Lithos 236–237 (2015) 1–15

Contents lists available at ScienceDirect

Lithos

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

Linking monazite geochronology with fluid infiltration and metamorphic histories: Nature and experiment

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ARTICLE INFO

Article history:
Received 22 April 2015
Accepted 4 August 2015
Available online 28 August 2015

Keywords:
Monazite
Coupled dissolution–reprecipitation
Experimental petrology
Migmatitic metapelite
Electron microprobe CHIME method

ABSTRACT

Migmatised metapelites from the Kodaikanal region, central Madurai Block, southern India have undergone ultrahigh-temperature metamorphism (950–1000 °C; 7–8 kbar). In-situ electron microprobe Th–U–Pb isochron (CHIME) dating of monazites in a leucosome and surrounding silica-saturated and silica-poor restites from the same outcrop indicates three principal ages that can be linked to the evolutionary history of these rocks. Monazite grains from the silica-saturated restite have well-defined, inherited cores with thick rims that yield an age of *ca.* 1684 Ma. This either dates the metamorphism of the original metapelite or is a detrital age of inherited monazite. Monazite grains from the silica-poor restite, thick rims from the silica-saturated restite, and monazite cores from the leucosome have ages ranging from 520 to 540 Ma suggesting a mean age of 530 Ma within the error bars. In the leucosome the altered rim of the monazite gives an age of *ca.* 502 Ma. Alteration takes the form of Th-depleted lobes of monazite with sharp curvilinear boundaries extending from the monazite grain rim into the core. We have replicated experimentally these altered rims in a monazite-leucosome experiment at 800 °C and 2 kbar. This experiment, coupled with earlier published monazite-fluid experiments involving high pH alkali-bearing fluids at high *P–T*, helps to confirm the idea that alkali-bearing fluids, in the melt and along grain boundaries during crystallization, were responsible for the formation of the altered monazite grain rims via the process of coupled dissolution–reprecipitation.

1. Introduction

Monazite, (La,Ce,Nd)PO_4, is an important geochronometer for the determination of texturally-controlled dating of metamorphism by the electron microprobe (EMP) based on the U–Th–total Pb (CHIME) method. Recent experimental studies (Harlov et al., 2011; Williams et al., 2011) have demonstrated that the isotopic age of monazite can be reset by fluid infiltration along a *P–T* path. This provides an invaluable tool to assess the timing of late fluid alteration in the metamorphic history of rocks. Kelsey et al. (2008), amongst others, pointed out that many known monazite or zircon ages may not actually represent peak metamorphic conditions, but rather reflect the saturation of LREE or Zr within the system at a given *P* and *T*. The reported peak metamorphic ages for high- to ultrahigh-temperature (UHT) rocks from southern India, specifically the Madurai Block, vary widely from 600 Ma to 450 Ma, indicating the need for more precise texturally-controlled geochronological determinations. Despite this wide range in ages, most previous geochronological and tectonic studies have concluded that a major thermal event affected the Madurai Block during the Neoproterozoic–Cambrian (e.g., Collins et al., 2007a,b). Noticeably, these studies did not take into account the texturally-related timing of LREE saturation and later fluid-driven U–Th–Pb alteration. Utilizing the EMP U–Th–total Pb (CHIME) method, the aim of this study is to consider the geochemical signatures and dates for a set of in situ monazite grains located in a leucosome and related restite from a specific migmatite in the Madurai Block. The altered rims were then experimentally reproduced in a simple experiment involving metasomatic alteration of natural monazite grain fragments in a H_2O-saturated K-feldspar–quartz leucosome melt at 800 °C and 2 kbar.

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http://dx.doi.org/10.1016/j.lithos.2015.08.008
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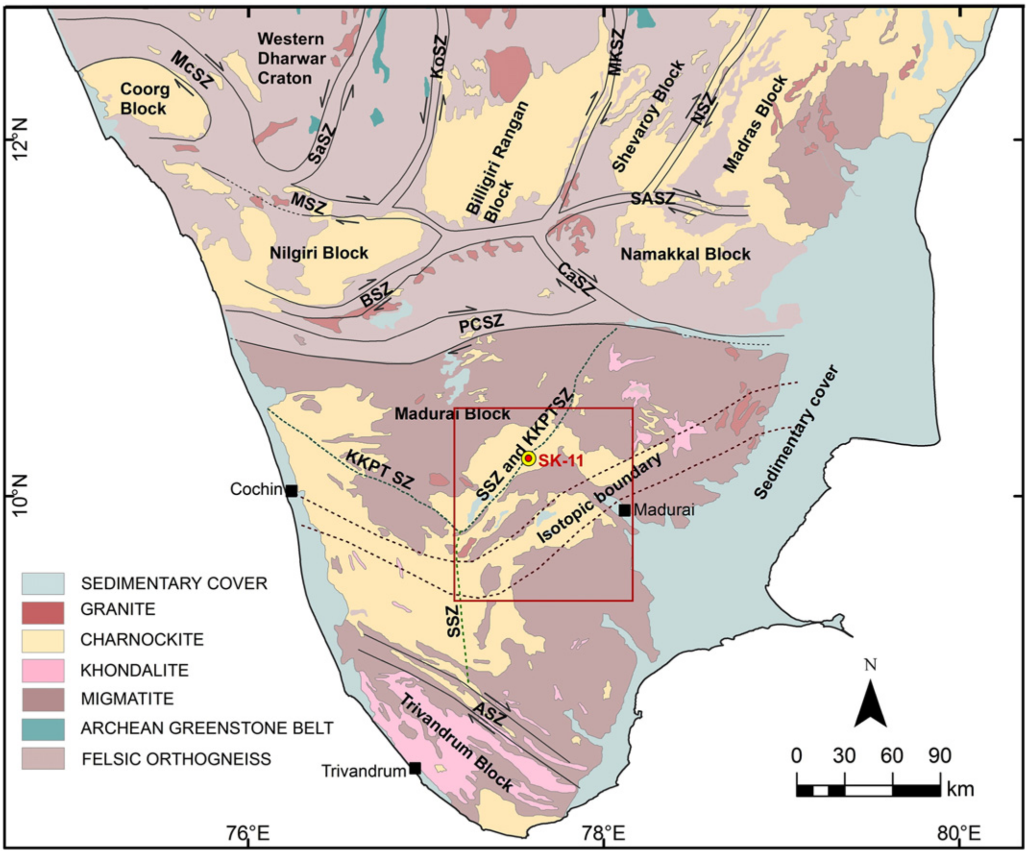

Fig. 1. Regional geology and tectonic framework map of southern India (after, Geological Survey of India, 1993; Drury and Holt, 1980; Ishwar-Kumar et al., 2013). Acronyms: McSZ-Mercara Shear Zone, MKSZ — Mettur–Kolar shear zone, NSZ — Nallamalai shear zone, MSZ — Moyar shear zone, SASZ — Salem–Attur shear zone; BSZ — Bhavani shear zone, CaSZ — Cauvery shear zone, PCSZ — Palghat–Cauvery shear zone; KKPTSZ — Karur–Kambam–Painavu–Trichur shear zone (after, Ghosh et al., 2004), SSZ — Suruli shear zone (after Brandt et al., 2014), ASZ — Achankovil shear zone, Isotopic boundary after Plavsa et al. (2014). The rectangle shows the position of Fig. 2.

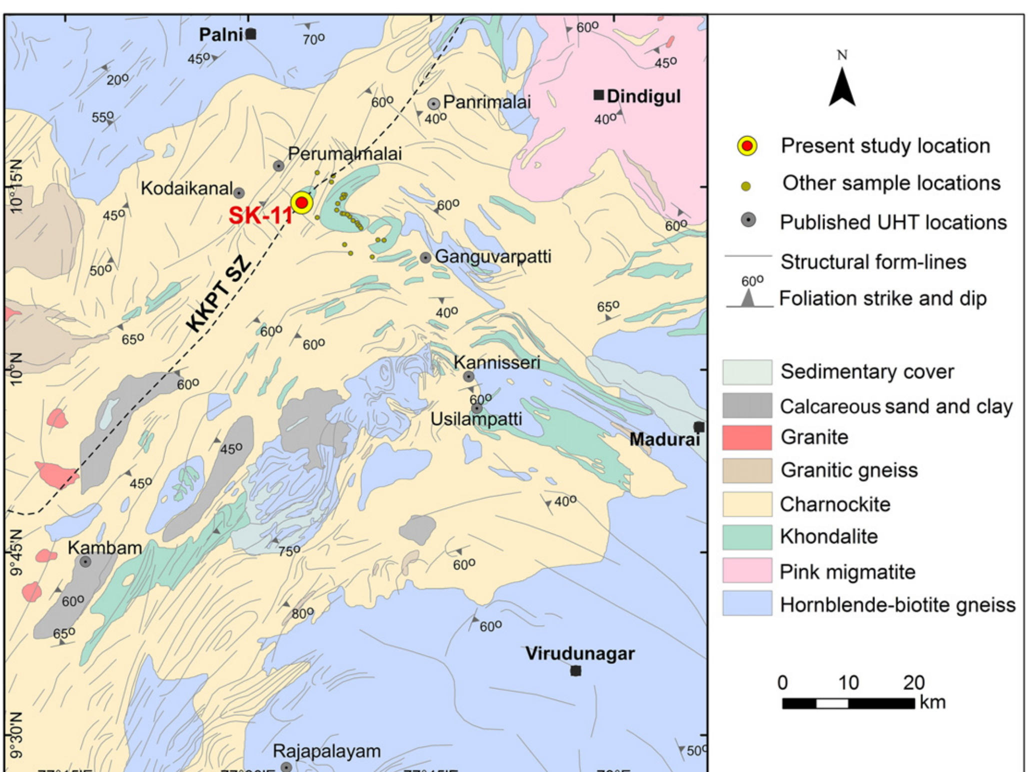

Fig. 2. Sample locations and structural lineaments on a geological map of the study area (modified after Geological Survey of India, 2005; Structural form-lines were extracted from Landsat ETM$^+$ satellite imagery and ASTER digital elevation model). Also plotted are the locations of ultra-high temperature (UHT) rocks.