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A Cambrian intra-oceanic subduction system in the Bozshakol area, Kazakhstan

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ABSTRACT

The Bozshakol area is one of the most important copper resource concentrations in Central Kazakhstan. We report in situ zircon U–Pb age and Hf isotope data, whole rock geochemical and Sr–Nd isotopic data for the volcanics and intrusions from the Bozshakol area.

Secondary ion mass spectrometry (SIMS) zircon U–Pb dating indicates that the volcanics erupted at 501.8 ± 3.2 Ma and the intrusions emplaced at 489.5 ± 3.3 Ma. The volcanics are subdivided into two types. Type I are tholeiitic to calc-alkaline basalt and calc-alkaline andesite and dacite, which are enriched in light rare earth elements (LREE) with a marked negative Nb anomaly and Th/Yb-enrichment. They also have low initial $^{87}Sr/^{86}Sr$ ratios (0.7026–0.7048), high zircon εHf(t) and whole-rock εNd(t) values (+9.7 to +17.0 and +5.4 to +6.7, respectively). Type II are Nb-enriched basalts (NEBs, Nb = 6–7 ppm), which are sodium-rich (Na_2O/K_2O = 3–10) and differ from the vast majority of arc basalts in their higher Nb, Zr, and TiO_2 contents and Nb/U ratio. NEBs also have low whole-rock initial $^{87}Sr/^{86}Sr$ ratios (0.7040) and high εNd(t) values (+5.6). Therefore Bozshakol volcanics were formed by partial melting of the mantle wedge and subducted slab.

The Bozshakol ore-bearing intrusive rocks include the fine- and medium-grained tonalite porphyry. They belong to the medium-K calc-alkaline series and are strongly enriched in LREE with a marked negative Nb anomaly and Th/Yb-enrichment. The fine-grained tonalite porphyries exhibit element characteristics similar to normal arc granitoids. They have low initial $^{87}Sr/^{86}Sr$ ratios (0.7036–0.7039), high zircon εHf(t) values (+10.7 to +17.2) and whole-rock εNd(t) values (+4.9 to +5.7). Compared with the fine-grained tonalite porphyries, the medium-grained tonalite porphyries have high Al_2O_3 and Sr contents (16–17 wt.% and 565–569 ppm, respectively) and low Yb and Y concentrations (0.9–1.1 ppm and 9.3–12.1 ppm, respectively), showing a geochemical affinity to adakites. Therefore, Bozshakol intrusive rocks were also derived from the mantle wedge and minor slab melts. We propose a model of intra-oceanic subduction for the Middle to Late Cambrian magmatic evolution of magmatic arcs in northwestern central Kazakhstan.

1. Introduction

The Central Asian Orogenic Belt (CAOB) is one of the largest accretionary orogens on Earth (Jahn et al., 2000; Şengör et al., 1993; Windley et al., 2007; Xiao et al., 2009). The Bozshakol (also known as Boshekul or Boshchekul) area in central Kazakhstan is located in the western part of the CAOB (Fig. 1). Its area is characterized by widespread early Paleozoic volcanic and intrusive rocks, many of which host copper and gold mineralization (Chen et al., 2014; Degtyarev and Ryazantsev, 2007; Kudryavtsev, 1996; Yakubchuk et al., 2012). The Bozshakol deposit contains 4.1 Mt of copper at an average grade of 0.31% and 100 t of gold at an average grade of 0.08 g/t (Yakubchuk et al., 2012). The mineralization occurs in the early Paleozoic tonalite porphyry dikes and adjacent volcanic rocks of the Bozshakol Group (Kudryavtsev, 1996).

The geology, geochemistry and geochronology of the early Paleozoic igneous rocks in the Bozshakol area have been studied by Khromykh (1986), Kudryavtsev (1996), and Degtyarev and Ryazantsev (2007). However, the data on the age of ore-bearing intrusive rocks remain insufficient and controversial (Degtyarev and Ryazantsev, 2007). In the opinion of Kudryavtsev (1996), the mineralized rocks are overlain by the Upper Cambrian–Lower Ordovician sedimentary units; however, Khromykh (1986) reported 568 ± 60 Ma Re–Os data for molybdenite from plagiogranite of the Bozshakol deposit. Kolesnikov et al. (1986) quoted 530 ± 15 and 457 Ma ages based on lead isotope data for galena, which are unlikely to be reliable (Yakubchuk et al., 2012). Kudryavtsev (1996) published widely cited 481 ± 23 Ma Rb–Sr dates for the tonalites

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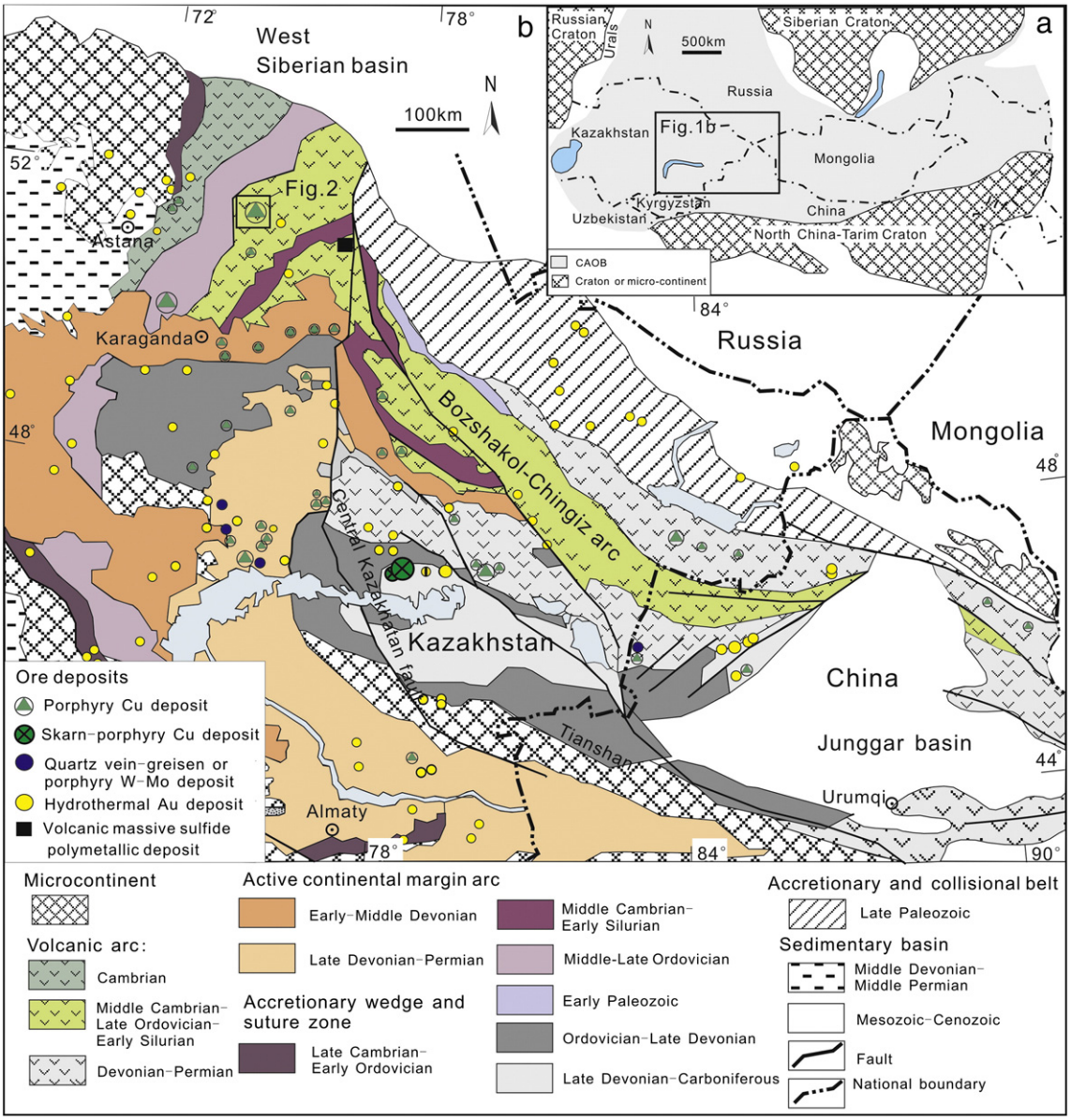

Fig. 1. (a) Central Kazakhstan in the Central Asia Orogenic Belt. (b) Simplified geotectonic map of Kazakhstan and contiguous China (modified after Abdulin et al., 1996; Windley et al., 2007).

from the Bozshakol deposit. In addition, the volcanic rocks of the Bozshakol Group near the deposit were mapped as products of the Early–Middle Cambrian volcanism (Degtyarev and Ryazantsev, 2007; Kudryavtsev, 1996) but the age of volcanic rocks has not yet been constrained. Previous researchers suggested that the igneous rocks in the Bozshakol area occurred in oceanic island arc (Degtyarev and Ryazantsev, 2007; Kröner et al., 2014; Windley et al., 2007; Yakubchuk et al., 2012) supported by a small number of geochemical data (Kröner et al., 2014).

In this study, we report combined in situ zircon U–Pb age and Hf isotope data, whole rock geochemical and Sr–Nd isotopic data for the volcanic and intrusive rocks in the Bozshakol area. These data are used to document the formation age and petrogenesis of the igneous rocks and to constrain their tectonic setting.

2. Geological outline

The Kazakh Uplands comprise a collage of Precambrian microcontinental fragments and Early Palaeozoic island arcs. Microcontinents are characterized by Palaeo- to Midproterozoic basement and Neoproterozoic to Early Palaeozoic cover (Degtyarev and Ryazantsev, 2007; Windley et al., 2007; Yakubchuk et al., 2012). Several generations of island arcs range in age from Cambrian to Early Silurian. The Bozshakol–Chingiz arc (part of the Kipchak arc of Şengör et al., 1993) hosts the Bozshakol porphyry copper deposit (Fig. 1).The volcanic formations are widespread in the Bozshakol area and occurred during the Early Cambrian to Early Ordovician (Figs. 2 and 3; Degtyarev and Ryazantsev, 2007). The Lower Cambrian Koksor Group, the stratigraphically lowest in the Bozshakol area, consists of mafic and felsic volcanic rocks. The Lower to Middle Cambrian Bozshakol Group contains basic and intermediate lavas and tuffs. The Middle Cambrian Qyzylqoyandy Group is a basalt unit. The Upper Cambrian to Lower Ordovician Ayaksor and Olenty Groups include diverse volcanic rocks. Lower to Middle Ordovician chert and cherty tuffite rocks of the Erzhan Formation occur in the north of the Bozshakol area; and the Lower to Middle Ordovician alkaline intermediate to felsic volcanics of the Ashchikol Group occur in the south of the Bozshakol area. All rocks were metamorphosed in amphibolite facies and were overlapped by the Middle Ordovician olistostrome. The Middle Ordovician flysch of