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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

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U–Pb and Lu–Hf isotopic records in detrital and magmatic zircons from the eastern and the western Dharwar craton (EDC and WDC) suggest presence of ≥3.4 Ga crustal components in both the blocks. Magmatic zircon from the western block has ages ranging between 3.1 and 3.2 Ga, while those from the eastern block show a bi-modal age distribution with records of 3.0–3.2 Ga protolith components as well as 2.7 and 2.5 Ga metamorphic overgrowths. Detrital and magmatic zircons from granitoid conglomerate clasts of the western Dharwar block show initial εHf values consistent with models for the early Archaean mantle, suggesting their juvenile character. Lower εHf values in younger as well as detrital zircons from eastern Dharwar block reflect importance of reworking of ≥3.2 Ga crust. The combined U–Pb and Hf isotope study strengthens suggestions for contemporaneous crust formation processes in both the western and eastern parts of the Dharwar craton.

1. Introduction

The evolution of Archaean cratons often span over several hundred million to over a billion years and provide records of complex geological processes of polymetamorphism and magmatic events involving recycling of old crust as well as the accretion of younger crust. Studies of supracrustal metasedimentary rocks, preserved within highly metamorphosed gneissic complexes help in delineating the evolutionary records of the continental crust during the Archaean (e.g., Zeh et al., 2007, 2009, 2010; Maibam et al., 2011). Archaean gneissic complexes interspersed with older tracts of metasedimentary rocks are polycyclic in origin. Relicts of gneisses generated during early epochs rarely retain their identity because of polymetamorphism and anatexis leading to migmatization that obliterates the early records (Nutman et al., 2004). Smaller intrusions present in these relicts are not always distinguishable in the field or evident from petrographic characteristics. U–Pb dating of individual zircons having distinct morphologies can provide chronological information that enables tracing the evolutionary history of such complex terranes. Studies of detrital zircon from Archaean metasediments have provided useful insight of the local provenance and in delineation of the regional and geochronological history of such provinces (e.g., Gerdes and Zeh, 2006; Zeh and Gerdes, 2012). In this study, we present results obtained from U–Pb dating as well as Lu–Hf isotope systematics of zircons from the Dharwar Craton of southern India to delineate the tectonomagmatic evolution of this ancient Archaean craton.

The Dharwar Craton (DC) comprises vast areas of 3.36–2.7 Ga tonalitic–trondhjemitic–granodioritic (TTG) gneisses (regionally known as Peninsular Gneisses), two generations of volcanic–sedimentary greenstone sequences (>3.0 Ga Sargur Group and 2.9–2.6 Ga Dharwar Supergroup) and 2.6–2.5 Ga calc-alkaline to high potassic granitoids (e.g., Jayananda et al., 2000, 2006; Chadwick et al., 2007). The craton is divided into two sub-blocks viz. the Western Dharwar Craton (WDC) and the Eastern Dharwar Craton (EDC) based on the nature and abundance of greenstones as well as the age of their surrounding basement and degree of regional metamorphism (Swami Nath et al., 1976). A recent study (Maibam et al., 2011) showed widespread occurrence of Archaean (>3.0 Ga) crustal components in the EDC that suggests that crust formation in both the WDC and EDC took place in the Mesoarchaean (>3.3 Ga) and continued until 2.5 Ga.

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It is important to establish the age distribution of the magmatic rocks as well as the source (juvenile or recycled) of the magmatic material to understand the genesis of any Archaean craton. U–Pb dating of zircons and Sm–Nd analysis of their host rocks have been generally used to define the source components (e.g., Baadsgaard et al., 1986; Bennett et al., 1993), the possibility of metamorphic disturbance in Sm–Nd systematics cannot always be ruled out (Vervoort and Patchett, 1996). This may be circumvented to a large extent by studying the Lu–Hf system in zircons of known U–Pb age (e.g., Thirlwall and Walder, 1995; Hawkesworth and Kemp, 2006; Zeh et al., 2007; Condie et al., 2009). The Lu–Hf system is resistant to high grade metamorphic re-crystallisation and zircons essentially preserve the initial $^{176}Hf/^{177}Hf$ of the source magma. Several studies of crustal genesis (Patchett et al., 1981; Smith et al., 1987; Vervoort and Patchett, 1996) have adopted this approach. However, analysis of zircon composites (which may contain different generations of zircon) restricted the usefulness of such studies. With the advent of laser ablation multi-collector ICP-MS (LAM-MC-ICPMS) it is now possible to obtain high-precision Hf-isotope data on small domains of individual zircon grains (Thirlwall and Walder, 1995; Gerdes and Zeh, 2006).

Combined U–Pb and Lu–Hf analyses of detrital zircon grains from siliciclastic rocks have been pursued extensively for sediment provenance and crustal evolution studies during the last decade (e.g., Hawkesworth and Kemp, 2006; Zeh et al., 2007, 2008; Condie et al., 2009). U–Pb analyses of detrital zircons constrain the timing of sediment deposition and magma intrusion in the hinterland, while Lu–Hf analyses provide valuable petrogenetic insights about the magma sources of the zircons. Such an approach has led to a better understanding of the tectono-magmatic and crustal evolution of several ancient gneissic terrains (see e.g., Kemp et al., 2006; Howard et al., 2009; Zeh et al., 2009, 2010). We present here the results of U–Pb and Lu–Hf isotope systematics of selected gneissic and detrital zircons from the Dharwar craton covering both the Eastern and Western blocks (EDC and WDC). The relative importance of mantle and crustal sources in the generation of Archaean magmas within the craton is evaluated based on this new data set and their implications are discussed in light of our current understanding of the evolution of the Dharwar craton.

2. Geology and chronology of older components

The Dharwar craton consists primarily of greenstone-granite gneiss terrain with gneiss-granulite terrain bordering it in the southern part (Fig. 1). The craton has been subdivided into two parts, namely the western Dharwar craton (WDC) and eastern Dharwar craton (EDC) based on the greenstone belt characteristics, degree of metamorphism and age, nature of the gneissic rocks and crustal thickness (e.g., Swami Nath and Ramakrishnan, 1981; Radhakrishna and Vaidyanathan, 1997; Jayananda et al., 2000; Gupta et al., 2003; Ramakrishnan and Vaidyanathan, 2008). The greenstone-granite gneiss terrain consists of N–S to NNW–SSE trending supracrustal belts, known as the Dharwar schist belts, which are separated from each other by gneisses, designated as the Peninsular Gneiss. The supracrustal sequence occurring in the Dharwar schist belts, and also as small to large enclaves in Peninsular Gneiss, has been classified into two litho-stratigraphic divisions: the older Sargur Group and the younger Dharwar Supergroup (Swami Nath and Ramakrishnan, 1981). The supracrustal rocks of the greenstone belts and the gneisses grade into a granulite complex in the southern part of the craton. According to Naha et al. (1993) the Peninsular Gneiss is a polyphase migmatite-gneiss complex that evolved over a protracted period between 3.5 and 2.6 Ga. Ramakrishnan and Vaidyanathan (2008) suggested that the Peninsular Gneiss is a complex, which evolved in three distinct episodes: 3.4–3.3 Ga, 3.0–3.1 Ga and 2.5–2.6 Ga. Based on Sm–Nd isotopic systematics, Jayananda et al. (2008) proposed that the ultramafic melts for the Sargur komatiite volcanism were extracted from the mantle at ca. 3.35 Ga. Based on U–Pb zircon geochronological study using the SHRIMP ion microprobe, Peucat et al. (1995) reported contemporaneous 3.3 Ga felsic volcanic rocks in the area. Earlier zircon geochronological study of a suite of rocks from the Dharwar craton using SHRIMP did not reveal detrital zircons younger than 3 Ga in the Sargur Group metasediments of the Holenarasipur schist belt and from a location near Banavar in the WDC (Nutman et al., 1992). Ages of most of the detrital zircons are 3.3–3.4 Ga along with presence of rare older zircons in Sargur quartzites. Based on this data set, it was inferred that the antiquity of the WDC goes beyond 3.5 Ga and the Sargur Group in the WDC accumulated prior to 3 Ga. Rb–Sr, Pb–Pb, Sm–Nd and SHRIMP U–Pb isotope dating also led to identification of orthogneisses with ages of 3.3–3.0 Ga in the WDC (e.g., Beckinsale et al., 1980; Naha et al., 1993; Peucat et al., 1993; Taylor et al., 1984).

In the EDC, there are sericitic and fuchsitic quartzites, metapelites (andalusite, corundum bearing or cordierite-hypersthene-sillimanite bearing schists and gneisses), calc-silicate rocks and banded manganiferous iron formations occurring as enclaves in orthogneisses. These have been correlated with the Sargur Group of the WDC (Swami Nath and Ramakrishnan, 1981). However, geochronological data for EDC to verify if some of these rocks are older than 3 Ga and whether they record evidences for sources as old as 3.3–3.5 Ga are lacking (Maibam et al., 2011). Available geochronological data has led to the view that bulk of the granitoids and orthogneisses in EDC are younger with ages of 2.5–2.6 Ga (see Dey et al., 2012; Jayananda et al., 2000, 2013). The WDC has been considered to be an Archaean nucleus to which Late Archaean to Early Proterozoic (2.7–2.5 Ga) terrane of EDC accreted (Radhakrishna and Naqvi, 1986; Balakrishnan et al., 1999). Chadwick et al. (1992) suggested that the WDC and EDC are separated by a shear zone that can be traced along the eastern boundary of the Chitradurga schist belt (Fig. 1). The gneisses of the WDC and the EDC have also been suggested to be distinct, with the gneisses of the WDC designated as Peninsular Gneiss, and the gneisses of the EDC as the 'Dharwar batholith' (Chadwick et al., 1996). In this study, we present U–Pb and Lu–Hf records in detrital and magmatic zircons from the Eastern and the Western Dharwar craton that is suggestive of contemporaneous evolution of the WDC and WDC.

3. Sample description

3.1. Western Dharwar Craton (WDC)

3.1.1. Gneissic clast from the conglomerate of the Dharwar Supergroup (Z-113, WD-1)

A gneissic clast from the polymictic Kaladurga conglomerates of the Dharwar Supergroup was sampled to constrain the age of a pre-Dharwar crustal component in the WDC. The sampling site was on the west side of the Shivpura railway station (13°25′32.2″ N, 76°09′08.5″ E) on the Kadur–Shimoga road. The conglomerate displays cobbles and boulders of tonalitic gneisses, migmatised amphibolites, metavolcanic rocks, quartzites, marbles and BIF. The matrix is composed of fine grained quartz, saussuritized plagioclase, biotite and muscovite. Kaladurga conglomerate contains phyllitic to greywacke matrix in the lower part with clasts of quartzite, BIF and amphibolite. The granitoid clasts and matrix to the upper part of the polymict conglomerate (Ramakrishnan and Vaidyanathan, 2008).