

***et al.* 2020**; **Mohan *et al.* 2020**; **Mondal *et al.* 2020**; **Singh *et al.* 2020**) (Fig. 3). The regional structural pattern, rock association and geochemical signatures of the greenstone belt volcanic rocks and the adjacent granitoids suggest accretion–collision of diverse plume- and arc-related terranes in convergent settings, which has been particularly well documented in the EDC (Dey *et al.* 2017*a*; Manikyamba *et al.* 2017; Chadwick *et al.* 2000; **Mohan *et al.* 2020**; Santosh *et al.* 2020; **Singh *et al.* 2020**).

In conclusion, Indian cratons provide testimony to the transition from a Paleoarchean–Mesoarchean dominantly pre-plate tectonic regime – characterized by diapirism or sagduction – to a plate tectonic-like regime during the late Neoarchean (2.7–2.5 Ga). Despite this fact, a common feature of all Archean cratons of India (and worldwide: Laurent *et al.* 2014; Cawood *et al.* 2018) is the succession of a relatively long period (250–850 myr) of episodic TTG magmatism, followed by a shorter period (30–100 myr) of granitoid diversification (the appearance of one or more of the following additional granitoid types: sanukitoid, K-rich anatectic granite and A-type granite) (see Fig. 3) with signatures of input from both mantle and crust. The granitoid diversification was a reflection of crust–mantle interaction (Laurent *et al.* 2014; Halla *et al.* 2017) and, possibly, the emergence of a variety of geodynamic processes facilitating such interaction (e.g. subduction, slab break-off, flake tectonics, crustal thickening and/or delamination), a signature of plate tectonics, at the last stage of the evolutionary history of a craton. The diversification is less prominent within the Paleoarchean–Mesoarchean Singhbhum and Western Dharwar cratons (less K-rich granites, negligible sanukitoid: Fig. 3), which can be construed as failed/incomplete attempts to develop plate tectonics. Conversely, the cratons that stabilized during the Neoarchean have more voluminous and diversified types of granitoids, which, together with regional structural and metamorphic patterns, signify a more evolved and stabilized plate-tectonic-like regime.

## The contributions

This Special Publication starts with a chapter by **Moyen (2020)**, who discusses the wide range of sources, melting conditions and subsequent modifications (e.g. fractionation, assimilation and mixing) leading to the origin of granitoid magmas in the Archean. The author, while stressing the difficulty in pigeonholing the granitoid magmas into discrete groups, classified the granitoids into two broad types: (i) crust-derived 'C-type' and (ii) enriched mantle-derived 'M-type'. The C-type granitoids are derived from a wide range of sources (mafic to felsic lithologies and metasediments), and include the TTGs, transitional TTGs, peraluminous potassic granites, common biotite granites and alkaline granites, including syenites. The M-type class comprises the sanukitoids and high-K calc-alkaline Closepet-type granitoids, and also shows wide-ranging chemical compositions grading into the C-types through hybrid granitoids, depending on the nature of the enrichment in the source mantle, magma mixing and crustal contamination. The author notes that on a global scale, as well as on a regional craton scale, the granitoids display a compositional diversity reflecting the evolving Earth gradually transitioning from a non-plate-tectonic regime to a plate-tectonic regime.

The Aravalli Craton also has a preserved long record of crust formation and crustal reworking from the Paleoarchean to the Paleoproterozoic. **Ahmad *et al.* (2020)** examine the geochemical and geochronological data of Archean granitoids of the craton and divide the granitoids into three groups – TTGs, transitional TTGs and sanukitoids – which intruded episodically over a period from 3.31 to 2.55 Ga. The authors explain the TTGs as a product of the melting of a subducted oceanic plateau at different depths. In contrast, the transitional TTGs are considered to have formed by the reworking of a heterogeneous crust consisting of mafic to felsic rocks. The sanukitoids (2.55 Ga) are interpreted to be a product of the melting of a metasomatized mantle wedge in a subduction setting.

**Singh *et al.* (2020)** present petrological and geochemical data of the Neoarchean TTGs and sanukitoids of the Bundelkhand Craton. A synthesis of the available geochemical and geochronological data suggests the emplacement of first-generation TTGs (both low and high pressure) at 3.5–3.2 Ga followed by second-generation TTGs (low pressure) at 2.69–2.65 Ga, sanukitoids at 2.58–2.54 Ga and high-K anatectic granites at 2.54–2.50 Ga. The authors present a tectonic model of the secular crustal evolution of the Bundelkhand Craton in which both the Paleoarchean and Neoarchean TTGs, showing a juvenile character, were formed in an intra-oceanic arc setting. At the end of the Neoarchean (2.58–2.50 Ga), the area converted into an active continental arc characterized by terrane accretion and, finally, continental collision. At this stage, the high-K anatectic granites formed through the reworking of older felsic crust, whereas the sanukitoids originated from the interaction between metasomatized mantle melts with anatectic granite melts.

An exceptionally long and almost complete record of crust formation from the Paleoarchean to the Paleoproterozoic is preserved in the Singhbhum Craton (Dey *et al.* 2019; Chaudhuri 2020). **Dey *et al.* (2020)** presented new geochemical and zircon U–Pb and Hf isotope data from 3.32–3.25 Ga TTGs from the northern part of the Singhbhum Craton, and interpreted them as being the product of the reworking of mafic rocks under low- to medium-pressure conditions. The rocks are coeval with the late K-rich granitoids of the craton. This fact suggests that, contrary to popular understanding, both K-rich and Na-rich granitoids can form at the terminal stage of cratonization through the reworking of heterogeneous crust. **Dey *et al.* (2020)** suggest that the craton nucleated in an oceanic plateau. The gradual change from sodic to K-rich granitoid magmatism within the craton over the period 3.53–3.25 Ga is explained through episodic crustal reworking due to recurrent plume-related mafic–ultramafic magmatism.

**Mondal *et al.* (2020)** synthesize available geochemical and geochronological data on Bastar granitoids, discuss their petrogenesis and suggest possible tectonic implications. Scanty geochronological data indicate the existence of 3.56 and 3.50 Ga gneisses that are divided into TTGs (both high- and low-heavy REEs (HREEs)) and transitional (enriched) TTGs. **Mondal *et al.* (2020)** propose melting at variable depths within a thick oceanic plateau to explain the occurrence of both low- and high-HREE TTGs. The reworking of the gneissic crust at 2.5–2.48 Ga produced K-rich granites.

Archean cratons generally show a transition from initial sodic granitoids (TTG) to late potassic granitoids, implying an increasing importance of the reworking of more felsic crust. The geodynamic implication of this change is controversial (Nebel *et al.* 2018). **Jayananda *et al.* (2020*c*)** describe three stages of granitoid magmatism in the southeastern part of the WDC and explain the mechanism of episodic crustal reworking leading to cratonization. The first stage is represented by 3.2 Ga granodiorites, transitional in composition between TTG and high-K granites, which intruded a 3.45–3.23 Ga TTG basement. Subsequently, mostly high-K granitoids (granodiorite, granite and quartz monzonite) formed by the mixing of two magma components: a dominant felsic magma derived by the partial melting of the TTG basement; and a minor mantle-derived, fractionated intermediate magma. **Jayananda *et al.* (2020*c*)** interpret the 3.0 Ga crustal reworking and attendant cratonization in terms of a mantle-plume-related thermal anomaly. The WDC witnessed another event of crustal reworking and the generation of high-K granites at 2.6 Ga.

The EDC is a classic granitoid–greenstone terrain and an ideal region to address important issues regarding Neoarchean crustal growth. **Mohan *et al.* (2020)** review the elemental and isotope geochemistry, geochronology, and petrogenesis of 2.7–2.5 Ga granitoids of the EDC. The authors divided the granitoids into four major types, namely: TTGs; sanukitoids; biotite and two-mica granites; and hybrid granite. The melting of hydrous basalt, metasomatized mantle and felsic crust has been proposed for the origin of the TTGs, sanukitoids and biotite granite (and two-mica granite), respectively. The hybrid granites are explained as the product of the interaction between two or more such types of granitoid magmas. **Mohan *et al.* (2020)** argue that terrane accretion followed by continental collision and crustal thickening was responsible for the close assembly of geochemically diverse sources. The interplay between mantle melting and the reworking of older crust in a collisional zone led to the formation of a spectrum of granitoids.

The quantity of fluids in the lithosphere significantly influences the partial melting and magma generation processes. **Nicoli (2020)** uses phase equilibria modelling to estimate the volume and flux of water within the Archean crust of the Dharwar Craton during the burial of supracrustal rocks into the TTG basement. The calculations indicate that rapid burial of the water-saturated supracrustal keel will expel water into the surrounding basement through devolatilization of hydrous minerals. The process results in water-fluxed partial melting of the basement, in addition to water-absent partial melting and the production of Neoarchean syn- to post-tectonic anatectic granites.

Working on the 2.51 Ga Closepet granite in the EDC, **Bhattacharya (2020)** shows that field and microstructural information, coupled with whole-rock and mineral chemical data, are valuable tools in understanding the ascent rate, deformation condition and emplacement mechanism of granitoid magmas. The Closepet granite has mineralogical–chemical variations between two end members: phenocryst-rich granodiorites and more evolved silica-rich granites. **Bhattacharya (2020)** interestingly concludes that the mineralogical–chemical variations are results of synmagmatic deformation-driven ascent of magma at variable rates (at a maximum in crystal-poor magma).

Late-magmatic fluids often play an important role in magma evolution and leave metasomatic imprints on granitoid plutons. **Słaby *et al.* (2020)** present whole-rock and mineral (feldspar and apatite) chemical analyses of the Closepet granite to investigate the role of fluids. By applying a new statistical tool (polytopic vector analysis) on the data, the authors identify intense fluid–rock/mineral interactions that are likely to involve four components (magmatic and fluid-rich) in a hybrid magma. A dynamic tectonic setting (possibly related to a mantle plume) characterized by heat influx, and redistribution and interaction between mantle- and crust-derived fluids, is proposed.

**Mamtani *et al.* (2020)** elucidate the utility of anisotropy of magnetic susceptibility (AMS) in unravelling the deformation history and emplacement mechanism of granitoid plutons, especially for those granitoids lacking visible foliations/lineations. The authors discuss three Precambrian case studies: the Godhra Granite (Aravalli–Delhi Fold Belt), the Chakradharpur Granitoid (North Singhbhum Mobile Belt) and the Mulund Granite (Dharwar Craton). It is explained that the AMS study, in combination with field and microstructural data, can be effectively applied to recognize regional superposed deformation, to understand the link between granite emplacement, fabric development and regional deformation, and even to quantify the vorticity of the magma flow.

Granitoids are important sources of metals, as well as hydrothermal fluids, and are genetically connected to a wide variety of metal deposits. **Pandit *et al.* (2020)** evaluate the ore-forming potential of granitoids associated with two different cases of mineralization: the Malanjkhand Cu (+Mo) deposit located within the 2.48 Ga Malanjkhand Granite, Bastar Craton; and the Neoarchean greenstone-belt-hosted Au mineralizations occurring near the 2.56–2.51 Ga granitoids, EDC. The authors show that the apatite and biotite chemistry of the Malanjkhand Granite, in combination with whole-rock geochemistry, can be used to characterize the water and halogen content of the magma, the evolution path of the magmatic-hydrothermal fluid, and removal of metals and consequent mineralization. Further, based on fluid-inclusion studies, **Pandit *et al.* (2020)** suggest that granitoid-derived oxidized, late magmatic fluids might have contributed to the gold mineralization, in addition to metamorphogenic fluids.

## Future directions

Vast tracts of Archean granitoid–greenstone belts are well exposed within the Indian cratons. The existing maps, mostly the result of commendable efforts by the Geological Survey of India (GSI), need to be updated by the application of modern concepts of granite typology. Academic institutions can play a significant role in the remapping of critical areas, which will also help in mineral exploration modelling. Also, geochronological and isotope geochemical data are still inadequate, especially for the granitoids of the Bastar, Bundelkhand and Aravalli cratons, to put the different juvenile crustal addition and crustal reworking events, and the secular changes in crustal evolution, within a global perspective.

With the advent of new, more affordable and faster analytical techniques, the next decade will see a flurry of data, particularly zircon U–Pb dates and Hf isotopes. However, the large amount of data should be utilized and appreciated effectively by being compiled, archived and integrated against a geological background to see the larger picture. In particular, the data should be rooted in a spatial/geological framework (e.g. maps) in order to better unravel patterns, trends and associations. This development will significantly improve our understanding of the antiquity and ancestry (in supercontinent or supercraton) of the Indian cratons. The recent discovery of Hadean xenocrystic zircons from the Singhbhum Granite (Chaudhuri *et al.* 2018) underlines the necessity of undertaking more such types of studies of Indian cratons in order to unravel very early Earth history. The Indian cratons offer ample scope for research over a broad spectrum of granitoid-related studies covering emplacement mechanism and processes, deformation and associated tectonics, fluid–rock interactions and attendant mineralizations, mineralogy and textural analysis (using techniques such as cathodoluminescence), exploration targeting, melting and formation of migmatites, and phase equilibria and experimental studies. This research will a play critical role in understanding the 'most common' but enigmatic granite systems better.

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## References

Ahmad, I., Mondal, M.E.A., Rahaman, M.S., Bhutani, R. & Satyanarayanan, M. 2020. Archean granitoids of the Aravalli Craton, northwest India. *Geological Society, London, Special Publications*, **489**, https://doi.org/10.1144/SP489-2018-195

Bhaskar Rao, Y.J., Vijaya Kumar, T., Sreenivas, B. & Babu, E.V.S.S.K. 2020. A review of Paleo- to Neoarchean crustal evolution in the Dharwar craton, southern India and the transition towards a plate tectonic regime. *Episodes*, **43**, 51–68, https://doi.org/10.18814/epiiugs/2020/020003

Bhattacharya, A. 2020. Deformation-driven emplacement-differentiation in the Closepet pluton, Dharwar Craton, South India: an alternate view. *Geological Society, London, Special Publications*, **489**, https://doi.org/10.1144/SP489-2019-315

Bouhallier, H., Chardon, D. & Choukroune, P. 1995. Strain patterns in Archaean dome-and-basin structures: the Dharwar Craton (Karnataka, South India). *Earth and Planetary Science Letters*, **135**, 57–75, https://doi.org/10.1016/0012-821X(95)00144-2

Cawood, P.A., Hawkesworth, C.J., Pisarevsky, S.A., Dhuime, B., Capitanio, F.A. & Nebel, O. 2018. Geological archive of the onset of plate tectonics. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, **376**, 20170405, https://doi.org/10.1098/rsta.2017.0405

Chadwick, B., Vasudev, V.N. & Hegde, G.V. 2000. The Dharwar craton, southern India, interpreted as the result of Late Archaean oblique convergence. *Precambrian Research*, **99**, 91–111, https://doi.org/10.1016/S0301-9268(99)00055-8

Champion, D.C. & Sheraton, J.W. 1997. Geochemistry and Nd isotope systematics of Archaean granites of the Eastern Goldfields, Yilgarn Craton, Australia: implications for crustal growth processes. *Precambrian Research*, **83**, 109–132, https://doi.org/10.1016/S0301-9268(97)00007-7

Champion, D.C. & Smithies, R.H. 2019. Geochemistry of Paleoarchean granites of the East Pilbara Terrane, Pilbara Craton, Western Australia: implications for early Archean crustal growth. *In*: Van Kranendonk, M.J., Bennett, V.C. & Hoffmann, J.E. (eds) *Earth's Oldest Rocks*. 2nd edn. Elsevier, Amsterdam, 487–518.

Chardon, D., Jayananda, M. & Peucat, J.-J. 2011. Lateral constrictional flow of hot orogenic crust: insights from the Neoarchean of south India, geological and geophysical implications for orogenic plateaux. *Geochemistry. Geophysics, Geosystems*, **12**, Q02005, https://doi.org/10.1029/2010GC003398

Chaudhuri, T. 2020. A review of Hadean to Neoarchean crust generation in the Singhbhum Craton, India and possible connection with Pilbara Craton, Australia: The geochronological perspective. *Earth-Science Reviews*, **202**, 103085, https://doi.org/10.1016/j.earscirev.2020.103085

Chaudhuri, T., Wan, Y., Mazumder, R., Ma, M. & Liu, D. 2018. Evidence of enriched, Hadean mantle reservoir from 4.2–4.0 Ga zircon xenocrysts from Paleoarchean TTGs of the Singhbhum Craton, Eastern India. *Scientific Reports*, **8**, 1–12, https://doi.org/10.1038/s41598-018-25494-6

Dey, S. 2013. Evolution of Archaean crust in the Dharwar craton: the Nd isotope record. *Precambrian Research*, **227**, 227–246, https://doi.org/10.1016/j.precamres.2012.05.005

Dey, S., Halla, J., Kurhila, M., Nandy, J., Heilimo, E. & Pal, S. 2017*a*. Geochronology of Neoarchaean granitoids of the NW eastern Dharwar craton: implications for crust formation. *Geological Society, London, Special Publications*, **449**, 89–121, https://doi.org/10.1144/SP449.9

Dey, S., Topno, A., Liu, Y. & Zong, K. 2017*b*. Generation and evolution of Palaeoarchean continental crust in the central part of the Singhbhum craton, eastern India. *Precambrian Research*, **298**, 268–291, https://doi.org/10.1016/j.precamres.2017.06.009

Dey, S., Mitra, A., Nandy, J., Mondal, S., Topno, A., Liu, Y. & Zong, K. 2019. Early Crustal Evolution as Recorded in the Granitoids of the Singhbhum and Western Dharwar Cratons. *In*: Van Kranendonk, M.J., Bennett, V.C. & Hoffmann, J.E. (eds) *Earth's Oldest Rocks*. 2nd edn. Elsevier, Amsterdam, 741–792, https://doi.org/10.1016/B978-0-444-63901-1.00030-7

Dey, S., Nayak, S.K., Mitra, A., Zong, K. & Liu, Y. 2020. Mechanism of Paleoarchean continental crust formation as archived in granitoids from northern part of Singhbhum Craton, eastern India. *Geological Society, London, Special Publications*, **489**, https://doi.org/10.1144/SP484-2019-202

Fareeduddin & Banerjee, D.M. 2020. Aravalli Craton and its mobile belts – an update. *Episodes*, **43**, 88–108, https://doi.org/10.18814/epiiugs/2020/020005

French, J.E., Heaman, L.M., Chacko, T. & Srivastava, R.K. 2008. 1891–1883 Ma southern Bastar-Cuddapah mafic igneous events, India: a newly recognized large igneous province. *Precambrian Research*, **160**, 308–322, https://doi.org/10.1016/j.precamres.2007.08.005

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, https://doi.org/10.1016/S1367-9120(03)00136-6

Ghosh, G. & Bose, S. 2020. Deformation and metamorphic history of the Singhbhum Craton vis-à-vis peripheral mobile belts, eastern India: implications on Precambrian crustal processes. *Journal of Mineralogical and Petrological Sciences*, **115**, 70–87, https://doi.org/10.2465/jmps.190824a

Guitreau, M., Mukasa, S.B., Loudin, L. & Krishnan, S. 2017. New constraints on the early formation of the Western Dharwar Craton (India) from igneous zircon U–Pb and Lu–Hf isotopes. *Precambrian Research*, **302**, 33–49, https://doi.org/10.1016/j.precamres.2017.09.016

Halla, J., Whitehouse, M.J., Ahmad, T. & Bagai, Z. 2017. Archaean granitoids: an overview and significance from a tectonic perspective. *Geological Society, London, Special Publications*, **449**, 1–18, https://doi.org/10.1144/SP449.10

Holtta, P., Heilimo, E. *et al.* 2012. Archean complexes of the Karelia Province in Finland. *Geological Survey of Finland, Special Papers*, **54**, 9–20.

Ishwar-Kumar, C., Santosh, M., Wilde, S.A., Tsunogae, T., Itaya, T., Windley, B.F. & Sajeev, K. 2016. Mesoproterozoic suturing of Archean crustal blocks in western peninsular India: implications for India–Madagascar correlations. *Lithos*, **263**, 143–160, https://doi.org/10.1016/j.lithos.2016.01.016

Jain, A.K., Banerjee, D.M. & Kale, V.S. 2020. *Tectonics of the Indian Subcontinent*. Springer, Cham, Switzerland, https://doi.org/10.1007/978-3-030-42845-7

Jayananda, M., Aadhiseshan, K.R. *et al.* 2020*a*. Multi-stage crustal growth and Neoarchean geodynamics in the Eastern Dharwar Craton, southern India. *Gondwana Research*, **78**, 228–260, https://doi.org/10.1016/j.gr.2019.09.005

Jayananda, M., Dey, S. & Aadhiseshan, K.R. 2020*b*. Evolving early Earth: Insights from Peninsular India. *In*: Gupta, N. & Tandon, S.K. (eds) *Geodynamics of the Indian Plate: Evolutionary Perspectives*. Springer, Cham, Switzerland, 5–103, https://doi.org/10.1007/978-3-030-15989-4_2

Jayananda, M., Guitreau, M., Thomas, T.T., Martin, H., Aadhiseshan, K.R., Gireesh, R.V. & Peucat, J.-J. 2020*c*. Geochronology and geochemistry of Meso- to Neoarchean magmatic epidote-bearing potassic granites, western Dharwar Craton (Bellur–Nagamangala–Pandavpura corridor), southern India: implications for the successive stages of crustal reworking and cratonization. *Geological Society, London, Special Publications*, **489**, https://doi.org/10.1144/SP489-2018-125

Joshi, K.B., Bhattacharjee, J., Rai, G., Halla, J., Ahmad, T., Kurhila, M. & Choudhary, A.K. 2016. The diversification of granitoids and plate tectonic implications at the Archaean–Proterozoic boundary in the Bundelkhand Craton, Central India. *Geological Society London Special Publications*, **449**, 123–157, https://doi.org/10.1144/SP449.8

Kaur, P., Zeh, A. & Chaudhri, N. 2014. Characterisation and U–Pb–Hf isotope record of the 3.55 Ga felsic crust from the Bundelkhand Craton, northern India. *Precambrian Research*, **255**, 236–244, https://doi.org/10.1016/j.precamres.2014.09.019

Kaur, P., Zeh, A., Chaudhari, N. & Eliyas, N. 2016. Unravelling the record of Archaean crustal evolution of the Bundelkhand craton, northern India using U–

Pb zircon-monazite ages, Lu–Hf isotope systematics, and whole-rock geochemistry of Granitoids. *Precambrian Research*, **281**, 384–413, https://doi.org/10.1016/j.precamres.2016.06.005

Kaur, P., Zeh, A. & Chaudhri, N. 2019. Archean crustal evolution of the Aravalli Banded Gneissic Complex, NW India: Constraints from zircon U–Pb ages, Lu–Hf isotope systematics, and whole-rock geochemistry of granitoids. *Precambrian Research*, **327**, 81–102, https://doi.org/10.1016/j.precamres.2019.03.004

Lancaster, P.J., Dey, S., Storey, C.D., Mitra, A. & Bhunia, R.K. 2015. Contrasting crustal evolution processes in the Dharwar craton: Insights from detrital zircon U–Pb and Hf isotopes. *Gondwana Research*, **28**, 1361–1372, https://doi.org/10.1016/j.gr.2014.10.010

Laurent, O., Martin, H., Moyen, J.-F. & Doucelance, R. 2014. The diversity and evolution of late-Archean granitoids: evidence for the onset of 'modern-style' plate tectonics between 3.0 and 2.5 Ga. *Lithos*, **208**, 205–235.

Maibam, B., Gerdes, A. & Goswami, J.N. 2016. U–Pb and Hf isotope records in detrital and magmatic zircon from eastern and western Dharwar craton, southern India: Evidence for coeval Archaean crustal evolution. *Precambrian Research*, **275**, 496–512, https://doi.org/10.1016/j.precamres.2016.01.009

Mamtani, M.A., Bhatt, S., Rana, V., Sen, K. & Mondal, T.K. 2020. Application of anisotropy of magnetic susceptibility (AMS) in understanding regional deformation, fabric development and granite emplacement: examples from Indian cratons. *Geological Society, London, Special Publications*, **489**, https://doi.org/10.1144/SP489-2019-292

Manikyamba, C., Chandan Kumar, B. *et al.* 2016. Zircon U–Pb geochronology, Lu–Hf isotope systematics, and geochemistry of bimodal volcanic rocks and associated granitoids from Kotri Belt, Central India: Implications for Neoarchean–Paleoproterozoic crustal growth. *Gondwana Research*, **38**, 313–333, https://doi.org/10.1016/j.gr.2015.12.008

Manikyamba, C., Ganguly, S., Santosh, M. & Subramanyam, S.V. 2017. Volcano-sedimentary and metallogenic records of the Dharwar greenstone terranes, India: Window to Archean plate tectonics, continent growth, and mineral endowment. *Gondwana Research*, **50**, 38–66, https://doi.org/10.1016/j.gr.2017.06.005

Martin, H., Smithies, R.H., Rapp, R., Moyen, J.-F. & Champion, D. 2005. An overview of adakite, tonalite–trondhjemite–granodiorite (TTG), and sanukitoids: relationships and some implications for crustal evolution. *Lithos*, **79**, 1–24, https://doi.org/10.1016/j.lithos.2004.04.048

Miller, S.R., Mueller, P.A., Meert, J.G., Kamenov, G.D., Pivarunas, A.F., Sinha, A.K. & Pandit, M.K. 2018. Detrital zircons reveal evidence of Hadean crust in the Singhbhum Craton, India. *The Journal of Geology*, **126**, 541–552, https://doi.org/10.1086/698844

Mitra, A., Dey, S., Zong, K., Liu, Y. & Mitra, A. 2019. Building the core of a Paleoarchean continent: Evidence from granitoids of Singhbhum Craton, eastern India. *Precambrian Research*, **335**, 105436, https://doi.org/10.1016/j.precamres.2019.105436

Mohan, M.R., Sarma, D.S. *et al.* 2014. SHRIMP zircon and titanite U–Pb ages, Lu–Hf isotope signatures and geochemical constraints for ~2.56 Ga granitic magmatism in Western Dharwar Craton, Southern India: Evidence for short-lived Neoarchean episodic crustal growth? *Precambrian Research*, **243**, 197–220, https://doi.org/10.1016/j.precamres.2013.12.017

Mohan, R.M., Asokan, A.D. & Wilde, S.A. 2020. Crustal growth of the Eastern Dharwar Craton: a Neoarchean collisional orogeny? *Geological Society, London, Special Publications*, **489**, https://doi.org/10.1144/SP489-2019-108

Mondal, M.E.A., Hussain, M.F. & Ahmad, T. 2020. Archean granitoids of the Bastar Craton, Central India. *Geological Society, London, Special Publications*, **489**, https://doi.org/10.1144/SP489-2019-311

Moyen, J.-F. 2020. Archean granitoids: classification, petrology, geochemistry and origin. *Geological Society, London, Special Publications*, **489**, https://doi.org/10.1144/SP489-2018-34

Moyen, J.-F., Martin, H., Jayananda, M. & Auvray, B. 2003. Late Archaean granites: a typology based on the Dharwar Craton (India). *Precambrian Research*, **127**, 103–123, https://doi.org/10.1016/S0301-9268(03)00183-9

Mukhopadhyay, D. & Matin, A. 2020. The architecture and evolution of the Singhbhum Craton. *Episodes*, **43**, 19–50, https://doi.org/10.18814/epiiugs/2020/020002

Mukhopadhyay, J., Mishra, B., Chakrabarti, K., De, S. & Ghosh, G. 2016. Uraniferous paleoplacers of the Mesoarchean Mahagiri Quartzite, Singhbhum craton, India: depositional controls, nature and source of >3.0 Ga detrital uraninites. *Ore Geology Reviews*, **72**, 1290–1306, https://doi.org/10.1016/j.oregeorev.2015.05.020

Narayana, B.L., Mallikharjuana Rao, J., Subba Rao, M.V., Murthy, N.N. & Divakara Rao, V. 2000. Geochemistry and origin of Early Proterozoic Dongargarh rapakivi granite complex, Central India – an example for magma mixing and differentiation. *Gondwana Research*, **3**, 507–520, https://doi.org/10.1016/S1342-937X(05)70757-7

Nebel, O., Capitanio, F.A., Moyen, J.F., Weinberg, R.F., Clots, F., Nebel-Jacobsen, Y.J. & Cawood, P. 2018. When crust comes of age: on the chemical evolution of Archaean, felsic continental crust by crustal drip tectonics. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, **376**, 20180103, https://doi.org/10.1098/rsta.2018.0103

Nelson, D., Bhattacharya, H.N., Thern, E.R. & Altermann, W. 2014. Geochemical and ion-microprobe U–Pb zircon constraints on the Archaean evolution of Singhbhum Craton, eastern India. *Precambrian Research*, **255**, 412–432, https://doi.org/10.1016/j.precamres.2014.09.024

Nicoli, G. 2020. Water budget and partial melting in an Archean crustal column: example from the Dharwar Craton, India. *Geological Society, London, Special Publications*, **489**, https://doi.org/10.1144/SP489-2018-88

Pandey, O.P., Mezger, K., Ranjan, S., Upadhyay, D., Villa, I.M., Nagler, F. & Vollstaedt, H. 2019. Genesis of the Singhbhum Craton, eastern India; implications for Archean crust–mantle evolution of the Earth. *Chemical Geology*, **512**, 85–106, https://doi.org/10.1016/j.chemgeo.2019.02.040

Pandit, D., Bhattacharya, S. & Panigrahi, M.K. 2020. Dissecting through the metallogenic potentials of Precambrian granitoids: case studies from the Bastar and Eastern Dharwar Cratons, India. *Geological Society, London, Special Publications*, **489**, https://doi.org/10.1144/SP489-2019-342

Panigrahi, M.K., Bream, B.R., Misra, K.C. & Naik, R.K. 2004. Age of granitic activity associated with copper–molybdenum mineralization at Malanjkhand, Central India. *Mineralium Deposita*, **39**, 670–677, https://doi.org/10.1007/s00126-004-0441-0

Percival, J.A., Skulski, T., Sanborn-Barrie, M, Stott, G.M., Leclair, A.D., Corkery, M.T. & Boily, M. 2012. Geology and tectonic evolution of the Superior Province, Canada. *Geological Association of Canada Special Papers*, **49**, 321–378.

Peucat, J.J., Jayananda, M., Chardon, D., Capdevila, R., Fanning, C.M. & Paquette, J.-L. 2013. The lower crust of the Dharwar Craton, Southern India: Patchwork of Archean granulitic domains. *Precambrian Research*, **227**, 4–29, https://doi.org/10.1016/j.precamres.2012.06.009

Prabhakar, N. & Bhattacharya, A. 2013. Paleoarchean partial convective overturn in the Singhbhum Craton, Eastern India. *Precambrian Research*, **231**, 106–121, https://doi.org/10.1016/j.precamres.2013.03.009

Rajesh, H.M., Mukhopadhyay, J., Beukes, J., Gutzmer, J., Belyanin, G.A. & Armstrong, R.A. 2009. Evidence for an early Archaean granite from Bastar craton, India. *Journal of the Geological Society, London*, **166**, 193–196, https://doi.org/10.1144/0016-76492008-089

Ramesh Babu, P.V. 1999. Rare metal and rare earth pegmatites of Central India. *Exploration and Research for Atomic Minerals*, **12**, 7–52.

Ranjan, S., Upadhyay, D., Abhinay, K. & Srikantappa, C. 2020*a*. Paleoarchean and Neoarchean Tonalite–Trondhjemite–Granodiorite (TTG) and granite magmatism in the Western Dharwar Craton, southern India: Implications for Archean continental growth and geodynamics. *Precambrian Research*, **340**, 105630, https://doi.org/10.1016/j.precamres.2020.105630

Ranjan, S., Upadhyay, D., Pruseth, K.L. & Nanda, J.K. 2020*b*. Detrital zircon evidence for change in geodynamic regime of continental crust formation 3.7–3.6 billion years ago. *Earth and Planetary Science Letters*, **538**, 116206, https://doi.org/10.1016/j.epsl.2020.116206

Raza, A. & Mondal, M.E.A. 2019. Geochemistry of the mafic metavolcanic rocks of Mauranipur–Babina greenstone belt, Bundelkhand craton, Central India: Implication for tectonic settings during the Archaean. *In*: Mondal, M.E.A. (ed.) *Geological Evolution of the Precambrian Indian Shield*. Springer, Cham, Switzerland, 577–607, https://doi.org/10.1007/978-3-319-89698-4_22

Roberts, N.M. & Santosh, M. 2018. Capturing the Mesoarchean emergence of continental crust in the Coorg Block, southern India. *Geophysical Research Letters*, **45**, 7444–7453, https://doi.org/10.1029/2018GL0 78114

Roy, A.B. & Jakhar, S.R. 2002. *Geology of Rajasthan: Precambrian to Recent*. Scientific Publishers, Jodhpur, India.

Saha, L., Frei, D. *et al.* 2016. Crustal geodynamics from the Archean Bundelkhand Craton, India: constraints from zircon U–Pb–Hf isotope studies. *Geol. Mag.*, **153**, 179–192, https://doi.org/10.1017/S0016756815000692

Santosh, M., Tsunogae, T., Yang, C., Han, Y., Hari, K.R., Manu Prasanth, M.P. & Uthup, S. 2020. The Bastar craton, central India: A window to Archean–Paleoproterozoic crustal evolution. *Gondwana Research*, **79**, 157–184. https://doi.org/10.1016/j.gr.2019.09.012

Sarkar, A., Sarkar, G., Paul, D.K. & Mitra, N.D. 1990. Precambrian geochronology of the central Indian Shield – a review. *Geological Survey of India Special Publications*, **28**, 453–482.

Sarkar, G., Corfu, F., Paul, D.K., McNaughton, N.J., Gupta, S.N. & Bishui, P.K. 1993. Early Archaean crust in Bastar craton, Central India: a geochemical and isotopic study. *Precambrian Research*, **62**, 127–137, https://doi.org/10.1016/0301-9268(93)90097-L

Sarkar, S.C. & Gupta, A. 2012. *Crustal Evolution and Metallogeny in India*. Springer, Cham, Switzerland, https://doi.org/10.1007/978-3-030-15989-4

Singh, V.K. & Slabunov, A. 2016. Two types of Archaean supracrustal belts in the Bundelkhand craton, India: Geology, geochemistry, age and implication for craton crustal evolution. *Journal of the Geological Society of India*, **88**, 539–548, https://doi.org/10.1007/s12594-016-0519-1

Singh, V.K., Verma, S.K., Singh, P.K., Slabunov, A.I., Mishra, S. & Chaudhary, N. 2020. Archean crustal evolution of the Bundelkhand Craton: evidence from granitoid magmatism. *Geological Society, London, Special Publications*, **489**, https://doi.org/10.1144/SP489-2018-72

Sinha-Roy, S. 1985. Granite-greenstone sequence and geotectonic development of SE Rajasthan. *Bulletin of the Geological Mining and Metallurgical Society of India*, **53**, 115–123.

Słaby, E., Gros, K. *et al.* 2020. Mineral–fluid interactions in the late Archean Closepet granite batholith, Dharwar Craton, southern India. *Geological Society, London, Special Publications*, **489**, https://doi.org/10.1144/SP489-2019-287

Sreenivas, B., Dey, S., Rao, Y.B., Kumar, T.V., Babu, E.V.S.S.K. & Williams, I.S. 2019. A new cache of Eoarchaean detrital zircons from the Singhbhum craton, eastern India and constraints on early Earth geodynamics, *Geoscience Frontiers*, **10**, 1359–1370, https://doi.org/10.1016/j.gsf.2019.02.001

Srinivasan, R. & Ojakangas, R.W. 1986. Sedimentology of quartz-pebble conglomerate and quartzites of the Archaean Bababudan Group: evidence for early crustal stability. *The Journal of Geology*, **94**, 199–214, https://doi.org/10.1086/629023

Yang, Q.Y. & Santosh, M. 2015. Zircon U–Pb geochronology and Lu–Hf isotopes from the Kolar greenstone belt, Dharwar Craton, India: Implications for crustal evolution in an ocean–trench–continent transect. *Journal of Asian Earth Sciences*, **113**, 797–811, https://doi.org/10.1016/j.jseaes.2015.05.023

Zhao, G., Sun, M. & Wilde, S. 2003. Correlations between the Eastern Block of the North China Craton and the South Indian Block of the Indian Shield: an Archaean to Palaeoproterozoic link. *Precambrian Research*, **122**, 201–233, https://doi.org/10.1016/S0301-9268(02)00212-7