Lithos 136–139 (2012) 10–26

Contents lists available at SciVerse ScienceDirect

Lithos

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

Geochronology of multi-stage metamorphic events: Constraints on episodic zircon growth from the UHP eclogite in the South Altyn, NW China

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ARTICLE INFO

Article history:
Received 19 December 2010
Accepted 22 September 2011
Available online 1 October 2011

Keywords:
South Altyn
UHP eclogite
Zircon
Multi-stage metamorphism
P–T–t path

ABSTRACT

Petrography, mineral chemistry and pressure–temperature (P–T) estimates were carried out for the eclogite from the South Altyn in NW China. The results suggest three stages of metamorphism: an ultra-high pressure (UHP) eclogite-facies metamorphism at 717–871 °C and ≥2.8 GPa, a high pressure (HP) granulite-facies metamorphism at 624–789 °C and 1.42–1.52 GPa, and an amphibolite-facies metamorphism at 597–728 °C and 0.99–1.17 GPa. Cathodoluminescence investigation revealed that zircons from the retrograde eclogite display a distinct core-rim structure. Cores are grey-white luminescent and contain mineral inclusions of Garnet + Omphacite + Rutile + Quartz, suggesting eclogite-facies metamorphic origin. The rims are dark grey luminescent and contain Garnet + Clinopyroxene + Pagioclase inclusions, forming at HP granulite-facies conditions. A few residual zircon grains with mottled internal structure also occur as the metamorphic cores. LA-ICPMS zircon U–Pb dating yielded three discrete age groups: (1) a Neoproterozoic protolith age of 752 ± 7 Ma for the residual grains, (2) an eclogite-facies metamorphic age of 500 ± 7 Ma for the metamorphic cores, and (3) a HP granulite-facies retrograde age of 455 ± 2 Ma for the rims. These ages indicate that the protolith of the Altyn eclogite probably formed in response to breakup of the Rodinia supercontinent during the Neoproterozoic; it was subjected to continental deep subduction and UHP metamorphism during early Paleozoic (~500 Ma) and subsequently underwent two stages of retrograde metamorphism during exhumation. The petrological and geochronological data suggest a clockwise P–T–t path for the UHP eclogite. According to pressures and ages for the peak UHP eclogite-facies and the retrograde HP granulite-facies metamorphism, an exhumation rate of 1.2 mm/yr was estimated for the eclogite, which is considerably slower than that of some UHP rocks from other UHP terranes (>5 mm/yr). While the peak metamorphic age of 500 Ma is consistent with previous dates of 480–504 Ma, it is 40–60 Myr older than the HP/UHP metamorphic ages of 420–461 Ma for UHP eclogites in North Qaidam. The retrograde metamorphic age is 455 ± 2 Ma for the Altyn eclogite, which is 30–55 Myr older than ~400–425 Ma for the North Qaidam eclogites. These age differences suggest that the South Altyn and North Qaidam eclogites do not belong to the same HP/UHP metamorphic zone.

1. Introduction

High-pressure/ultrahigh-pressure (HP/UHP) metamorphic zones mark the convergent lithospheric plate boundaries due to the paleo-oceanic subduction and continental collision, and record the geodynamic processes from subduction to exhumation of crustal materials (Carswell and Zhang, 1999; Ernst, 2001, 2006; Maruyama et al., 1996; Smith, 1988; Song et al., 2006; Wang et al., 2010). Although eclogites are just minor components of collisional orogens, they are related to plate subduction–collision and provide valuable insights on the formation of orogenic belts. Therefore, the ages of protolith, of peak and retrograde metamorphism for UHP eclogites are a key to understand the process of orogenic formation and evolution.

The South Altyn in the northwestern China was recognized as HP/UHP terrane in the last decade. The HP/UHP rocks, located in the Jianggalesayi, Danshuiquan and Yinggelisayi areas (Fig. 1a), include eclogite, garnet (Grt) pelitic gneiss, K-feldspar (Kfs)-bearing Grt clinopyroxenite, Grt-bearing granitic gneiss and magnesite-bearing Grt peridotite (Liu et al., 2002, 2004, 2005, 2007a; Wang et al., 2011; Zhang et al., 2002a). Previous studies indicate that the metamorphic ages of these HP/UHP rocks ranges from 480 to 504 Ma (Cao et al., 2009; Liu et al., 2007b, 2009, 2010; Wang et al., 2011; Zhang et al., 1999, 2004, 2005a). However, no retrograde metamorphic age has been reported for these HP/UHP rocks. Consequently, the metamorphic pressure–temperature–time (P–T–t) path and the exhumation rate for the South Altyn UHP rocks remain unknown. In addition, the North Qaidam terrane, the adjacent area of South

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0024-4937/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.lithos.2011.09.014

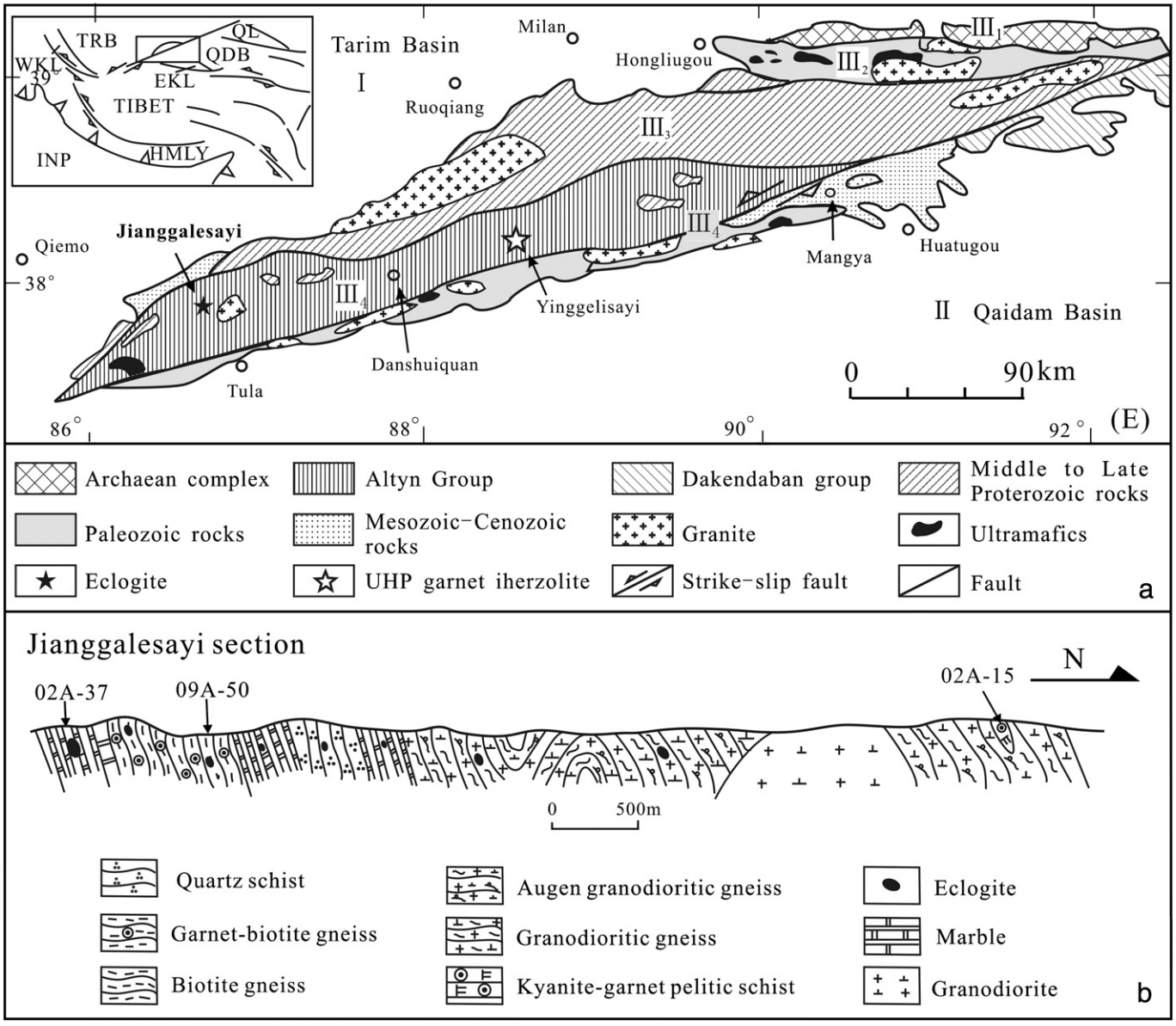

Fig. 1. Geological and tectonic map of the Altyn Tagh orogen (A) and profile map of the Jianggalesayi section (B) (after Liu et al., 2009). TRB. Tarim basin; QL. Qilian Mountains; QDB. Qaidam basin; HMLY. Himalaya Mountains; INP. Indian plate; WKL. western Kunlun Mountains; EKL. eastern Kunlun Mountains; I. Tarim block; II. Qaidam block; III. Altyn Tagh orogenic belt; III1. North Altyn Tagh Archean complex; III2. North Altyn Tagh subduction–collision complex; III3. Milanhe–Jinyanshan block; III4. South Altyn subduction–collision complex.

Altyn, contains well-documented HP/UHP eclogite, Grt peridotite and coesite bearing pelitic gneiss (Song et al., 2004, 2005a, b; Yang et al., 1994, 1998, 2001; Zhang et al., 2009b; Zhang et al., 2009c). However, there is controversy concerning the genetic relationship between the two HP/UHP terranes (Liu et al., 2009; Xu et al., 1999; Yang et al., 2003).

In this paper, we present not only P–T estimates for the multi-stage metamorphism of eclogite from the Jianggalesayi, but also the morphology, mineral inclusion and U–Pb ages of zircon from the retrograde eclogite The results allow us to define the protolith, the peak and retrograde metamorphic ages of the eclogite, and to decipher the metamorphic evolution of eclogite and the rate of exhumation for the South Altyn HP/UHP terrane. Combined on these peak and retrograde metamorphic ages, we also discuss the correlation between South Altyn and North Qaidam HP/UHP terrane. Mineral abbreviations are after Whitney and Evans (2010).

2. Geological background

The Altyn Tagh marks the northern margin of the Qinghai–Tibet Plateau, lying between the Tarim block to the north and the Qaidam block, the Qilian orogen and the Kunlun belt to the south. From north to south, the Altyn Tagh can be divided into four units from north to south (Liu et al., 2009): (1) the north Altyn Archean complex; (2) the north Altyn oceanic-type subduction complex; (3) the Milanhe–Jinyanshan block; (4) the south Altyn continental-type subduction–collision complex (Fig. 1a). The eclogite in the South Altyn subduction complex crops out principally in the western Altyn Tagh and extends 250 km from the west of the Mangya to the south of the Qiemo. The complex mainly consists of the Altyn Group medium- to high-grade metamorphic rocks, ophiolite (Liu et al., 1998; Wang et al., 1999), granite and minor clastic sediments. Field mapping revealed that the Altyn Group consists of ~70% tonalitic–granoritic gneiss, ~25%