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An exotic Mesoarchean microcontinent: The Coorg Block, southern India

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ABSTRACT

Sandwiched between the Dharwar Craton in the north and the Neoarchean–Proterozoic crustal blocks to the south, the Coorg Block in southern India is composed dominantly of a suite of arc magmatic rocks including charnockites, TTG (tonalite–trondhjemite–granodiorite)-related granitoid suite and felsic volcanic tuffs together with minor accreted oceanic remnants along the periphery of the block. Coeval mafic and felsic magmatism with magma mixing and mingling in an arc setting is well represented in the block. Here we present the petrology, geochemistry, zircon U–Pb geochronology and Lu–Hf isotopes of all the major lithologies from this block. Computation of metamorphic P–T conditions from mineral chemical data shows consistent granulite-facies P–T conditions of 820–870 °C and up to 6 kbar. Our geochemical data from major, trace and REE on representative samples of the dominant rock types from the Coorg Block corroborate an arc-related signature, with magma generation in a convergent margin setting. The zircon data yield weighted mean $^{207}Pb/^{206}Pb$ ages of 3153.4 ± 9 to 3184.0 ± 5.5 Ma for syenogranites, 3170.3 ± 6.8 Ma for biotite granite, 3275 ± 5.1 Ma for trondhjemite, 3133 ± 12 to 3163.8 ±6.9 Ma for charnockites, 3156 ± 10 to 3158.3 ± 8.2 for mafic enclaves, 3161 ± 16 Ma for diorite and 3173 ± 16 Ma for felsic volcanic tuff. An upper intercept age of 3363 ± 59 Ma and a lower intercept age of 2896 ± 130 Ma on zircons from a charnockite, as well as an evaluation of the Th/U values of the zircon domains against respective $^{207}Pb/^{206}Pb$ ages suggest that the Mesoarchean magma emplacement which probably ranged from >3.3 to 3.1 Ga was immediately followed by metamorphism at ca. 3.0 to 2.9 Ga. The ages of magmatic zircons from the charnockites and their mafic granulite enclaves, as well as those from the volcanic tuff and biotite granite, are all remarkably consistent and concordant marking ca. 3.1 Ga as the peak of subduction-related crust building in this block, within the tectonic milieu of an active convergent margin. The majority of zircons from the Coorg rocks show Hf isotope features typical of crystallization from magmas derived from juvenile sources. Their Hf crustal model ages suggest that the crust building might have also involved partial recycling of basement rocks as old as ca. 3.8 Ga. The crustal blocks in the Southern Granulite Terrane in India preserve strong imprints of major tectonothermal events at 2.5 Ga, 2.0 Ga, 0.8 Ga and 0.55 Ga associated with various subduction–accretion–collision or rifting events. However, the Coorg Block is exceptional with our data suggesting that none of the above events affected this block. Importantly, there is also no record in the Coorg Block for the 2.5 Ga pervasive regional metamorphism that affected all the other blocks in this region. The geochronological data raise the intriguing possibility that this block is an exotic entity within the dominantly Neoarchean collage in the northern domain of the Southern Granulite Terrane of India. The Mesoarchean arc-related rocks in the Coorg Block suggest that the magma factories and their tectonic architecture in the Early Earth were not markedly different from those associated with the modern-style plate tectonics.

1. Introduction

The growth, preservation and destruction of continental crust constitute a unified theme to address the evolution of our planet from its Hadean to modern history, including the making and breaking of continents, cratons, supercontinents, the formation of mineral resources, and the evolution of life and surface environment (e.g., Stern, 2011; Zhai and Santosh, 2011; Condie and Kröner, 2013; Zhai and Santosh, 2013; Nance et al., 2014). Although the transitions in Solid Earth processes and mantle dynamics greatly impacted the secular changes in the evolving Earth, it is becoming increasingly evident that plate tectonics in the early Earth might not have been entirely different from the style in which it operates in the modern Earth (e.g., Kusky et al., 2013 and references there in). Arcs are the fundamental building blocks of continents, with arc–arc parallel collision generating composite arcs which amalgamate to form primitive continents, and these in turn grow through vertical and lateral accretion (Santosh, 2013 and references therein). The

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Central Asian Orogenic Belt (CAOB) offers one of the best examples from the Phanerozoic world for multiple convergence and accretions of various orogenic components generating huge orogenic collages through parallel amalgamation, circum-microcontinent amalgamation and oroclinal bending in a long-lived (lasting for more than 800 m.y.) accretionary regime (Xiao and Santosh, (under review); Xiao et al., 2013). If the models on Archean plate tectonics are valid, and accretionary orogeny had its roots from the early evolution of the Earth, continent building in the past might have occurred in a manner similar to that in the CAOB, but indeed on a different scale with regard to the volume, extent and time span.

Continent building and recycling through subduction–accretion–collision tectonics has recently received much attention in Precambrian geology, and southern Peninsular India is one of the key regions of the world for investigations related to Precambrian tectonics as an important natural laboratory to test the continent building models. The southern part of the Indian shield comprises the Archean Dharwar Craton, and a number of discrete crustal blocks to the south welded onto it along major suture zones (Drury et al., 1984; Harris et al., 1994; Bhaskar Rao et al., 2003; Collins et al., 2007; Santosh et al., 2009). The Dharwar Craton preserves the vestiges of Archean continental crust (Friend and Nutman, 1991; Jayananda et al., 2013; Peucat et al., 2013), broadly divided into the older Western Dharwar Craton (3.3–2.7 Ga) and the younger Eastern Dharwar craton (3.0–2.5 Ga) (Swaminath and Ramakrishnan, 1981; Naqvi and Rogers, 1987; Chadwick et al., 2000). Manikyamba and Kerrich (2012) and some other workers proposed that the eastern portion of the Dharwar Craton formed as a result of island arcs accreting to an older (>3500 Ma), unified western craton, whereas Chadwick et al. (2000) and others suggested that the already formed island arcs and granitic plutons constituted a single landmass—the 'Dharwar Batholith' and that the greenstone belts developed as a result of intra-arc basins. Jayananda et al. (2000), Chardon et al. (2002), and others favor vertical tectonics as the most likely mechanism for the formation of the Eastern Dharwar Craton. U–Pb ages of detrital zircons obtained in recent studies suggest the presence of ≥3.4 Ga crustal components in both the western block and the eastern blocks of the Dharwar craton. The continental blocks south of the Dharwar Craton, together constituting the 'Southern Granulite Terrane' show distinct trends in their evolution and preserved dismembered suprasubduction-zone suites and arc magmatic complexes with ages testifying to both Neoarchean and Neoproterozoic convergent margin tectonics and accretionary history, and crust building style similar to that of the modern Pacific-style orogeny (e.g., Santosh et al., 2009; Santosh et al., 2012; Yellappa et al., 2012; Mohan et al., 2013; Praveen et al., 2014).

Sandwiched between the Dharwar Craton in the north and the Neoarchean–Proterozoic crustal blocks to the south, and with its western margin abutting against ocean along the rifted continental margin of India is a relatively small crustal block, the Coorg Block (Fig. 1). In contrast to the several investigations carried out by various workers on the blocks further to the south including the Nilgiri, Salem, Madurai, Trivandrum and Nagercoil, revealing major Neoarchean, Paleoproterozoic and Neoproterozoic tectonic cycles, no detailed investigations have been carried out on the Coorg Block as yet, apart from some early reports on metamorphic petrology and a few recent attempts on zircon geochronology. In this study, we focus on the evolution of the Coorg Block through a comprehensive investigation involving field studies along various traverses throughout the block, petrology, geochemistry and zircon U–Pb geochronology and Lu–Hf isotopes. Our results reveal that the Coorg Block is an exotic Mesoarchean microcontinent that did not witness any of the subsequent Neoarchean, Paleoproterozoic and Neoproterozoic tectonothermal events commonly recorded in the other blocks of southern India. Our results contribute to the understanding of continental growth in the early Earth in a broad perspective, and to the Precambrian evolutionary history of southern Peninsular India in particular.

2. Geological background

The Coorg Block is bound on the north by the Mercara Shear Zone and to the south by the western extension of the Moyar Shear Zone (Fig. 2a), and both these shear zones converge to the east (Chetty et al., 2012). The Mercara Shear Zone welds the Coorg Block with the Dharwar Craton to the north and is marked by steep gravity gradients (Sunil et al., 2010) interpreted to suggest the presence of underplated high-density material in the lower crust. Previous studies considered the Coorg Block to be higher grade southern extension of the Western Dharwar Craton, with its continuity into the Biligiri Rangan Hills. Granulite facies rocks dominated by charnockites and mafic granulites occur as massifs of large areal extent in the Coorg Block (Asha Manjari and Malur, 1997). The Coorg–Nilgiri–Biligiri Rangan–Salem–Madras Blocks were previously grouped together, and considered to have witnessed a common late Archean (ca. 2.5 Ga) granulite facies metamorphism (Bhaskar Rao et al., 1992; Peucat et al., 1993; Janardhan et al., 1994; Janardhan and Anto, 1996; Raith et al., 1999; Bhaskar Rao et al., 2003; Devaraju and Janardhan, 2004; Ghosh, 2004; Clark et al., 2009; Sato et al., 2011). Srikantappa et al. (1994) reported near-peak P–T conditions of 7–8.6 kbar and 720–760 °C and the presence of high-density (1.07–1.09 g/cm ^{3}) CO_2-rich fluid inclusions from the Coorg granulites. However, in a recent thermodynamic modeling of mafic granulites from the Coorg Block, Ishwar-Kumar et al. (2013a) obtained much higher metamorphic P–T conditions of ~1000 °C and 15–20 kbar.

Peucat et al. (2013) obtained Sm–Nd whole-rock isochron ages for the charnockites, garnet granulites and migmatitic gneisses from the Coorg Block, ranging from 2910 to 3700 Ma. In another recent study, Vijaya Kumar et al. (2013) reported U–Pb data on zircons in two samples from the western flank of the Biligiri Rangan hills and the northern part of the Coorg massif which show Mesoarchean crystallisation ages ≥ 3.3 Ga, with the oldest concordant zircons at 3.39 and 3.38 Ga. The zircons from these charnockite samples show $\varepsilon Hf(t)$ values between −5 and +4, and Hf-depleted mantle model ages between 3.35 and 3.70 Ga, suggesting Mesoarchean juvenile magmatism and involvement of Neoarchean crustal components in the generation of the protoliths.

In this study, we carried out detailed field investigations along several traverses both within the Coorg Block as well as in the Mercara and Moyar Suture Zones which bound the block. Orthopyroxene-bearing greasy green charnockites are the dominant rock types in the block (Fig. 2b) which are exposed as large masses and hill ranges including those around Kinningar, Kuttiyanam, Bettikkal, Narakodu and other localities (Fig. 3a,b). The charnockites are mostly coarse to medium grained and felsic in composition with both hornblende and biotite as accessories suggesting magmatic calc-alkaline protoliths. The intermediate varieties (commonly referred to as enderbitic charnockites) also carry clinopyroxene. Garnet is generally absent. The charnockites at many places incorporate enclaves and bands of mafic granulite (two pyroxene granulite) of various dimensions ranging from a few mm to few meters, showing gradational contacts and structures similar to mafic magmatic enclaves in felsic suites developed by magma mixing and mingling. The protoliths of these melanocratic enclaves have a dioritic composition with plagioclase, orthopyroxene, clinopyroxene and hornblende as the dominant minerals, such as the meta-diorite (mafic granulite) from Edneer within granodiorite (Fig. 3c). The next dominant lithology is the TTG (tonalite–trondhjemite–granodiorite) suite (Fig. 3e) represented by biotite granites of Padoor and trondhjemitic granitoids of Paivalike. At Paivalike, the granite shows porphyritic textures and carries minor enclaves of hornblendite. The disequilibrium texture with porphyritic feldspar carrying mineral inclusions and medium to fine grained matrix suggest magma mixing. The trondhjemitic gneisses are leucocratic and coarse grained with plagioclase and quartz as the dominant constituents. Minor amphibolite/hornblende gneisses in association with bands of BIF (banded iron formation) occur sporadically, mostly along the periphery of the block, such as those around