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Structure, age, and tectonic development of the Huoshishan–Niujuanzi ophiolitic mélange, Beishan, southernmost Altaids

Zhonghua Tian [a,b], Wenjiao Xiao [a,c,*], Brian F. Windley [d], Li'na Lin [a,b], Chunming Han [a,c], Ji'en Zhang [a,c], Bo Wan [a,c], Songjian Ao [a,c], Dongfang Song [a,b], Jianyun Feng [a,b]

[a] State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, PR China
[b] Graduate University of Chinese Academy of Sciences, Beijing 100049, PR China
[c] Xinjiang Research Center for Mineral Resources, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi, Xinjiang 830011, PR China
[d] Department of Geology, University of Leicester, Leicester LE1 7RH, UK

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ABSTRACT

The Huoshishan–Niujuanzi ophiolitic mélange (HNO) is located near the central part of the Beishan Orogenic Belt in the southernmost Altaids. The HNO consists of ultramafic rocks, cumulate gabbros, gabbros, plagiogranites, diorites, diabases, basalts, andesites, rhyolitic volcaniclastic rocks and siliceous sedimentary rocks, many of which are in a schist matrix (Gongpoquan Group). Geochemical data of the mafic rocks indicate a calc-alkaline or a mixture of calc-alkaline and tholeiitic rocks with negative Nb, Ta and positive Pb, Ba and La anomalies, suggesting formation in an island arc or supra-subduction zone setting. A gabbro from a block in the mélange in the Niujuanzi area has a zircon age of 435.0 ± 1.9 Ma and a plagiogranite with an age of 444.3 ± 1.9 Ma, and another gabbro from the Huoshishan area has an age of 410.5 ± 3.7 Ma. The schist matrix has a zircon age of 512 ± 5.3 Ma and contains Silurian, Devonian and Carboniferous fossils, thus the mélange formed in the late Carboniferous or later. Our structural analysis of fault planes in the HNO, the crenulation cleavages (S_2) of the schist, and fold axial planes of early Permian sandy limestone/quartz veins and late Permian sandstones indicates that the mélange underwent a north-to-south compression, and the orientation of stretching lineations, slickensides and fold hinge lines implies that the HNO experienced top-to-the north (or -northwest) movement. The entire planar and linear structural data set suggests that the subduction polarity was probably to the south in the late Paleozoic. The emplacement age of the HNO was probably near the end-Permian based on the age of the youngest rocks in the ophiolitic mélange, and by the presence of a late Permian unconformity. From our work, integrated with published regional data, we outline a comprehensive geodynamic model for the central BOC.

1. Introduction

The Altaids (Sengör et al., 1993) is the southern, younger part of the Central Asia Orogenic Belt (Carroll et al., 1995; Buslov et al., 2001; Jahn, 2004; Wilhem et al., 2012), which is one of the largest of the world's accretionary orogenic belts. It was produced by multiple accretions and amalgamations of island arcs, seamounts, oceanic islands, accretionary wedges, oceanic plateaus and microcontinents as a result of the subduction and closure of the Paleo-Asian Ocean (Xiao et al., 2003, 2004; Windley et al., 2007; Gao et al., 2009; Xiao et al., 2009, 2010a; Wan et al., 2011). In the southernmost Altaids, the Beishan Orogenic College (BOC) connects the southern Tianshan suture zone to the west with the Solonker suture zone to the east (Fig. 1a, Xiao et al., 2010b). It provides an ideal site for studying the accretionary tectonics and final closure time of the Paleo-Asian Ocean (Gong et al., 2003; Mao, 2008; Xiao et al., 2010b), but its accretionary history is still controversial. For example, Zuo et al. (1990) interpreted it as an early Paleozoic orogen that ended prior to the Silurian–Devonian because of the occurrence of Ordovician–Silurian ophiolites and Devonian molasse in the Dundunshan arc (Fig. 1b). In contrast, from their study of the Liuyuan turbidites and mélange Guo et al. (2012), and Mao et al. (2012b) respectively suggested that the Paleo-Asian Ocean was still open in the early Permian. Similarly, Tian et al. (in press) proposed late Permian to early Triassic terminal accretion based on deciphering deformation stages of fold superimposition in the central Beishan. Xu et al. (2009) and Su et al. (2011) regarded the BOC as an early Paleozoic orogen that evolved into a continental rift in the Permian. Thus, it is still hotly debated whether the orogenesis terminated in the Devonian (Zuo et al., 1990, 1991; He et al., 2002; Gong et al., 2003) or in the late Paleozoic–early Triassic (Xiao et al., 2010b; Guo et al., 2012; Tian et al., in press).

* Corresponding author at: State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, PR China. Tel.: +86 10 82998524; fax: +86 10 62010846.
E-mail address: wj-xiao@mail.iggcas.ac.cn (W. Xiao).

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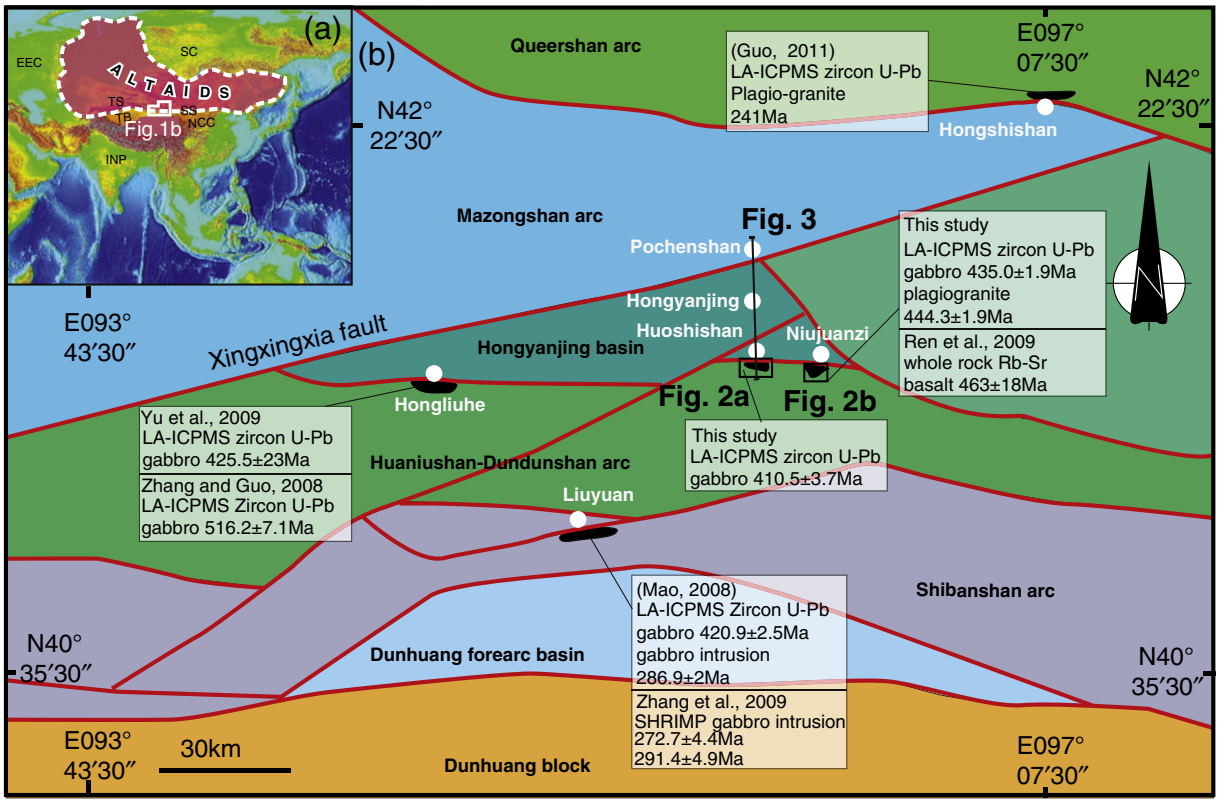

Fig. 1. (a) Topographic map showing the location of the Altaids bound on the north by the Siberian and East European cratons, and on the south by the Tarim basin and North China craton (modified after Xiao et al., 2010b). (b) Simplified tectonic map of the Beishan Orogenic Collage (BOC) (modified after Zuo et al., 1990; Xiao et al., 2010b; Guo et al., 2012). The capital letters behind the arcs are short for geological periods. Figs. 2a, b and 3 are shown in this map; Abbreviations: TS, Tianshan; TB, Tarim basin; NCC, North China craton; SS, Solonker suture; SC, Siberian craton; EEC, East European craton.

Ophiolites often occur as dismembered fragments in suture zones especially in accretionary orogenic belts (e.g., Cawood et al., 2009), because the multiple subduction–accretion events offer more opportunities for creation of suture zones. Ophiolites have long been considered as fragments of oceanic crust (Dewey and Bird, 1971; Coleman, 1977; Dilek and Furnes, 2011; Kusky et al., 2011), which may be incorporated into a continental or accretionary margin by arc–arc/continent–arc/continent–continent collisions (Dilek and Flower, 2003), ridge–trench interaction (Cloos, 1993; Kusky and Young, 1999) or subduction–accretion (Cawood et al., 2009). Accreted oceanic fragments may be incorporated into an ophiolitic mélange typically in a suture zone that marks the boundary between two different amalgamated plates or accreted terranes (Nicolas, 1989; Dilek and Flower, 2003; Lister and Forster, 2009; Dilek and Furnes, 2011). Investigation of the formation and emplacement age of an ophiolite can unravel the processes of accretionary orogenesis, and there are many suitable ophiolites and ophiolitic mélanges in the Chinese Altay, Tianshan and Beishan in the southern Altaids (Xiao et al., 2009, 2013).

The widespread ophiolite belts (Fig. 1b) in the BOC also provide a potentially significant age constraint on the final attachment of the Tarim and North China cratons to the southern accretionary margin of the Altaids (Jahn, 2004; Xiao et al., 2010b; Mao et al., 2012b).

The aim of this paper is to present new structural, geochemical and geochronological data on the Huoshishan–Niujianzi ophiolitic mélange (HNO) in the central BOC, in order to better understand the timing, growth and emplacement of this ophiolite and the structural history of the mélange and suture zone, because it has a critical role to play in the terminal history of the Altaids. We also include a new structural cross-section from the HNO to the Carboniferous Pochengshan arc, which provides an improved understanding of the regional geology of the central Beishan orogen. Finally, we discuss the geodynamic evolution of the HON within the framework of the regional tectonics of the central BOC.

2. Geological background

The Beishan Orogenic Collage is bound by the Tarim–Dunhuang block to the south and the arcs of the southern Altaids to the north (Fig. 1a). Thus it occupies a key position on the southern junction of the accretionary orogen of the Altaids or CAOB (Zuo et al., 1990, 1991; He et al., 2002; Gong et al., 2003; Xiao et al., 2010b).

2.1. Tectonic framework of the BOC

In previous studies the BOC was divided into several tectonic units (e.g. Zuo et al., 1990, 1991; He et al., 2002; Gong et al., 2003; Mao, 2008; Xiao et al., 2010b; Guo et al., 2012). From our recent work on the BOC, we suggest that from south to north, it comprises: the Dunhuang block, the Dunhuang forearc Basin, the Shibanshan Carboniferous–Permian arc, the Huaniushan–Dundunshan Silurian–Devonian arc, the Hongyanjing Permian inter-arc basin, the Mazhongshan Carboniferous arc and the Queershan arc. The Dunhuang block mainly contains medium- to high-grade orthogneisses and paragneisses in the southernmost part of the BOC and is regarded as a Precambrian block similar to the Tarim block (Song et al., 2013). On the northern margin of the Dunhuang block is the Dunhuang forearc basin, probably Mesozoic in age, and the Shibanshan arc that largely consists of Carboniferous clastic sediments, felsic to intermediate volcanic and pyroclastic rocks, and Permian volcanic and pyroclastic rocks (Zuo et al., 1990). The Dundunshan–Huaniushan arc consists of the Gongpoquan Schist, intrusive rocks and Devonian conglomerates, sandstones, basalts, andesites, rhyolites, agglomerates, tuffs and limestones. There have been different opinions about the age of the Gongpoquan Group, because it includes