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Early Paleozoic magmatic record from the northern margin of the Tarim Craton: Further insights on the evolution of the Central Asian Orogenic Belt

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ABSTRACT

The Southern Tianshan Orogenic Belt (STOB) is an important region to understand the prolonged evolution of the Central Asian Orogenic Belt (CAOB). A comprehensive study of zircon U–Pb ages and Lu–Hf isotopes, whole-rock elements and Sr–Nd isotopes was carried out for two intermediate-mafic intrusions in the Baicheng and Heiyingshan areas of Southwest Tianshan. LA–ICP-MS zircon U–Pb dating yielded crystallization ages of 431 ± 3 Ma (MSWD = 0.073, n = 31) and 430 ± 3 Ma (MSWD = 0.104, n = 30) for the Baicheng diorites, and 423.9 ± 2.1 Ma (MSWD = 0.5, n = 12) for the Heiyingshan gabbros. These data, in combination with other Late Silurian ages previously reported for the intrusive suites from the STOB, indicate an Early Paleozoic magmatic event in the region. In-situ zircon Hf isotope data on two samples from the Baicheng diorites show $\varepsilon_{Hf}(t)$ values of −2.4 to 4.9 and 0.2 to 6, and the Heiyingshan gabbros exhibit similar $\varepsilon_{Hf}(t)$ values from −1 to 1.8. The dioritic pluton exhibits Na-rich, arc-type geochemical and calc-alkaline affinity, and shows trace element patterns characterized by enrichment in large ion lithophile elements (Rb, Ba, K and Sr) and depletion in high strength field elements (Nb, Ta, Ti, Zr and Hf). These features resemble those of arc-type igneous rocks. Combined with initial $^{87}Sr/^{86}Sr$ ratios of 0.7047 to 0.7064 and $\varepsilon_{Nd}(t)$ of −1.6 to −5.06, we infer that the magma from which the Baicheng dioritic pluton formed was sourced from a mantle wedge which was subjected to metasomatism by fluids and melts related to subducted oceanic slab and the overlying sediments. The Heiyingshan gabbro shows a Na-rich nature and tholeiitic affinity. They not only display supra-subduction zone affinity, but also are geochemically similar to E-MORB, possible implying a back-arc basin setting. The initial $^{87}Sr/^{86}Sr$ ratios of the Heiyingshan samples range from 0.7046 to 0.7051 and $\varepsilon_{Nd}(t)$ values vary from 1.76 to 5.19. We speculate that the upwelling of the asthenospheric mantle to the supra-subduction wedge, facilitated by subduction roll-back, provided the source for the Heiyingshan gabbroic rocks. Together with other geologic evidence, we correlate the generation of the Baicheng diorite with the southward subduction of the South-Tianshan Ocean during the Early Paleozoic. The Heiyingshan gabbroic plutons were probably formed in a back-arc basin in response to the southward subduction of the Paleo-Tianshan Ocean. In combination with coeval arc-type magmatic rocks widely exposed in the southern margin of the Central Tianshan Block, a double-sided subduction model is proposed to explain the evolution of the South-Tianshan Ocean in the Silurian.

1. Introduction

The Central Asian Orogenic Belt (CAOB) (Fig. 1a), one of the largest Phanerozoic accretionary orogens in the world, is bounded by the Siberian Craton in the north and by the Tarim and North China (Sino-Korean) Cratons in the south (Jahn et al., 2000a,b; Kovalenko et al., 2004; Kröner et al., 2007; Charvet et al., 2011; Rojas-Agramonte et al., 2011; Safonova et al., 2011; Yarmolyuk et al., 2012; Xiao et al., 2013; Kröner et al., 2014; Xiao and Santosh, 2014). This huge orogenic belt developed by multiple accretionary and collisional events during the closure of the Paleo-Asian Ocean (PAO), located between the Russian, Siberian, Tarim and Sino-Korean continents (Dobretsov et al., 1995; Windley et al., 2007; Xiao et al., 2010). The CAOB is well-known for the large-scale Phanerozoic continental growth by the addition of juvenile materials from the mantle (Jahn, 2004; Kovalenko et al., 2004; Yarmolyuk et al., 2012; Safonova and Santosh, 2014).

The Tianshan (or Tien Shan) Mountains extend over a distance of 3000 km from northwestern China to Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan. The Paleozoic tectonic evolution of Tianshan has been correlated to the subduction and accretionary orogeny during the closure of several intervening ancient oceanic basins located between the Junggar Block, Balkhash–Yili Block (BYB), Central Tianshan Block (CTB) and Tarim Craton (Dobretsov et al., 1995; Gao et al., 1998;

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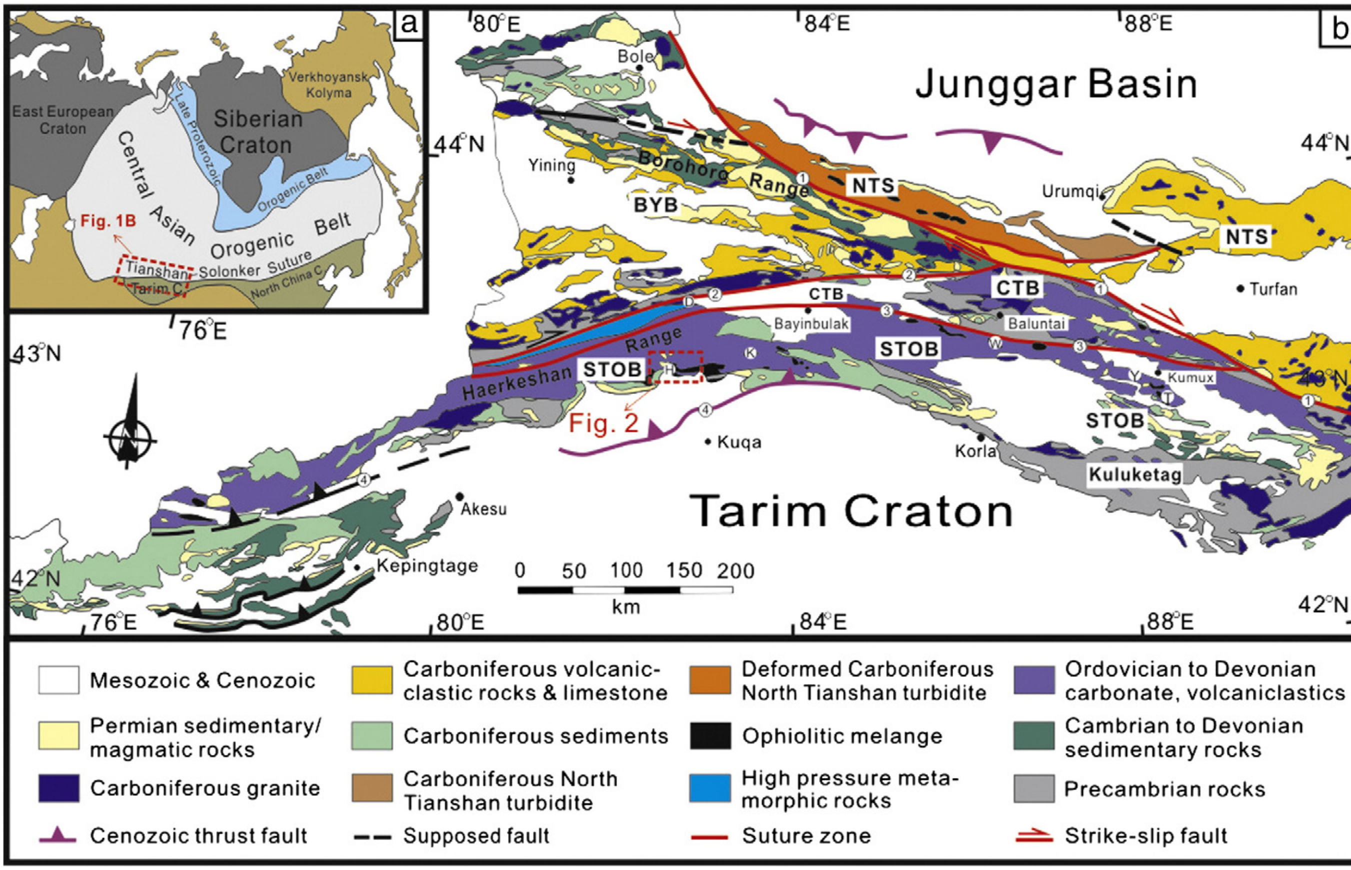

Fig. 1. (a) Sketch map showing the location of the CAOB and other orogenic collages in Asia (modified from Sengör et al., 1993). (b) Geological map of the Chinese western Tianshan Belt (modified from XBGMR, Xinjiang Bureau of Geology and Mineral Resources, 1993). Numbers in circles refer to the faults: 1) North Tianshan Suture–Main Tianshan Shear Zone; 2) Nikolaev Line–North Narati Suture; 3) Southern Central Tianshan Suture; and 4) North Tarim Trust. Letters refer to the name of ophiolite mélanges cited in the text: D—Dalubayi; H—Heiyingshan; K—Kulehu; T—Tonghuashan; W—Wuwamen; Y—Yushugou.

Dobretsov et al., 2003; Xiao et al., 2004; Li, 2006; Safonova, 2009; Wang et al., 2010; Charvet et al., 2011; Gao et al., 2011; Xu et al., 2013). Based on the spatial and temporal distribution of ophiolite mélanges, HP–UHP metamorphic belts and arc magmatic units, many geologists believe that there are at least three ancient oceanic basins which were involved in the evolution of the Tianshan Orogen during the Paleozoic, from north to south, including: 1) the North-Tianshan Ocean (also termed as Junggar Ocean) between the BYB and Junggar Block, 2) the Paleo-Tianshan Ocean (PTO) (also named as Terskey Ocean) between the BYB and the CTB, and 3) the South-Tianshan Ocean (STO) between the CTB and the Tarim Craton (Charvet et al., 2007; Xiao et al., 2009; Wang et al., 2010; Gao et al., 2011; Wang et al., 2011). All of these oceans belonged to the southwestern part of the Paleo-Asian Ocean and the South-Tianshan Ocean occupied the southernmost part. Besides, since the Tarim Block is considered to be the last terrane to dock on the CAOB following the final closure of the South-Tianshan Ocean, the formation of the South Tianshan Orogenic Belt may mark the termination of the prolonged Paleozoic Central Asian accretionary orogenesis (Xiao et al., 2010, 2013 and references therein).

In spite of the several investigations on the geology of this region, some fundamental aspects regarding the evolution of the South-Tianshan Ocean are still in dispute. For instance, the subduction polarity of the Paleo-Tianshan Ocean and South-Tianshan Ocean is one of the most debated issues. Some workers, largely based on the high pressure–ultrahigh pressure (HP–UHP) metamorphic rocks along the northern margin of the South Tianshan accretionary complex, proposed that the South Tianshan Orogenic Belt was formed by the northward subduction and collision of the Tarim plate beneath the CTB during the closure of the South-Tianshan Ocean (Gao et al., 1998; Li and Zhang, 2004; Zhang et al., 2007; Xiao et al., 2009; Seltmann et al., 2011). This model suggests that the northern Tarim Craton was a long-lived passive continental margin during the Silurian to Late Carboniferous. The other model supported by the north-verging ductile deformation in the accretionary complexes (Charvet et al., 2007; Lin et al., 2009; Wang et al., 2011) proposes that during the Early Paleozoic, the southward subduction of the Paleo-Tianshan Ocean under the Tarim Craton led to the detachment of the Central Tianshan Block, triggered by the back-arc extension, with the simultaneous opening of the South-Tianshan Ocean which subsequently subducted southward beneath the Tarim Craton during the Late Paleozoic (Wang et al., 2011; Ge et al., 2012). This model argues that the northern Tarim Craton was an active continental margin with considerable tectonic accretion as well as crustal growth through the addition of mantle-derived magmas. In addition to the aforementioned models characterized by single-direction subduction, a bilateral subduction model for the subduction process of the Paleo-Tianshan Ocean has also been recently proposed by Ge et al. (2012).

If the tectonic model on oceanic subduction for the south Tianshan is valid, this should manifest in prominent arc magmatism along the active continental margin. Therefore, the distribution of continental arc-type rocks is the key to constrain the evolution of the South-Tianshan Ocean. However, previous studies mainly focused on the arc-type rocks in the Central Tianshan Block, with little attention on the northern margin of the Tarim Craton (geologically represented by the southern Chinese part of the South Tianshan Orogenic Belt (STOB), see below). Our recent field studies led to the identification of two