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Early Paleozoic (ca. 465 Ma) eclogites from Beishan (NW China) and their bearing on the tectonic evolution of the southern Central Asian Orogenic Belt

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ABSTRACT

The Beishan orogen is situated in the southern margin of the Central Asian Orogenic Belt (CAOB). It is connected with the Tianshan orogen to the west and the Mongolia-Xing'anling orogen to the east. This orogen exhibits a well-preserved Neoproterozoic to Late Paleozoic sequence containing ophiolites, accretionary complexes and eclogites. In this paper we provide new geochronological data for eclogites and their country paragneiss to constrain the tectonic evolution of the Beishan orogen. U–Pb zircon dating of eclogites yielded two concordant ages, 886 ± 4 Ma for the cores and 465 ± 10 Ma for the rims. The zircon cores display bright luminescence with homogeneous or planar/sector zoning, intermediate Th/U ratios (0.17–0.47), and HREE-enriched patterns with negative Eu anomalies ($Eu/Eu^* = 0.16–0.58$). These features, coupled with their formation temperatures of 680–710 °C, suggest that the core age represents the time of an earlier upper amphibolite facies metamorphic episode. By contrast, the zircon rims have dark luminescence with homogeneous or fir-tree zoning, low Th/U ratios (<0.02), and flat HREE distributions with small or no negative Eu anomalies ($Eu/Eu^* = 0.55–1.16$). Thus, the rim age reflects the time of the eclogite facies metamorphism. The occurrence of tiny inclusions of garnet, omphacite and rutile in the zircon rims is consistent with the above age interpretation. In addition, the mineral inclusions and host zircons yielded *P–T* conditions of 660 °C and >12 kbar for the eclogite facies metamorphism. On the other hand, zircon dating of a paragneiss near the eclogite produced two major groups of ages, ca. 1450 Ma for a magmatic event and ca. 900 Ma for a metamorphic event. It seems that eclogites and their country rocks have suffered the same earlier metamorphic episode. Based on the available age data obtained for eclogites, ophiolites and granitoids from the Beishan area, a tectonic scenario can be constructed as follows. The ca. 1000 Ma oceanic crust representing by protoliths of the eclogites was involved in Early Neoproterozoic orogenesis to have formed a microcontinental block. During the Early Paleozoic, island arcs and microcontinental blocks were progressively accreted to the northern margin of the Tarim craton (Dunhuang block). This was followed by the closure of Paleoasian Ocean and final amalgamation between the Tarim craton and Kazakhstan block in the Late Paleozoic.

1. Introduction

The Central Asian Orogenic Belt (CAOB), also known as the Altaids, is a complex collage of microcontinental blocks, island arcs, remnants of oceanic crust and continental margins between the Siberian craton to the north and the Sino-Korean and Tarim cratons to the south (e.g. Sengör et al., 1993; Sengör and Natal'in, 1996; Jahn et al., 2000; Xiao et al., 2003; Jahn, 2004; Kröner et al., 2007; Windley et al., 2007). The orogenic belt was formed by multiple subduction-accretion and collision processes from the early of Neoproterozoic (ca. 1000 Ma) to the end of the Permian (ca. 250 Ma). One of the most important features of the CAOB is the widespread occurrence of high-pressure (HP) and ultrahigh-pressure (UHP) eclogites and eclogite facies rocks in many terranes or tectonic units, such as Muya in eastern Siberia (ca. 650 Ma; Shatsky et al., 1996), Gorny Altai in southern Siberia (ca. 630 Ma; Buslov et al., 2002; Ota et al., 2007), Kokchetav in northern Kazakhstan (ca. 530 Ma; Parkinson et al., 2002), Chara in eastern Kazakhstan (ca. 510–485 Ma; Dobretsov and Buslov, 2004), Makbal in Kyrgyzstan (ca. 480 Ma; Tagiri et al., 1995; Togonbaeva et al., 2009), Maksyutov in southern Urals (ca. 380 Ma; Beane and Connelly, 2000), western Tianshan in northwestern China (ca. 345 Ma or ca. 230 Ma; Gao and Klemd, 2003; Zhang et al.,

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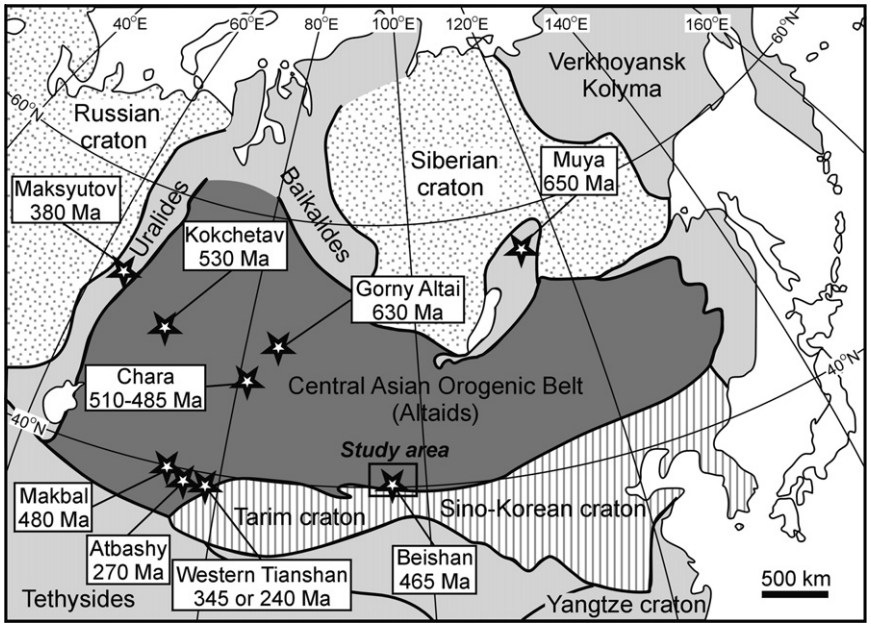

Fig. 1. Simplified tectonic map of the Central Asian Orogenic Belt with distribution and peak metamorphic age of recognized eclogites (modified after Sengör et al., 1993 and Xiao et al., 2009).

2007a), and Atbashy in Kyrgyzstan (ca. 270 Ma; Tagiri et al., 1995) (Fig. 1). These HP/UHP rocks were exhumed from deep crustal levels or mantle depths, and hence provide significant constraints to the subduction-accretion and collision histories of the CAOB.

The Beishan orogen in NW China represents a southern segment of the CAOB and links the Tianshan orogen to the west and the Mongolia-Xing'anling orogen to the east. This orogen exhibits a well-preserved Neoproterozoic to Late Paleozoic sequence and comprises ophiolites, island arcs and microcontinents formed by earlier subduction-accretion along the continental margin and subsequent collision between the Tarim craton and Kazakhstan block (Zuo and He, 1990; Zuo et al., 1991; Zuo and Li, 1996; Yue et al., 2001). Eclogites were discovered in the southernmost part of the Beishan orogen more than a decade ago (Mei et al., 1998), and their geological characteristics have been mostly described in the Chinese literature (Yu et al., 1999a,b; Liu et al., 2002; Yang et al., 2006). However, the metamorphic *P–T* conditions, ages and geochemical signature of the eclogites are poorly studied. In this paper, we report the results of U–Pb zircon dating for eclogites and their country paragneiss from the Beishan area. Combining the trace element analyses of zircons and their mineral inclusions, we document the ages of multiple metamorphism of the eclogite and paragneiss. Furthermore, in conjunction with the available age data from Beishan and adjacent areas, we discuss the tectonic evolution of the southern margin of the CAOB.

2. Geological background and characteristics of the Beishan eclogites

The Beishan orogen is separated from the Tianshan orogen to the west by the Ruoqiang-Xingxingxia fault, and from the Mongolia-Xing'anling orogen to the east by the Altyn Tagh–Alxa fault (Fig. 2). To the south of the Beishan orogen is the Dunhuang block, which is the eastern continuation of the Tarim craton. The Beishan orogen can be divided into, from south to north, four tectonic units or terranes: the Liuyuan continental margin, the Dongqiyishan arc, the Hanshan microcontinent and the Yuanbaoshan arc (Zuo and He, 1990; Zuo et al., 1991; Zuo and Li, 1996; Yue et al., 2001; He et al., 2005). The Liuyuan continental margin is actually a continental fragment (we call it the Liuyuan microcontinent in this paper) bounded by a Carboniferous to Permian volcanic rift zone to the south; The Dongqiyishan arc is characterized by the occurrence of Ordovician to Silurian arc assemblages; the Hanshan microcontinent comprises Precambrian massifs and a Carboniferous to Permian arc complex; whereas the Yuanbaoshan arc consists of a continuous Ordovician to Permian arc-related sequence. The boundaries between these units are the Hongliuhe–Xichangjing, Shibanjing-Xiaohuangshan and Hongshishan-Baiheshan sutures marked by ophiolites. To the south of the Beishan orogen there exists a Precambrian crystalline basement composed of amphibolite facies rocks (i.e. Shibandun Group). The basement forms the northeastern margin of the Dunhuang block (Zuo and He, 1990; Li, 1994). Intense igneous activity from the Ordovician to the Triassic (Zuo and He, 1990; Zuo and Li, 1996; Jiang et al., 2003; Jiang and Nie, 2006; Liu et al., 2006; Zhao et al., 2007; Zhang et al., 2008) produced granitic batholiths and stocks, which make up ca. 30% of the Beishan area.

In the Liuyuan microcontinent and Dongqiyishan arc terrane, the pre-arc continental crust is composed of Proterozoic medium-grade metamorphic basement complexes and Neoproterozoic (Sinian) to Lower Ordovician cover sequences of lower greenschist facies (Zuo and He, 1990; Zuo and Li, 1996). The basement complexes comprise the Baihu Group in the north and the Huaniushan Group in the south; both are separated by the Hongliuhe-Xichangjing ophiolite zone. The main lithology of the complexes is dominated by amphibolite facies granitic gneisses, paragneisses (pelitic–psammitic schists) and quartzites, with subordinate amphibolite layers or lenses. U–Pb zircon dating of granitic gneisses gave upper intercept ages of 1756 ± 88 Ma and 1660 ± 28 Ma for those from the Baihu Group (Mei et al., 1998), and of 880 ± 31 Ma for those from the Huaniushan Group (Mei et al., 1999). However, reliable metamorphic ages of the rocks have not yet been obtained. The Neoproterozoic strata comprise neritic limestones and clastic interlayers, whereas the Cambrian–Lower Ordovician strata comprise a turbiditic suite composed of