Precambrian Research 174 (2009) 129–144

Contents lists available at ScienceDirect

Precambrian Research

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

The *P-T-t* architecture of a Gondwanan suture: REE, U–Pb and Ti-in-zircon thermometric constraints from the Palghat Cauvery shear system, South India

Chris Clark[a,*], Alan S. Collins[b], M. Santosh[c], Richard Taylor[d], Benjamin P. Wade[b]

[a] The Institute for Geoscience Research (TIGeR), Department of Applied Geology, Curtin University of Technology, GPO Box 1987, Perth WA 6845, Australia
[b] Tectonics, Resources and Exploration (TRaX), School of Earth & Environmental Sciences, University of Adelaide, Adelaide 5005, Australia
[c] Faculty of Science, Kochi University, Akebono-cho 2-5-1, Kochi 780-8520, Japan
[d] Grant Institute of Earth Science, School of GeoSciences, University of Edinburgh, Kings Buildings, West Mains Rd, Edinburgh EH9 3JW, Scotland, United Kingdom

ARTICLE INFO

Article history:
Received 2 February 2009
Received in revised form 30 June 2009
Accepted 7 July 2009

Keywords:
Gondwana
UHT metamorphism
Monazite
Zircon
Garnet
THERMOCALC

ABSTRACT

Understanding the relationship between accessory mineral growth and the evolution of silicate mineral assemblages along the entirety of a *P-T-t* path is a critical step in developing models for evolving tectonic systems. Here we combine U–Pb age data (for zircon and monazite), rare earth element (REE) data and compositionally specific phase diagrams (*P-T* pseudosections) for the rocks of the Palghat Cauvery shear system (PCSS), Southern Indian order to constrain the periodicity of heating/cooling and burial/exhumation events during the Ediacaran/Cambrian amalgamation of Gondwana. HREE data from zircon are consistent with zircon grow that 672–724 °C during the breakdown of garnet in the kyanite stability field at 535.0 ± 4.9 Ma. This represents a cooling that punctuates the *P-T-t* path. Subsequent monazite growth and symplectite formation occurred at 920 °C and 7.5 kbar, ~10 Ma after zircon growth which reflects a period of reheating and decompression related to delamination and the collapse of the East African orogen. The REE chemistry of the monazite is consistent with the system having undergone partial melting prior to monazite growth, thereby altering the bulk rock chemistry. The periodicity of the heating and cooling cycles (~10 Ma) from this study is consistent with recently proposed tectonic switching models for the formation of granulite metamorphism in accretionary/collisional tectonic settings. The elevated heat flows required to generate the UHT metamorphism are achievable in the proposed back-arc setting for the PCSS during Gondwana amalgamation.

1. Introduction

The integration of the textural and chemical characteristics of accessory and silicate minerals provides invaluable information when investigating the metamorphic and tectonic history of a terrane (e.g. Buick et al., 2006; Hermann and Rubatto, 2003; Kelsey et al., 2007; Rubatto, 2002; Rubatto and Hermann, 2007; Rubatto et al., 2001, 2006; Whitehouse and Platt, 2003). In particular, the information extracted from mineral assemblages can be used to great effect in making inferences about poorly understood processes such as those involved in the generation, preservation and tectonic significance of ultrahigh temperature (UHT) metamorphic assemblages (Harley, 1998a,b; Harley and Kelly, 2007; Kelly and Harley, 2005; Kelsey et al., 2003). Coupling these observations with calculated metamorphic phase diagrams for specific equilibrium bulk rock compositions (*P-T* pseudosections) allows a clearer picture of the whole *P-T-t* evolution of a terrane to be reconstructed (e.g. Clark et al., 2007; Kelsey et al., 2007). This approach is especially important in terranes that have undergone UHT metamorphism due to the uncertainty surrounding the ability of geochronometers to record the timing of peak metamorphism (Fraser et al., 1997; Harley, 2004; Roberts and Finger, 1997; Tomkins et al., 2005). This uncertainty reflects: (1) the lack of absolute knowledge regarding closure temperature and rates of elemental diffusion in key geochronometers such as zircon and monazite and (2) the lack of certainty as to the exact controls on the growth of zircon and monazite and how it relates to mineral reactions above and below the solidus. Recent advances in the application of accessory phase thermometry (e.g. Watson and Harrison, 2005; Watson et al., 2006) allow constraints to be placed on the temperatures at which accessory phase growth occurred. This information can then be incorporated with the metamorphic forward models allowing a detailed event chronology, linking textural, temporal and thermal observations, to be constructed. It is only when this information is gathered that insights into the tectonic processes that created the metamorphism are generated and the significance of the nature and timing of metamorphism for plate-tectonic global reconstructions (e.g. Boger and

* Corresponding author. Tel.: +61 08 9266 2446; fax: +61 08 9266 3153.
E-mail address: C.Clark@curtin.edu.au (C. Clark).

0301-9268/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.precamres.2009.07.003

Wilson, 2005; Collins and Pisarevsky, 2005; Li et al., 2008) can be addressed.

In this paper we investigate the major and trace element compositions of garnet, zircon and monazite in order to constrain the timing and rates of processes in the Palghat Cauvery shear system (PCSS) in southern India (Fig. 1). This region preserves a distinctive record of high-grade metamorphism coupled with accessory mineral development and is a key area in understanding the tectonic scenarios that may lead to the generation of ultrahigh temperature crustal metamorphism. There is also a recent debate surrounding the report of eclogite facies rocks from this area (Kelsey et al., 2006; Shimpo et al., 2006; Tsunogae and Santosh, 2006) and the significance that these rocks have in defining the location of major suture/collision zones during the amalgamation of Gondwana (Collins et al., 2007a; Collins and Pisarevsky, 2005; Santosh et al., 2009).

2. Regional geology

The PCSS is an approximately 70 km by 400 km E–W zone characterised by an anastomising network of mainly dextral shear zones, typically 1–10 km wide, separating the Dharwar Craton from the Southern Granulite Terrane (SGT) in southern India (Chetty et al., 2003; Tomson et al., 2006) (Fig. 1). The lithologies within the PCSS consist of deformed Neoarchaean rocks; variably retrograded charnockitic gneisses associated with biotite and hornblende-bearing migmatitic gneisses intercalated with supracrustal rocks that include, metapelites, calc-silicate marbles and quartzites (Bhaskar Rao et al., 1996; Chetty and Bhaskar Rao, 2006). In a recent study, Santosh et al. (2009) suggested a model involving Pacific-type subduction-accretion leading to Himalayan-style collision with the PCSS marking the collisional suture.

A number of previous studies have found significant differences in the structural style, lithological units, Nd model ages, Rb–Sr mineral ages and metamorphic *P-T* conditions of the lithologies within the PCSS when compared to the Dharwar Craton and SGT (Bartlett et al., 1998; Ghosh et al., 2004; Harris et al., 1994b; Meissner et al., 2002; Santosh et al., 2003, 2005). As a result the PCSS has been proposed to represent a major structural feature within southern India. The PCSS has been interpreted as (1) a dextral transcurrent shear belt (Drury et al., 1984); (2) a suture zone (Bhaskar Rao et al., 2003; Meissner et al., 2002); (3) an Archaean-Palaeoproterozoic terrane boundary (Harris et al., 1994b); (4) a collapsed marginal basin (Drury and Holt, 1980) and (5) a zone of Palaeoproterozoic and Neoproterozoic re-working of Archaean crust (Bhaskar Rao et al., 1996; Chetty et al., 2003; Ghosh et al., 2004; Harris et al., 1994b; Santosh et al., 2003; Tomson et al., 2006). The notion that the PCSS represents the Archaean-Proterozoic or Neoproterozoic terrane boundary has been contested based on new U–Pb zircon age data and Sm–Nd model ages for charnockitic and migmatitic gneisses (Bhaskar Rao et al., 2003; Ghosh et al., 2004). These studies suggest that the Archaean crust may extend south of the PCSZ up to Karur–Kamban–Painavu–Trichur (KKPT) shear zone (Ghosh et al., 2004) (Fig. 1).

In tight-fit reconstructions of Gondwana, southern India is juxtaposed against Madagascar and East Antarctica (Reeves and de Wit, 2000), where the major suture zones of the amalgamation of eastern Gondwana have been identified and correlated through adjoining crustal blocks (Boger and Miller, 2004; Collins et al., 2007a,b; Collins and Pisarevsky, 2005; Fitzsimons, 2000; Meert, 2003; Meert and Van der Voo, 1997; Shaju et al., 1998). A number of different microcontinents have been identified within the models of the amalgamation of eastern Gondwana; the most significant of which, in the context of southern India, is Azania—a microcontinent consisting of central Madagascar, part of eastern Africa and the Al-Mafid Block in Yemen (Collins and Pisarevsky, 2005). Prior to the formation of Gondwana, the Mozambique Ocean was located between Azania and India. The closure of the Mozambique Ocean formed the ∼550–510 Ma Malagasy Orogeny (Collins and Pisarevsky, 2005). The site of this closure has been identified in eastern Madagascar as the Betsimisaraka suture (Collins, 2006; Collins and Windley, 2002), but its southern continuations contentious. Recent work has demonstrated that the PCSS marks an isotopic boundary between the Northern Granulite and Southern Granulite terranes (Clark et al., 2009), contains discontinuous ultramafic bodies that are coincident with crust penetrating shear

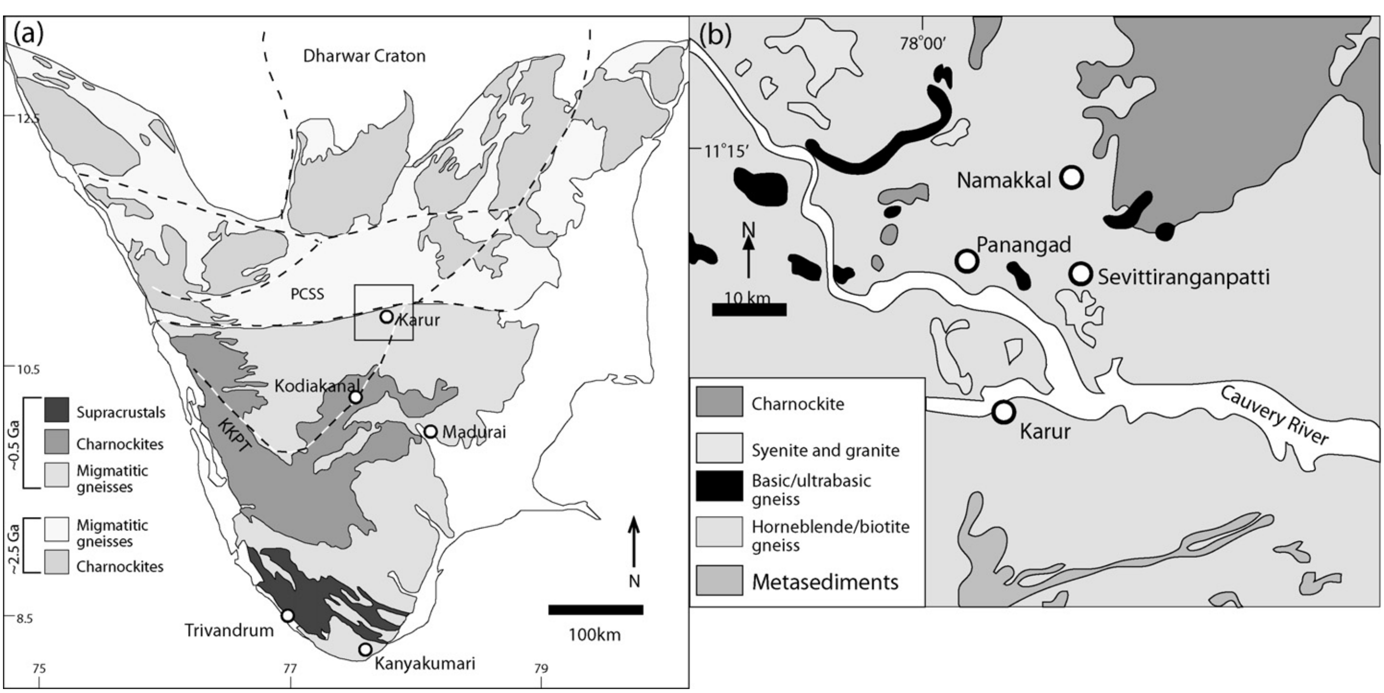

Fig. 1. (a) Map of southern India showing the various protolith ages and major structural features. (b) Enlargement of area in (a) showing the location of the Panangad sample area.