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The Cambrian initiation of intra-oceanic subduction in the southern Paleo-Asian Ocean: Further evidence from the Barleik subduction-related metamorphic complex in the West Junggar region, NW China

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ABSTRACT

In this study, we present new evidence from the Barleik subduction-related metamorphic complex in the southern West Junggar region, northwestern China, for the Cambrian initiation of intra-oceanic subduction in the southern Paleo-Asian Ocean. The Barleik metamorphic complex is mainly composed of blueschist and amphibolite blocks within an ophiolitic mélange and their protoliths are calc-alkaline andesite and alkali and tholeiitic basalts. The calc-alkaline andesite has a zircon U–Pb age of 502 ± 2 Ma, obtained from magmatic cores of zircon grains, and shares geochemical features similar to the 515–485 Ma intra-oceanic arc magmatic rocks in the West Junggar region. By contrast, the alkali and tholeiitic basalts have trace element features similar to ocean island and enriched mid-ocean ridge basalts, respectively. Rutile and sodic–calcic amphibole from the amphibolite have a U–Pb age of 502 ± 25 Ma and a $^{40}Ar/^{39}Ar$ age of ~504 Ma, respectively, which are in good agreement within errors with a $^{40}Ar/^{39}Ar$ age of 492 ± 4 Ma for phengite from the blueschist. These metamorphic ages of ~500 Ma are interpreted to represent the timing of Pacific-type subduction-related metamorphism and are also compatible with ages of the oldest supra-subduction zone ophiolites (531–512 Ma) and intra-oceanic arc plutons (515–485 Ma) in the southern West Junggar region. Being one of the oldest subduction-related metamorphic complexes (509–490 Ma) in the southern Central Asian Orogenic Belt, the Barleik metamorphic complex, together with the oldest arc plutons, definitely indicate the initial intra-oceanic subduction in the southern Paleo-Asian Ocean at least in the Early Cambrian.

1. Introduction

The Central Asian Orogenic Belt (CAOB), or Altaids (Sengör et al., 1993) or Central Asian Orogenic System (Briggs et al., 2007), is the world's largest Phanerozoic accretionary orogen with considerable crustal growth (Fig. 1a; Zonenshaĭn et al., 1990; Sengör et al., 1993; Han et al., 1997, 2010b, 2011; Jahn et al., 2000; Wu et al., 2000; Patchett and Samson, 2003; Chen and Arakawa, 2005; Windley et al., 2007). It has undergone complicated accretion–collision processes either through the strike-slip duplication of one to three major island arcs (the Kipchak model, e.g., Sengör et al., 1993; Yakubchuk et al., 2001) or through the successive accretion of intra-oceanic arcs, seamounts, oceanic plateaus, and micro-continents (the archipelago-type model, e.g., Zonenshaĭn et al., 1990; Dobretsov et al., 1995; Badarch et al., 2002; Buslov et al., 2002; Briggs et al., 2007; Windley et al., 2007; Xiao et al., 2008; Ren et al., 2014) during the evolution of the Paleo-Asian Ocean (PAO). It is widely accepted that the subduction initiation in the northern PAO was much older than that in the south (Zonenshaĭn et al., 1990; Sengör et al., 1993; Windley et al., 2007; Ren et al., 2014). The initial subduction of the northern PAO was thought to begin prior to ~1000 Ma, based on the identification of the oldest supra-subduction zone (SSZ)-type ophiolites and arc complexes along the southern margin of the Siberian Craton (the Baikalian orogen; Fig. 1a). For example, the latest Mesoproterozoic ophiolites and arc tonalite–trondhjemite suites were revealed in the Dunzhugur and Arzybey complexes of East Sayan (Fig. 1a; 1020–1017 Ma, Khain et al., 2002; Turkina et al., 2004). The mid-ocean ridge basalt (MORB)-derived amphibolite yielded a zircon U–Pb age of 918 ± 15 Ma is present in the Shaman zone (Fig. 1a; Ruzhentsev et al., 2010). The plagiogranite and gabbro in

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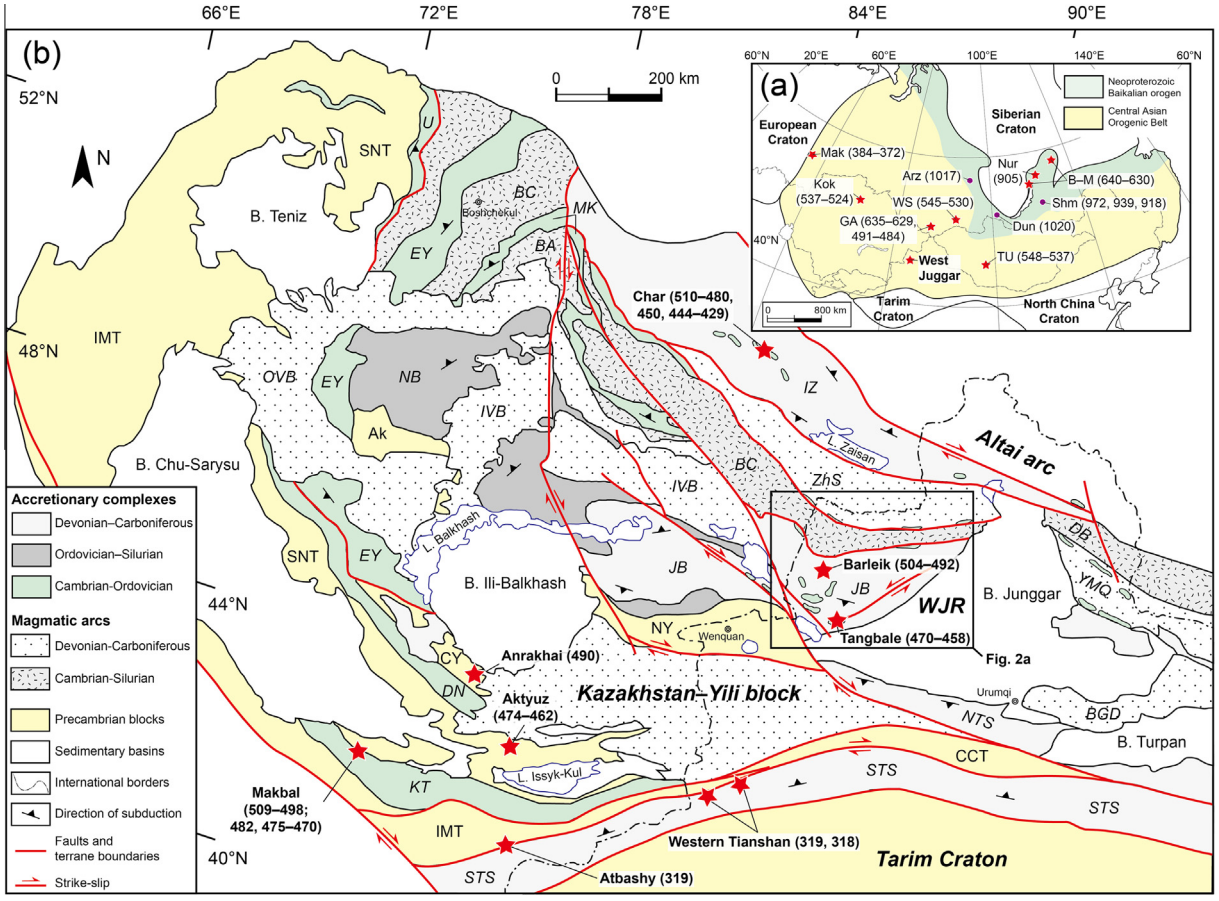

Fig. 1. (a) Simplified tectonic map of the CAOB (modified after Han et al., 2010b). Purple dot = SSZ-type ophiolite; Red star = subduction-related metamorphic complex; numbers (in Ma) are ages of the dated rocks. Data from: Dun = Dunzhugur (Khain et al., 2002); Arz = Arzybey (Turkina et al., 2004); Shm = Shaman (Nekrasov et al., 2007; Gordienko et al., 2009; Ruzhentsev et al., 2010); Nur = Nurundukan (Makrygina et al., 1993); B–M = Baikal–Muya (Kröner et al., 2015); GA = Gorny Altai (Buslov et al., 2002; Volkova et al., 2005; Ota et al., 2007); WS = West Sayan (Dobretsov and Buslov, 2004); TU = Tsakhir Uul (Štípská et al., 2010); Kok = Kokchetav (Schertl and Sobolev, 2013; Glorie et al., 2015); Mak = Maksyutov (Beane and Connelly, 2000). (b) Tectonic map of the southern CAOB with the approximate location of Fig. 2a (modified after Windley et al., 2007; Han et al., 2010b; Wang et al., 2014). Data sources are listed in Table 5. Microcontinents with Precambrian basement: SNT = Stepnyak-North Tian Shan; IMT = Ishim-Middle Tian Shan; Ak = Aktau; CY = Chu–Yili; NY = North Yili; CCT = Chinese Central Tian Shan. Accretionary complex and suture zone: U = Urumbai; EY = Erementau–Yili; DN = Dzhalair–Naiman; KT = Kirgiz–Terskey; MK = Maikain–Kyzyltas; IZ = Irtysh–Zaisan; NB = North Balkhash; JB = West Junggar–Balkhash; NTS = North Tian Shan; STS = South Tian Shan. Magmatic arc: OVB = outer volcanic belt; IVB = inter volcanic belt; ZhS = Zharma–Saur; BC = Boshchekul–Chingiz; DB = Dulate–Baytag; YMQ = Yemaquan; BGD = Bogda.

ophiolites from the same unit were dated at 972 and 939 Ma, respectively (Fig. 1a; Nekrasov et al., 2007; Gordienko et al., 2009). In addition, the zircons from the granulite and charnockite of Nurundukan ophiolite yielded a Pb–Pb age of 905 ± 30 Ma (Fig. 1a; Makrygina et al., 1993).

In contrast, the oldest SSZ-type ophiolites (zircons U–Pb ages of 521–513 Ma, Kröner et al., 2007, 2012; Ryazantsev et al., 2009), arc plutons (zircons U–Pb ages of 534–509 Ma, Kröner et al., 2007; Konopelko et al., 2008, 2012; Alexeiev et al., 2011), and ocean island basalt (OIB)- and MORB-derived eclogites/garnet pyroxenites (Fig. 1b; Makbal and Anrakhai: zircons U–Pb and K–Ar ages of 509–490 Ma, Tagiri et al., 2010; Alexeiev et al., 2011; Konopelko et al., 2012; Meyer et al., 2013) in the Kazakhstan and Kyrgyzstan Northern Tianshan were interpreted to have formed during the earliest stage of subduction of the southern PAO (Alexeiev et al., 2011; Konopelko et al., 2012; Kröner et al., 2012; Meyer et al., 2013). Recently, the Cambrian SSZ-type ophiolites (531–512 Ma) and intra-oceanic arc plutons (515–485 Ma) have been also identified in the southern West Junggar region (WJR), northwestern China, as evidence for subduction initiation in the Early Cambrian (Fig. 1b; Xu et al., 2012a, 2013; Ren et al., 2014). However, it is uncertain whether the oceanic-type metamorphic rocks, coeval with those of the Makbal and Anrakhai (Fig. 1b), are also present in the southern WJR. Up to date, the Tangbale blueschist is the oldest known metamorphic complex in the southern WJR (Fig. 1b; glaucophane and crossite $^{40}Ar/^{39}Ar$ ages of 470–458 Ma, Zhang, 1997). North of the Tangbale metamorphic complex is another newly-identified Barleik metamorphic complex (Fig. 1b; Zhao et al., 2012), but little is known about its origin, protolith and metamorphic age, and geological implications. In this paper, we present the first geochemical and geochronological data from blueschists and associated amphibolites of the Barleik Mountains, with an attempt to place constraints on their protoliths and timing of metamorphism and to provide insights into the initial subduction process in the southern PAO.

2. Regional geology

The WJR, an important component of the southern CAOB, is located between the Altai arc to the north and the Kazakhstan–Yili block to the south (Fig. 1b) and has recorded accretionary processes associated with the Paleozoic consumption of the southern PAO (e.g., Coleman, 1989; Feng et al., 1989; Wang et al., 2003; Buckman and Aitchison, 2004; Xiao et al., 2008; Xu et al., 2012a, 2013; Ren et al., 2014; Li et al., 2016). Unlike the Kazakhstan–Yili