Lithos 196–197 (2014) 1–13

Contents lists available at ScienceDirect

Lithos

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

Metamorphic P–T–t evolution of mafic HP granulites in the northeastern segment of the Tarim Craton (Dunhuang block): Evidence for early Paleozoic continental subduction

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ARTICLE INFO

Article history:
Received 1 November 2013
Accepted 21 February 2014
Available online 5 March 2014

Keywords:
CAOB
Dunhuang block
Early Paleozoic
HP granulite
Beishan orogenic collage
P–T–t path

ABSTRACT

The Dunhuang block, which constitutes the northeastern segment of the Tarim Craton, is located between the Central Asian Orogenic Belt (CAOB) to the north and the Altyn–Qilian Orogenic Belt to the south. The present study reveals that the early Paleozoic HP mafic granulites from the Dunhuang block underwent four stages of metamorphism: prograde amphibolite-facies (M1), peak high-pressure (HP) granulite-facies (M2) and two late stages of amphibolite-facies retrograde metamorphism. Based on phase equilibrium modeling, P–T conditions of the four stages of metamorphism are estimated at 720–750 °C and 11–13 kbar, 760–800 °C and 14–16 kbar, 690–720 °C and 8–8.5 kbar, and at <6 kbar and <640 °C respectively. Peak granulite-facies metamorphism is characterized by a low geothermal gradient of ca. 16 °C/km. Zircon U–Pb dating shows that the HP granulite-facies metamorphism occurred at ca. 431 Ma and the early retrograde amphibolite-facies overprint at ca. 403 Ma. Thus the investigated mafic rocks here reveal a clockwise P–T–t path involving burial heating before peak granulite-facies metamorphism and subsequent decompression–cooling with an uplift rate of ca. 0.8 km/Ma. This, together with a continental affinity of the HP metamorphic rocks, indicates that the Dunhuang block experienced a collisional orogenesis during the early Paleozoic.

1. Introduction

The North China, South China and Tarim Cratons are the three largest cratons in China. The Tarim Craton is located in northwestern China and covers an area of more than 600,000 km^2. In comparison with the detailed geological studies of the North China and South China Cratons, the geological evolution of the Tarim Craton is less well understood (see Zhao and Cawood, 2012; Zheng et al., 2013 and references therein). This is due to the fact that more than 85% of the Tarim Craton is covered by desert, and thus the basement rocks are only locally exposed for instance at Tieklik in the southwest, Keping in the northwest, Dunhuang and Kuluketage in the northeast of the craton margin (Lu et al., 2008; Zhang et al., 2013a; Zhao and Cawood, 2012 and references therein).

The Dunhuang block, forming the northeastern segment of the Tarim Craton, is located between the Altyn–North Qilian Orogen to the south and the Beishan Orogen (the southern margin of the Central Asian Orogenic Belt, CAOB) to the north (inset of Fig. 1a). Significant amounts of high-grade metamorphic rocks and early Precambrian basement rocks are exposed in the Dunhuang block. On the basis of TIMS U–Pb zircon dating of one tonalite, Mei et al. (1998a) suggested that the tonalite–trondhjemite–granodiorite (TTG) gneisses in the Dunhuang block formed at ~2.67 Ga and underwent Neoproterozoic (~1.0 Ga) alteration events. Zhang et al. (2009) and Meng et al. (2011) suggested that the Dunhuang block witnessed an early Paleozoic collision event characterized by high-grade metamorphism and granitoid activity. In addition, Zhang et al. (2012, 2013b) proposed that the TTG gneisses in the Dunhuang block underwent a ~2.5 Ga magmatic–metamorphic event and Paleoproterozoic (~1.85 Ga) high-pressure (HP) granulite metamorphism. Zong et al. (2013) suggested that the TTG gneisses formed at ca. 2.7–2.6 Ga, and were altered by subsequent Paleoproterozoic (ca. 2.0–1.9 Ga) and early Paleozoic (ca. 430 Ma) HP metamorphic events.

Recently, we reported the first finding of early Paleozoic HP granulites in the Dunhuang block (Zong et al., 2012). Zircon U–Pb geochronology indicates that the Dunhuang mafic granulites and associated kyanite-bearing garnet gneisses and garnet-mica schists underwent HP metamorphism at ca. 440–430 Ma. This implies that the northeastern margin of the Tarim Craton underwent an early Paleozoic collision with the southern part of the CAOB. The only recently detected HP granulite-facies metamorphic event provided important constraints on the Paleozoic multiple subduction–accretion and collision processes

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http://dx.doi.org/10.1016/j.lithos.2014.02.020
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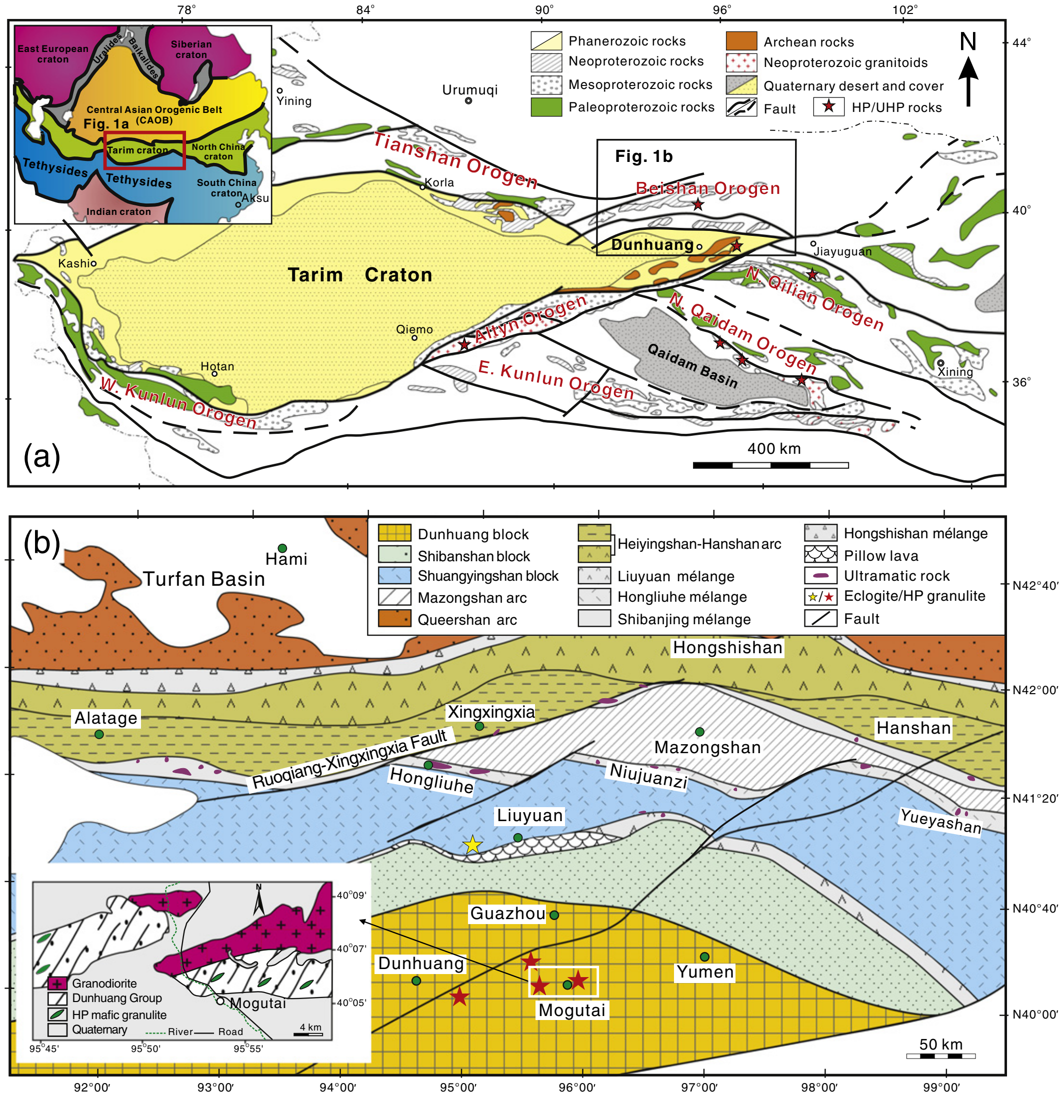

Fig. 1. Simplified geological map of the Tarim Craton and adjacent areas (modified after Lu et al., 2008 and Zong et al., 2012) showing locations of the Dunhuang HP granulite, as well as HP and ultrahigh-pressure (UHP) metamorphic rocks from the adjacent orogens. Inset figure shows a simplified tectonic map of the Central Asian Orogenic Belt (modified after Xiao et al., 2010a); (b) Simplified tectonic map of the Beishan orogen showing the major tectonic subdivisions (modified after Xiao et al., 2010b; Liu et al., 2011 and Song et al., 2013b). Inset figure represents the geological map of the Mogutai area in the Dunhuang block, showing the major mafic granulite locations.

of the CAOB (Xiao et al., 2010a, 2010b, 2013; Zong et al., 2012). However, the metamorphic P–T–t evolution and exact tectonic setting of the early Paleozoic HP granulites remain ambiguous.

In this paper we report detailed petrological, geochronological and phase modeling studies for the early Paleozoic Dunhuang HP granulites in order to reveal their metamorphic evolution and discuss the tectonic significance of the HP metamorphism of the Dunhuang block. The results provide robust evidence for an early Paleozoic collisional orogeny along the northeastern margin of the Tarim Craton, and new insight into the tectonic history of the southern CAOB. The mineral abbreviations used in this paper are: Ab = albite, Alm = almandine, Am = amphibole, An = anorthite, Bt = biotite, Chl = chlorite, Cpx = clinopyroxene, Grs = grossular, Gt = garnet, Ilm = ilmenite, Ky = kyanite, Ms = muscovite, Ol = olivine, Opx = orthopyroxene, Pl = plagioclase, Prp = pyrope, Qz = quartz, Rt = rutile, Spe = spessartine, Zo = zoisite and w = water (H_2O).

2. Geological background

The Dunhuang block is composed of a series of supracrustal rocks (termed the Dunhuang Group) and subordinate TTG-like intrusions, both of them underwent medium- to high-grade metamorphism (Mei et al., 1997). The Dunhuang Group is dominated by metasedimentary rocks including schist, marble, amphibolite, mafic granulite, gneiss and quartzite and a few metavolcanic rocks (Mei et al., 1997; Yu et al., 1998). The sedimentary protoliths of the Dunhuang Group are believed to represent an active continental margin of the Tarim Craton (Yu et al., 1998). Based on detrital zircon geochronology and Hf isotopes, Meng et al. (2011) suggested that the Dunhuang Group represents a sedimentary cover above the Precambrian basement with deposition commencing after ca. 765 Ma. The presence of Ordovician–Silurian granitoids (Zhang et al., 2009) and amphibolite-facies rocks (Meng et al., 2011) indicates an early Paleozoic tectonothermal overprint of the Dunhuang Group.

The Beishan orogen, which occurs adjacent to the northeastern margin of the Tarim Craton, is believed to have formed during the Paleozoic through multiple accretion of different arcs, accretionary complexes and microcontinents along the southern part of the CAOB (Cleven et al., 2013; Song et al., 2013a; Tian et al., 2014; Xiao et al., 2010a, 2010b). Abundant medium- to high-grade metamorphic rocks occur in several tectonostratigraphic terranes of the Beishan. The metamorphic rocks were previously considered as Precambrian basement and