Precambrian Research 268 (2015) 295–322

Contents lists available at ScienceDirect

Precambrian Research

journal homepage: www.elsevier.com/locate/precamres

Paleo- to Mesoarchean TTG accretion and continental growth in the western Dharwar craton, Southern India: Constraints from SHRIMP U–Pb zircon geochronology, whole-rock geochemistry and Nd–Sr isotopes

M. Jayananda[a,b,*], D. Chardon[c,d,e], J.-J. Peucat[f], Tushipokla[b], C.M. Fanning[g]

[a] Centre for Earth and Space Sciences, University of Hyderabad, Gachibowli, Hyderabad 500 046, India
[b] Department of Geology, University of Delhi, Delhi 110 007, India
[c] IRD, UR 234, GET, 14 avenue Edouard Belin, 31400 Toulouse, France
[d] CNRS, GET, 31400 Toulouse, France
[e] Université de Toulouse, UPS (OMP), GET, 31400 Toulouse, France
[f] Géosciences-Rennes, UMR-CNRS 6118, Université de Rennes 1, UEB, 35042 Rennes cedex, France
[g] Research School of Earth Sciences, Australian National University, Canberra, Australia

ARTICLE INFO

Article history:
Received 4 April 2015
Received in revised form 18 July 2015
Accepted 27 July 2015
Available online 4 August 2015

Keywords:
Archean TTG
Dharwar craton
SHRIMP U–Pb zircon ages
Nd–Sr isotopes
Whole rock geochemistry
Continental growth

ABSTRACT

A multidisciplinary study involving field, petrographic, SHRIMP U–Pb zircon/titanite ages, whole rock geochemical and Nd–Sr isotope data is presented for the Peninsular Gneisses and associated plutons forming core of the Dharwar craton. Two major periods (3350–3280 Ma and 3230–3200 Ma) of crustal growth through TTG accretion sub-contemporaneous with greenstone volcanism are documented. Elemental and Nd–Sr isotope data suggest that the TTGs originated by low and high pressure melting of heterogeneous mafic sources (thickened island arc or oceanic plateau crust) at different depths. Among the early accreted TTGs, magmatic protoliths of low-Al gneisses formed by low-pressure (10–12 kbar) melting of a depleted mafic source at shallow levels (island arc type crust) with plagioclase + amphibole ± ilmenite in the residue, whilst high-Al gneisses were probably produced by high pressure melting (14–18 kbar) of a chondritic or a less depleted mafic source with garnet ± amphibole ± pyroxene + ilmenite in the residue (base of Island arc crust or thickened oceanic plateau). The 3230–3200 Ma trondhjemitic plutons marking the second accretion event derived by higher pressure (14–16 kbar) melting of a mafic source (island arc type crust with garnet ± plagiocalse ± hornblende + ilmenite) with a minor involvement of previously accreted TTGs. This plutonism was coeval with a major phase of crustal-scale diapiric overturn that had a major imprint on crustal reworking. A later magmatic episode at ca. 3100 Ma produced granitic plutons derived from crustal melting and leucocratic gneisses derived from a depleted mafic source in the lower crust. Documentation of depleted shallow and deep mantle reservoirs during 3350–3280 Ma magmatism implies massive differentiation of the mantle during an earlier episode of crust formation around 3800–600 Ma, as substantiated by Nd model ages and published Pb-isotope data, as well as U–Pb detrital zircon ages with in situ Hf isotope data.

1. Introduction

Much of the preserved Archean continental crust comprises associations of composite gray gneisses which are collectively termed TTG (tonalite, trondhjemite, granodiorite; Jahn et al., 1981) and considered to be first differentiates of felsic continental crust from the mantle. TTG gneisses represent ~80% of the felsic crust of Archean cratons and the knowledge of their origin contributes to our understanding of the differentiation of crust from mantle, continental growth and tectonic regimes of the early Earth (see, for recent reviews, Moyen, 2011; Moyen and Martin, 2012; Cawood et al., 2013; Hawkesworth et al., 2010; Nagel et al., 2012; Martin et al., 2014). Despite numerous multidisciplinary studies, the physical processes and the tectonic context of TTG accretion is still a topic of much discussion and debate. End-member models for the

* Corresponding author at: Centre for Earth and Space Sciences, University of Hyderabad, Gachibowli, Hyderabad 500 046, India. Tel.: +91 40 23132676.
E-mail address: mjayan.geol@gmail.com (M. Jayananda).

http://dx.doi.org/10.1016/j.precamres.2015.07.015
0301-9268/

origin of TTG magmas include hydrous melting of oceanic crust in subduction zones (e.g., Martin, 1986, 1994; Foley et al., 2002; Rapp et al., 2003; Feng and Kerrich, 1992), melting of the base of oceanic plateaus (e.g., Stein and Goldstein, 1996; Bédard, 2006; Willbold et al., 2009) and melting of thickened island-arc mafic crust (e.g., Smithies, 2000; Adams et al., 2012; Nagel et al., 2012; Polat, 2012) or melting of subducted oceanic plateau crust (Martin et al., 2014).

The western Dharwar craton (Fig. 1) is the Archean nucleus of Southern India and is essentially made of TTG gneisses and plutons collectively named as Peninsular Gneiss complex (e.g., Radhakrishna and Naqvi, 1986; Naqvi et al., 2009). Those gneisses are notably involved in a typical granite–greenstone dome-and-basin structural pattern at the Holenarsipur type locality (Bouhallier et al., 1993, 1995) and have been considered as the oldest gneisses of Southern India at ca. 3400 Ma (e.g., Beckinsale et al., 1980). However, the time framework of their magmatic and thermal history is not well constrained as the published ages are mainly based on Rb–Sr or Pb–Pb whole rock isochrons and single zircon evaporation ages with large errors (e.g., Beckinsale et al., 1980; Bhaskar Rao et al., 1991; Meen et al., 1992; Peucat et al., 1993; Naqvi et al., 2009). Furthermore, even though structural relationships among the Peninsular gneisses and the greenstones have been documented, their petrographic, chemical and isotopic characteristics are poorly known, their sources and accretion modes remaining largely conjectural.

This study presents field, petrographic, SHRIMP U–Pb zircon and titanite ages, Nd–Sr isotopes and whole rock geochemical (major and trace elements) data on the Peninsular gneisses and associated plutons from the core of the western Dharwar craton (i.e., the Holenarsipur granite–greenstone pattern, and the Chikmagalur region, further to the northwest; Fig. 1). We constrain the magmatic accretion, reworking and thermal history of the Peninsular gneiss complex from ~3450 to 3100 Ma and document a thermal overprint at ~2450 Ma. An attempt is also made to investigate their petrogenesis (i.e., characterization of their mafic sources and their melting conditions) in order to evaluate their tectonic context of emplacement.

2. Regional geological and tectonic framework

The Dharwar craton (Fig. 1) is the largest preserved Archean continental nucleus in Asia. The craton exposes a tilted oblique crustal section through Paleo- to Neoarchean granite–greenstone and high-grade terrains that have been involved in a large hot orogen at the end of Neoarchean (Chardon et al., 2008, 2011; Jayananda et al., 2013a,b). The craton had been divided into two crustal sub-provinces, namely the Western and Eastern Dharwar craton (Swami Nath and Ramakrishnan, 1981; Jayananda et al., 2006; Chardon et al., 2008; Fig. 1). The shear zone marking the eastern margin of the Chitradurga greenstone belt marks the structural boundary between the two sub-cratons (e.g., Jayananda et al., 2006; Chardon et al., 2008, 2011). Recent U–Pb zircon ages and Nd isotope data have allowed refining this scheme by defining the Western Dharwar Craton (WDC) with dominant old crust (3400–3200 Ma), the Central Dharwar Province (CDP) with mixed old (3400–3200 Ma) and younger (2700–2520 Ma) crust, and the Eastern Dharwar Province (EDP) with mainly younger (2700–2520 Ma) crust without significant crustal remnants older than 2700 Ma (Chardon et al., 2011; Peucat et al., 2013; Fig. 1). The three provinces have undergone contrasting thermal histories before involvement in Late Neoarchean (2550–2510 Ma) orogeny and HT-LP granulite facies metamorphism during the Latest Archean (2520–2510 Ma) (Chardon et al., 2008, 2011; Peucat et al., 2013; Jayananda et al., 2011, 2013b). Recently, Santosh et al. (2014) suggested that the Coorg granulitic massif (Fig. 1) was an exotic block with respect to the WDC, arguing that granulite metamorphism would be as old as 3000–2900 Ma and that the 2500 Ma high-grade metamorphic event was absent in that massif.

The WDC comprises the Peninsular gneiss complex, two generations of greenstones (3400–3200 Ma Sargur Group and 2910–2720 Ma Dharwar Supergroup) and 2620 Ma potassic plutons (see Jayananda et al., 2006 and Chardon et al., 2008 for a review; Fig. 1). Rb–Sr and Pb–Pb whole rock isochrons and single zircon evaporation ages of the Peninsular gneiss complex indicate ages ranging from 3400–3000 Ma (Beckinsale et al., 1980, 1982; Taylor et al., 1984; Bhaskar Rao et al., 1991, 2008; Meen et al., 1992; Peucat et al., 1993). Radiogenic Pb in feldspar of 3400 Ma gneisses reveals crustal inheritance up to 3800 Ma (Meen et al., 1992). The Peninsular gneisses and associated potassic plutons from the CDP yielded in situ magmatic zircon ages of 3370–3230 Ma and 3000–2990 Ma, respectively (Chardon et al., 2011; Jayananda et al., 2013a,b and our own unpublished data).

The Sargur Group is dominated by komatiite – high Mg-basalt associations. Komatiites have Sm–Nd whole rock isochron ages ranging from 3380 to 3200 Ma (Jayananda et al., 2008) whilst magmatic zircons from interbedded rhyolitic flows have a 3300 Ma zircon U–Pb SHRIMP age (Peucat et al., 1995). Detrital zircons from pelites and quartzites in the Sargur Group have U–Pb SHRIMP ages ranging from 3600 to 3200 Ma (Ramakrishnan et al., 1994; Bidyananda et al., 2011; Nutman et al., 1992; Hokada et al., 2013; Lancaster et al., 2015). Sargur greenstone belts are intensely deformed together with the adjoining Peninsular gneisses and have undergone amphibolite to granulite facies metamorphism. The Dharwar Supergroup unconformably overlies the Peninsular gneisses and Sargur Group greenstone belts (Swami Nath and Ramakrishnan, 1981; Ramakrishnan and Viswanatha, 1987; Venkata Dasu et al., 1991). Mafic volcanics near the base of the Dharwar Supergroup yielded Sm–Nd whole-rock isochron ages of 2910–2850 Ma (Kumar et al., 1996) whilst zircons from stratigraphically overlying felsic volcanics yielded SHRIMP U–Pb ages of 2700 Ma and 2670 Ma (Nutman et al., 1996; Trendall et al., 1997; Jayananda et al., 2013a).

3. Field relations and petrography

The study area comprises gneisses and plutons adjoining the Holenarsipur greenstone belt (Figs. 1 and 2) and gneisses and plutons exposed further to the northwest along the southern margin of the Bababudan greenstone belt (Figs. 1 and 3).

3.1. Gneisses and plutons adjoining the Holenarsipur greenstone belt

The area exposes a typical dome-and-basin granite–greenstone diapiric pattern, with synforms occupied by the Holenarsipur greenstone belt (Bouhallier et al., 1993, 1995; Fig. 2). The belt belongs to the Sargur Group and essentially comprises komatiite to komatiite basalts and amphibolites (Hussain and Naqvi, 1983). Interlayered felsic flows yielded a magmatic zircon SHRIMP U–Pb age of 3300 Ma (Peucat et al., 1995) and anorthosites intruding the southern part of the belt yielded an Sm–Nd whole-rock isochron age of ca. 3200 Ma (Bhaskar Rao et al., 2000). Sediments are limited and include quartzites, conglomerates, pelites and BIFs. Detrital zircons from the pelites have SHRIMP U–Pb ages as old as 3580 Ma (Nutman et al., 1992). Field occurrences of the three main types of gneisses and plutons of the Holenarsipur area are presented below.

3.1.1. Gorur TTG gneisses

The Gorur TTG gneisses dominate the western part of the study area (Fig. 2). They comprise a dark gray banded tonalitic facies and a gray banded granodioritic facies both of which are cut