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Fluids in high- to ultrahigh-temperature metamorphism along collisional sutures: Record from fluid inclusions

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A B S T R A C T

Petrographic studies and microthermometric investigations on fluid inclusions associated with high- to ultrahigh-temperature metamorphic rocks in three major Precambrian suture zones on the globe demonstrate the dominant occurrence of CO_2-rich fluids. These rocks form part of hot orogens developed along collisional plate boundaries. The sapphirine-quartz-bearing Mg–Al-rich rock from the Palghat-Cauvery Suture Zone, a trace of the Cambrian Gondwana suture zone in southern India, preserves evidence for a prograde high-pressure event and subsequent peak ultrahigh-temperature metamorphism along a clockwise path, and contains abundant CO_2-rich inclusions in corundum, garnet, and sapphirine. Most of the fluid inclusions are either primary or secondary and preserve low-density CO_2-rich fluids (0.569–0.807 g/cm^3). Similar low-density CO_2-rich fluid inclusions (0.853–0.953 g/cm^3) are also present in pelitic granulites from the Limpopo Complex of southern Africa, a Neoarchean granulite-facies orogen formed by continent–continent collision. In contrast, the garnet–orthopyroxene granulite from Tonagh Island in the Neoarchean Napier Complex in East Antarctica contains very high-density primary (1.095–1.129 g/cm^3) and secondary (0.960–1.179 g/cm^3) carbonic inclusions in garnet and quartz. The calculated isochores for the fluid inclusions from the Palghat-Cauvery Suture Zone and the Limpopo Complex yield significantly lower-pressure estimates than those predicted from peak metamorphic conditions. We interpret this as a result of significant density decrease due to rapid decompression along a clockwise *P–T* trajectory. In contrast, the estimated isochores for primary inclusions in garnet–orthopyroxene granulites from the Napier Complex are consistent with the peak *P–T* conditions estimated from mineral phase equilibria for the Tonagh Island rocks, suggesting that most of the fluid inclusions in these rocks did not undergo any marked effect of volume change and density decrease. The contrasting fluid densities among the localities investigated in this study are probably related to the nature of the *P–T* trajectory; the Tonagh Island rocks had a near-isochoric exhumation history whereas the metamorphic orogens in the other two sutures witnessed rapid decompression. Our results suggest that whereas the composition of the syn-metamorphic fluids are preserved in all cases, density reversal occurs within inclusions as a function of the tectonic history and exhumation style.

1. Introduction

The *P–T–t* architecture and fluid regimes of metamorphic orogens have received wide attention in evaluating the history of evolution of continents and supercontinents, and have also been central to some of the recent debates surrounding the plate tectonic paradigm (e.g., Brown, 2010; Ernst, 2010; Maruyama et al., 2010; Tirone and Ganguly, 2010; Santosh, 2010; Santosh et al., 2009a). Chemical and physical characterization of the role of fluids associated with high-grade metamorphism has been one of the focal themes in petrological research, particularly in understanding the stability of mineral assemblages, fluid–rock interaction processes, and degree of partial melting in lower crust (e.g., Santosh and Omori, 2008; Omori et al., 2009; Touret, 2009). The nature of fluids associated with metamorphic processes has been inferred through a number of techniques including thermodynamic calculations of mineral assemblages, geochemical and isotopic studies and investigation of fluids trapped within inclusions in various minerals. Among these, detailed investigation of the fluid inclusions in various metamorphic minerals provides direct information on the nature, composition, and density of fluids at various stages of the metamorphic processes (e.g., Touret, 1985, 2001, 2009). Recent investigations on the characterization of fluids associated with

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high- to ultrahigh-temperature metamorphism, particularly along collisional suture zones, have provided critical information on *P–T* evolution and exhumation history of hot orogens along collisional plate boundaries (e.g., Ohyama et al., 2008; Santosh et al., 2008, 2010; Tsunogae and Santosh, 2010). However, not many studies have attempted to compare the fluid inclusion data from ultrahigh-temperature rocks formed within Precambrian collision sutures in understanding the nature and role of fluids.

In this study, we synthesize information on the occurrence, composition, and density of fluid inclusions trapped in various granulite-facies minerals from ultrahigh-temperature metamorphic rocks in three collisional orogenic belts: Neoproterozoic to Cambrian Palghat-Cauvery Suture Zone (Southern India; Fig. 1a), Neoarchean to Mesoproterozoic Limpopo Complex (Southern Africa; Fig. 1b), and Neoarchean Napier Complex (East Antarctica; Fig. 1c). Together with newly obtained data, we attempt a comparison on the nature of the trapped fluids from these regions. The Palghat-Cauvery Suture Zone and the Limpopo Complex are regarded as collisional sutures that record the history of high-pressure and ultrahigh-temperature metamorphism (e.g., van Reenen et al., 2008; Santosh et al., 2009b) and should thus preserve fluids associated with the collisional event. The tectonic evolution of

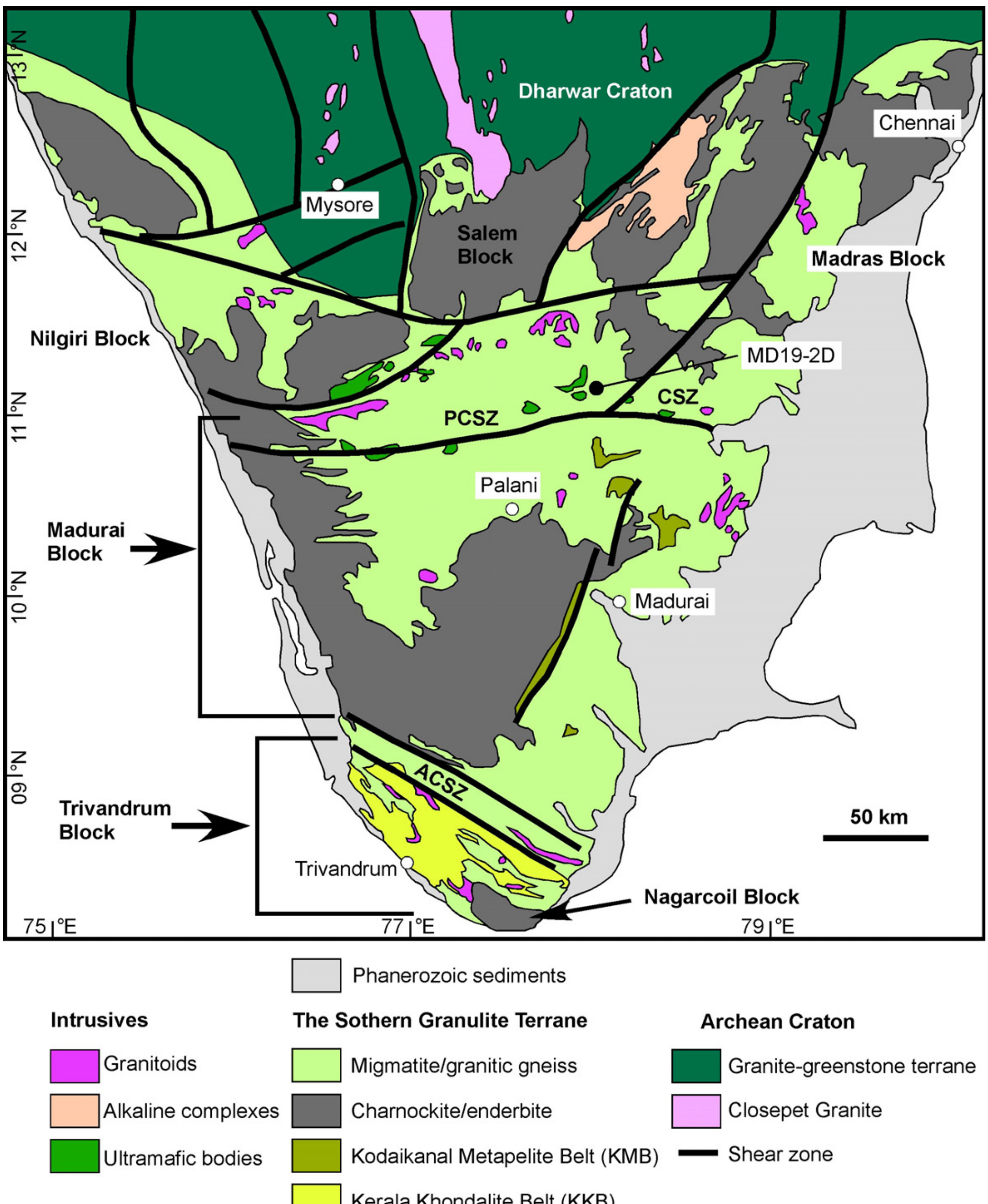

Fig. 1a. Geological maps of the study areas with sample localities (solid circles). Geological map of southern India showing various granulite blocks and major shear/suture zones (modified after Santosh and Sajeev, 2006). ACSZ: Achankovil Shear Zone, CSZ: Cauvery Suture Zone, PCSZ: Palghat-Cauvery Suture Zone.