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Zircon U–Pb SHRIMP and monazite EPMA U–Th–total Pb geochronology of granulites of the western boundary, Eastern Ghats Belt, India: a new possibility for Neoproterozoic exhumation history

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Abstract: We present detailed and high-precision geochronological data on granulites occurring along the western boundary of the Eastern Ghats Belt, India. Age data on systematically sampled rocks coupled with geochemical observation have a potential to unravel the overprinted tectonothermal events operated during Precambrian time. Zircon U–Pb SHRIMP and monazite electron probe microanalysis (EPMA) U–Th–total Pb analyses, chemical zoning, microtextural investigation, and pressure–temperature calculations were carried out on samples of four different rock types. Inherited zircons from migmatitic quartzofeldspathic gneiss and mafic granulite yielded ages of approximately 2900–2350 Ma, representing an older crustal component. The age of granulite metamorphism recorded from charnockite and pelitic granulite ranges between approximately 950 and 930 Ma (from zircon and monazite). A possible decompression event from this area that occurred during Rodinia break-up is recorded from the Y-rich zones of monazite closely associated with porphyroblastic garnet in pelitic granulite and dates from approximately 800 to 750 Ma. Zircon grains of charnockite also yield a similar age. The youngest age of approximately 525–510 Ma documented from the monazite grains of migmatitic quartzofeldspathic gneiss and pelitic granulite, along with a spot age from zircon of migmatitic quartzofeldspathic gneiss, testifies to the final assembly of East Antarctica with cratonic India as a part of East Gondwana.

Orogenic belts may record multiple phases of deformation and metamorphism, and eventually culminate in cratonization of the deep crustal rocks. It is known that many of the orogenic belts evolved finally in a collisional setting, and the tectonic nature of collision is best studied in places where such a belt is docked to the adjacent craton (Gray *et al.* 1997). Therefore, craton-margin orogenic belts are important as they preserve the growth history of the continents (Ghosh *et al.* 2016). Careful analysis of petrological and structural information complemented by precise geochronological data can help in determining the tectonothermal evolution and growth history of ancient orogens prior to its cratonization. Such history can also be used as a tool for transcontinental correlation involving dispersed continental fragments (Zegers *et al.* 1998). This is particularly true for high-grade poly-metamorphosed and poly-deformed Precambrian orogenic belts with cryptic geological rock records (Mueller & Wooden 1988; Condie 1989). The exercise is difficult because the majority of the rocks lose primary mineralogical and textural features during multiple events of metamorphism and deformation. Obliteration of such primary signatures also depends on bulk-rock compositions (Kelsey *et al.* 2008), the influence of water and the degree of metamorphic overprinting. Depending on these factors, few rocks may preserve these initial signatures despite multiple phases of deformation and metamorphism. Hence, in order to understand the tectonothermal evolution and growth of a continent with time, systematic and detailed analysis of such rocks is central. Generally, it is observed that the bulk-rock chemistry, apart from pressure–temperature–fluid conditions, controls the development and preservation of mineralogical and textural records of different tectonothermal events that a high-grade terrain suffers. The same is applicable for the dateable minerals such as zircon and monazite from various bulk-rock compositions, which often record the age values of different tectonothermal event(s) in a poly-deformed, poly-metamorphosed terrain (Das *et al.* 2011; Bose *et al.* 2016). In such terrains,

From: PANT, N. C. & DASGUPTA, S. (eds) *Crustal Evolution of India and Antarctica: The Supercontinent Connection*. Geological Society, London, Special Publications, **457**, https://doi.org/10.1144/SP457.1

JOURNAL OF PETROLOGY

Journal of Petrology, 2018, 1–34
doi: 10.1093/petrology/egx078
Advance Access Publication Date: 2 January 2018
Original Article

OXFORD

Origin of Spinel + Quartz Assemblage in a Si-undersaturated Ultrahigh-temperature Aluminous Granulite and its Implication for the *P–T*–fluid History of the Phulbani Domain, Eastern Ghats Belt, India

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Received February 3, 2017; Accepted December 11, 2017

ABSTRACT

A suite of high-grade rocks including felsic gneiss, aluminous granulite, charnockite and calc-silicate granulite is exposed at Phulbani, which belongs to a petrologically little understood crustal domain (Phulbani domain) of the Eastern Ghats Belt. The aluminous granulite is constituted of corundum + spinel + ilmenite + garnet + sillimanite + quartz ± K-feldspar ± plagioclase ± biotite. Textural analysis indicates that corundum, spinel, garnet and/or K-feldspar were formed as a result of biotite dehydration melting of a Si-poor protolith during prograde metamorphism. Although corundum and quartz coexist in micro-scale domains, phase diagram modelling suggests that garnet + corundum + spinel + ilmenite + sillimanite (up to 800°C at 8 kbar) and garnet + spinel + sillimanite + ilmenite + quartz (above 950°C at 8 kbar) assemblages were stabilized in two different temperature intervals while attaining the ultrahigh-temperature metamorphic peak. The transformation from corundum- to quartz-bearing assemblages was principally governed by chemical reactions. Quartz, formed at the peak stage, produced complex reaction textures involving spinel, corundum, garnet and sillimanite during near-isobaric cooling. Intersection of the same mineral reactions during the prograde and the retrograde paths implies the near-closed-system behaviour of the lower crust, at least at microdomain-scale, possibly achieved after large-scale melt loss along the prograde-to-peak stage of evolution. The pressure–temperature path remained near-isobaric during the prograde and the retrograde evolution of the assemblages. High-density (up to 1·03 g cm^{-3}) CO_2-rich fluid inclusions in aluminous granulite, coarse-grained charnockite and felsic gneiss indicate that peak metamorphism and subsequent evolution occurred under a CO_2-dominated fluid regime. The pressure–temperature–fluid evolutionary history of the Phulbani domain shows similarity to that of the adjacent Visakhapatnam domain of the Eastern Ghats Belt and poses questions on the status of the boundary separating these two domains.

Key words: Si-undersaturation; spinel + quartz; CO_2 fluid; Phulbani domain; Eastern Ghats Belt

Precambrian Research 316 (2018) 1–23

Contents lists available at ScienceDirect

Precambrian Research

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

U-Pb zircon and U-Th-total Pb monazite ages from the Phulbani domain of the Eastern Ghats Belt, India: Time constraints on high-grade metamorphism and magmatism in the lower crust

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ARTICLE INFO

Keywords:
Zircon U-Pb age
Monazite U-Th-total Pb age
Charnockite magmatism
UHT metamorphism
Phulbani domain
Eastern Ghats Belt

ABSTRACT

We present zircon U-Pb (SHRIMP) and monazite U-Th-total Pb (EPMA) ages from a suite of high-grade rocks of the Phulbani domain of the Eastern Ghats Belt, India. These ages are integrated with the metamorphic and magmatic histories of the Phulbani domain to put precise time constraints on the tectonothermal evolution of the northern part of the Eastern Ghats Belt. Zircon from the coarse-grained charnockite rock shows crystallization age of ca. 970 Ma. Aluminous granulite contains spinel and quartz-bearing mineral assemblage indicating ultrahigh temperature metamorphism (> 900 °C at 8–10 kbar) which possibly occurred during ca. 987 Ma as revealed from monazite included in porphyroblastic garnet. Monazite in the aluminous granulite and the migmatitic felsic gneiss grew dominantly at 966 ± 4 Ma and 968 ± 4 Ma ages respectively, which are interpreted as the cooling ages subsequent to peak metamorphism. Oscillatory-zoned zircon grains of the felsic augen gneiss yield ca. 1173 Ma age which is interpreted as the crystallization age of the granitic protolith. This ca. 1173 Ma age granite possibly composed a part of the Proterozoic basement of the Eastern Ghats Province. A monazite age of 781 ± 15 Ma from the aluminous granulite may indicate the timing of a localized shear-induced thermal process in the Phulbani domain. The presently studied rock suite thus recorded three distinct events (ca. 1173 Ma, ca. 1000–900 Ma and ca. 781 Ma) of magmatism, metamorphism and deformation of Eastern Ghats Belt. Metamorphic and magmatic histories of the Phulbani domain are similar to those of the adjacent Visakhapatnam domain and the Rayner Province of East Antarctica during the time frame ca. 1000–900 Ma.

1. Introduction

The Eastern Ghats Belt (EGB)-Rayner Province is considered to be a composite orogenic belt (R-EG orogeny of Morrissey et al., 2015) that joined the cratonic blocks of India (Dharwar, Bastar and Singhbhum cratons) and the cratonic blocks of Ruker Province, Northern Prince Charles Mountains of East Antarctica (Li et al., 2008; Harley et al., 2013) as a part of the Meso-Neoproterozoic supercontinent Rodinia (Harley, 2003; Morrissey et al., 2015; Dasgupta et al., 2013, 2017). During ca. 1000–500 Ma time span, parts of the Rodinia were affected by magmatism, metamorphism, metasomatism and intensive deformation which are recorded in parts of the Rayner Province (White and Clarke, 1993; Dunkley et al., 2002; Halpin et al., 2005, 2007a). These are the manifestations of processes related to the assembly and breakup of the Rodinia, followed by assembly of the Gondwana supercontinent (Li et al., 2008). Compared to the Rayner Province, geochronological records of the EGB are meager and highly localized considering the vast expanse of the belt. A large number of age data in the range of ca. 1000–900 Ma is reported from these locales and there is a general agreement that the mentioned time frame represents the timing of major tectonometamorphic events in the EGB (reviewed in Dasgupta et al., 2017). However, geochronological history of the EGB during the later part of the Neoproterozoic era (ca. 900–500 Ma) is cryptic (e.g. Bose et al., 2016a) except for the areas where these lower crustal high-grade rocks were thrusted over the shallow levels of cratonic blocks (Bhadra et al., 2004; Biswal et al., 2007; Das et al., 2008; Upadhyay et al., 2009; Chatterjee et al., 2017a). It would be interesting to know if this ca. 1000–500 Ma history of the EGB can be correlated with the

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https://doi.org/10.1016/j.precamres.2018.07.024
Received 16 November 2017; Received in revised form 29 July 2018; Accepted 31 July 2018
Available online 01 August 2018
0301-9268/