Gondwana Research 23 (2013) 726–747

Contents lists available at SciVerse ScienceDirect

Gondwana Research

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

The origin and response of zircon in eclogite to metamorphism during the multi-stage evolution of the Huwan Shear Zone, China: Insights from Lu–Hf and U–Pb isotopic and trace element geochemistry

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ARTICLE INFO

Article history:
Received 8 December 2011
Received in revised form 26 April 2012
Accepted 11 May 2012
Available online 5 June 2012

Handling Editor: M. Santosh

Keywords:
Geochemistry
Zircon Hf-isotopes
Continental subduction
Eclogite facies metamorphism
Qinling–Dabie orogen

ABSTRACT

The Huwan Shear Zone (HSZ) is an eclogite bearing transpressive wrench zone located along the Shangdan Suture that juxtaposes the Paleozoic Qinling and Mesozoic Hong'an–Dabie orogenic terrains. The region preserves a complex history that bridges the gap between adjacent orogenic terrains. Simultaneous in-situ trace element, U–Th–Pb and Lu–Hf-isotope analysis of zircon grains from samples of the Xiongdian and Sujiahe eclogite identify a late Carboniferous to early Permian period of high pressure metamorphism, ca. 283 to 306 Ma. Zircon grains are observed to respond to metamorphic overprint via a two stage process: (1) An initial prograde stage of fluid catalyzed interface coupled dissolution–reprecipitation, involving exsolution of a non-ideal solid solution thorite ($ThSiO_4$) end member and loss of highly incompatible components (LREE and Pb), (2) A second stage of coupled zircon dissolution, coarsening, and new rim growth in equilibrium with garnet at high pressure conditions.

We identify Proterozoic whole rock Sm–Nd and zircon grain Lu–Hf isotopic evidence which challenges the traditional interpretation that the Xiongdian and Sujiahe eclogite formed in response to early Paleozoic mantle melting and oceanic crust generation. We argue the Huwan Shear Zone contains no conclusive evidence of early/middle Paleozoic oceanic crust, but rather Proterozoic crustal components analogous to those found in the Northern Qinling Terrain and associated with formation of the Shangdan Suture. We present a simpler geodynamic model involving continuous convergence and accretion of terrains onto the southern margin of the North China Block during the Paleozoic Qinling and Mesozoic Dabie orogenies.

1. Introduction

Zircon is ubiquitous accessory mineral in crustal lithologies and typically a residual phase during processes associated with crustal recycling and continental evolution. Zircon's ability to concentrate U whilst rejecting Pb (Watson et al., 1997) makes it a particularly important geochronometer and its robust crystalline lattice is effective at preventing intra element diffusion or structural breakdown up to the most extreme crustal temperatures and pressures (Cherniak and Watson, 2003; Cherniak, 2010).

High grade metamorphic terrains associated with continental subduction and orogenesis are witness to the most extreme geodynamic processes acting upon the earth's crust. For such environments, zircon is commonly the only available phase that can preserve geochronological information to constrain specific dates for peak metamorphic conditions and rates of subduction and exhumation (E.g. Liati and Gebauer, 1999; Rubatto et al., 1999; Hermann et al., 2001; Rubatto and Hermann, 2003; Wan et al., 2005; Liu et al., 2006; Harley et al., 2007; Rubatto and Hermann, 2007a,b; Liu and Liou, 2011).

It has been proposed that zircon grains in eclogites and other high grade metamorphic rocks require a catalyzing hydrous fluid phase to facilitate new growth or recrystallization, and thus record dehydration metamorphic reactions associated with high to ultrahigh pressure (HP/UHP) tectonic events (e.g. Corfu et al., 2003; Rubatto and Hermann, 2003; Breeding et al., 2004a,b; Wu et al., 2006; Rubatto and Hermann, 2007a,b; Wu et al., 2009a; Rubatto et al., 2008). The ability to constrain the timing of fluid production during high grade metamorphism is an important step in understanding metamorphic PTt paths and consequently the geodynamics of orogenic mountain belts (e.g. Peacock, 1987, 1990, 1993; Williams et al., 1996; Leech, 2001; Breeding et al., 2004a; Spinelli and Wang, 2009; Touret and Huizenga, 2012). Understanding the response of zircon and conditions responsible for generation of U–Pb dates during high grade metamorphic processes,

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doi:10.1016/j.gr.2012.05.008

however, is a particularly challenging endeavor. The identification of key features that link zircon growth or recrystallization to specific metamorphic conditions requires a detailed geochemical and petrological investigation of both analyzed zircon grains and their host rock.

For our study, we focus on the extensive Central China orogenic belt (Fig. 1). Geochronological exploration across the Hong'an, Dabie and Sulu HP/UHP metamorphic terrains in the eastern portion of the belt identifies an unambiguous history of Triassic HP/UHP metamorphism during continental collision between the South China Block (SCB) and North China Block (NCB) (see review in Zhang et al., 2009). In contrast, however, geochronological evidence from the Qinling and Tongbai terrains in the western portion of the belt have produced evidence for an earlier Paleozoic timing of collision between the SCB and NCB (e.g. Kröner et al., 1993). Bridging the gap between Paleozoic and Mesozoic orogenic events now relies upon accurately unraveling the complex metamorphic and geodynamic histories for a number of thin and highly deformed transpressive wrench zones, or shear zones, located along the Shangdan Suture, which marks the suture between the SCB and NCB, and the northern extent of Triassic HP/UHP metamorphism.

To help understand the origin and response of zircon to metamorphism in this orogenic belt, we present whole rock compositional and Sr-Nd isotopic data combined with in-situ measurements of zircon trace element concentrations and U–Pb and Lu-Hf-isotopes for four samples located in the western portion of the Huwan Shear Zone

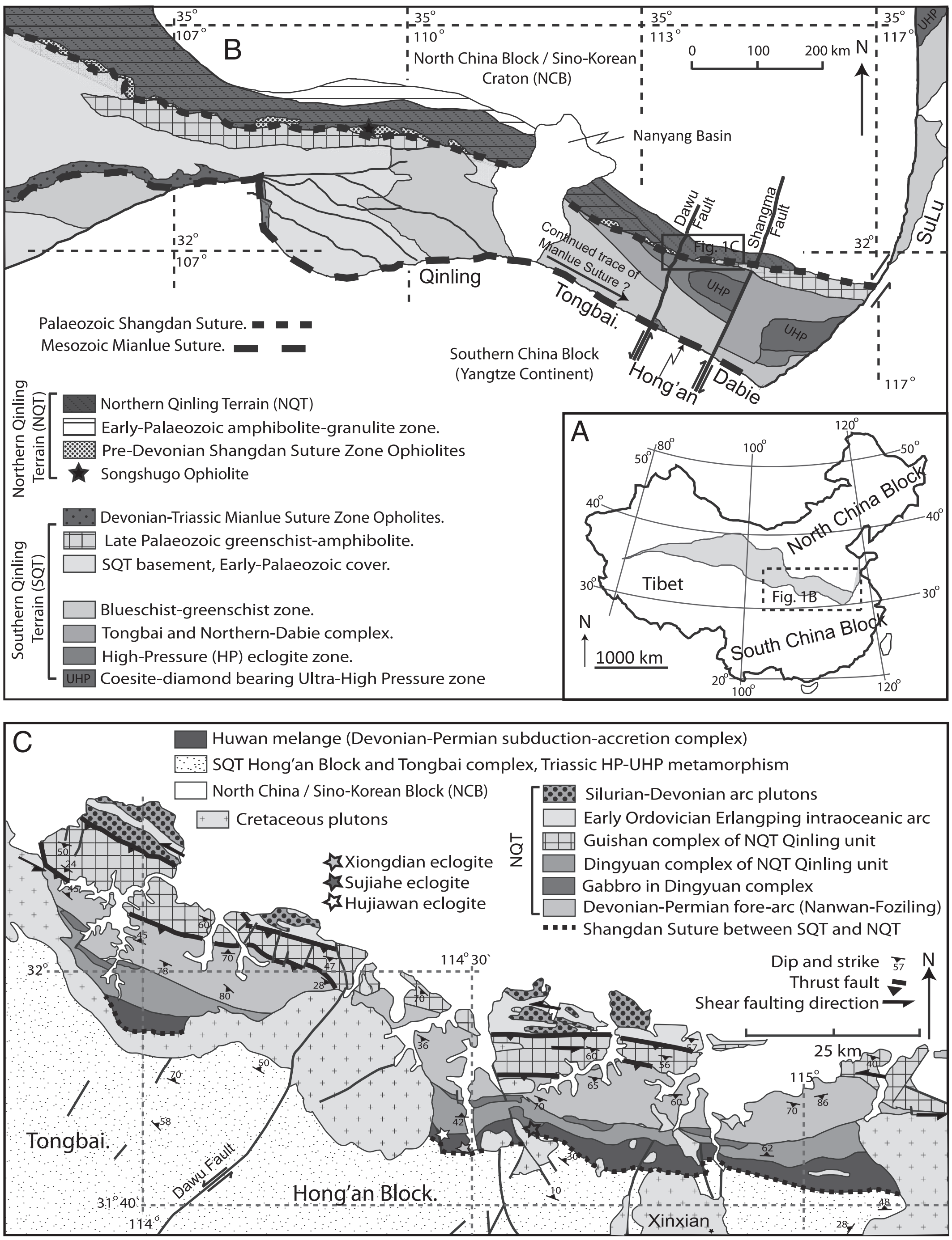

Fig. 1. (A) General tectonic map of the Qinling-Tongbai-Hong'an–Dabie-Sulu Mesozoic metamorphic belt and Southern and Northern Qinling Terrains: After Liu et al., 2011b; Dong et al., 2008, 2011: (B) Geological map of Tongbai-Hong'an Mesozoic metamorphic-orogenic belt including the Huwan Shear Zone and sample locations (after Ratschbacher et al., 2006). See Ratschbacher et al. (2003, 2006) for detailed lithological descriptions.