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Geochemistry and petrogenesis of suprasubduction volcanic complexes of the Char shear zone, eastern Kazakhstan[1]

E.V. Kurganskaya, I.Yu. Safonova *, V.A. Simonov

V.S. Sobolev Institute of Geology and Mineralogy, Siberian Branch of the Russian Academy of Sciences, pr. Akademika Koptyuga 3, Novosibirsk, 630090, Russia

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Abstract

The paper presents new petrographic, geochemical, and petrologic data from volcanic rocks of suprasubduction origin of the Char shear zone in eastern Kazakhstan. We discuss bulk rock composition (concentrations of major and trace elements), types of mantle sources and parameters of their melting, conditions of crystallization of mafic magma, and geodynamic settings of basalt eruption. According to the major element composition, the volcanic rocks are basalt, andesibasalt, and andesite of tholeiitic and transitional, from tholeiitic to calc-alkaline, series. They are characterized by low TiO_2 (0.85 wt.% on average) and crystallization trends in MgO–major elements plots. In terms of trace element composition, the volcanic rocks possess moderately LREE-enriched rare-earth element patterns and are characterized by negative Nb anomalies present on the multi-element spectra (Nb/La_{pm} = 0.14–0.47; Nb/Th_{pm} = 0.7–1.6). The distribution of rare-earth elements (La/Sm_n = 0.8–2.3, Gd/Yb_n = 0.7–1.9) and the results of geochemical modeling in the Nb–Yb system suggest high degrees of melting of a depleted mantle source at spinel facies depths. Fractional crystallization of clinopyroxene, plagioclase, and opaque minerals also affected the final composition of the volcanic rocks. Clinopyroxene monomineral thermometry calculations suggest that the melts crystallized within a range of 1020–1180 °C. We think that this volcanic complex formed at a western active margin of the Paleo-Asian Ocean.
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Keywords: Central Asian Orogenic Belt; Paleo-Asian Ocean; Vendian–Cambrian subduction; melting conditions; fractional crystallization; mantle sources

Introduction

The Char suture-shear zone, formerly referred to as Char ophiolite belt or Char shear zone, is located in eastern Kazakhstan. In the 1960–1980-ties, the Char (also known as Chara or Charsk) ophiolite belt was studied mainly for regional geology, stratigraphy, and tectonics (Belyaev, 1985; Ermolov et al., 1981; Polyanskii et al., 1979). New data on the tectonics of the Char belt, biostratigraphy of its hosted oceanic sedimentary rocks, petrology and geochemistry of magmatic and metamorphic rocks have been obtained during the last 20 years (Buslov et al., 2001, 2003; Iwata et al., 1997; Safonova et al., 2004a, 2012a,b; Sennikov et al., 2003; Simonov et al., 2010; Volkova et al., 2008). M.M. Buslov and co-authors (2001, 2003) were the first to apply terrane analysis to this region; they identified an accretionary complex there, which probably formed at an active margin of the Kazakhstan composite continent, and suggested to consider this area as a shear zone (Buslov et al., 2001, 2003; Dobretsov and Buslov, 2007).

The Char shear zone (SZ) is in the western Central Asian Orogenic Belt, CAOB (Figs. 1, 2), which is the world largest Phanerozoic accretionary orogen (e.g., Berzin et al., 1994; Kröner et al., 2013; Safonova et al., 2011b; Sengör et al., 1993; Windley et al., 2007; Zonenshain et al., 1990). Numerous accretionary complexes and foldbelts of the CAOB host compositionally and lithologically variable volcanic units, which study is of primary importance for reconstructing the formation of orogenic belts after closure of paleo-oceans. Most of those volcanic units formed in oceanic and convergent margin settings. The oceanic volcanic rocks keep information about evolution of paleo-oceans, whereas the latter record settings of volcanic eruptions in intra-oceanic primitive and normal island arcs and continental margin magmatic arcs. The major and trace element composition of volcanic rocks, in particular, basalts, andesibasalts and andesites, is a key point for discriminating geodynamic settings of their formation.

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* Corresponding author.
E-mail address: inna@igm.nsc.ru (I.Yu. Safonova)

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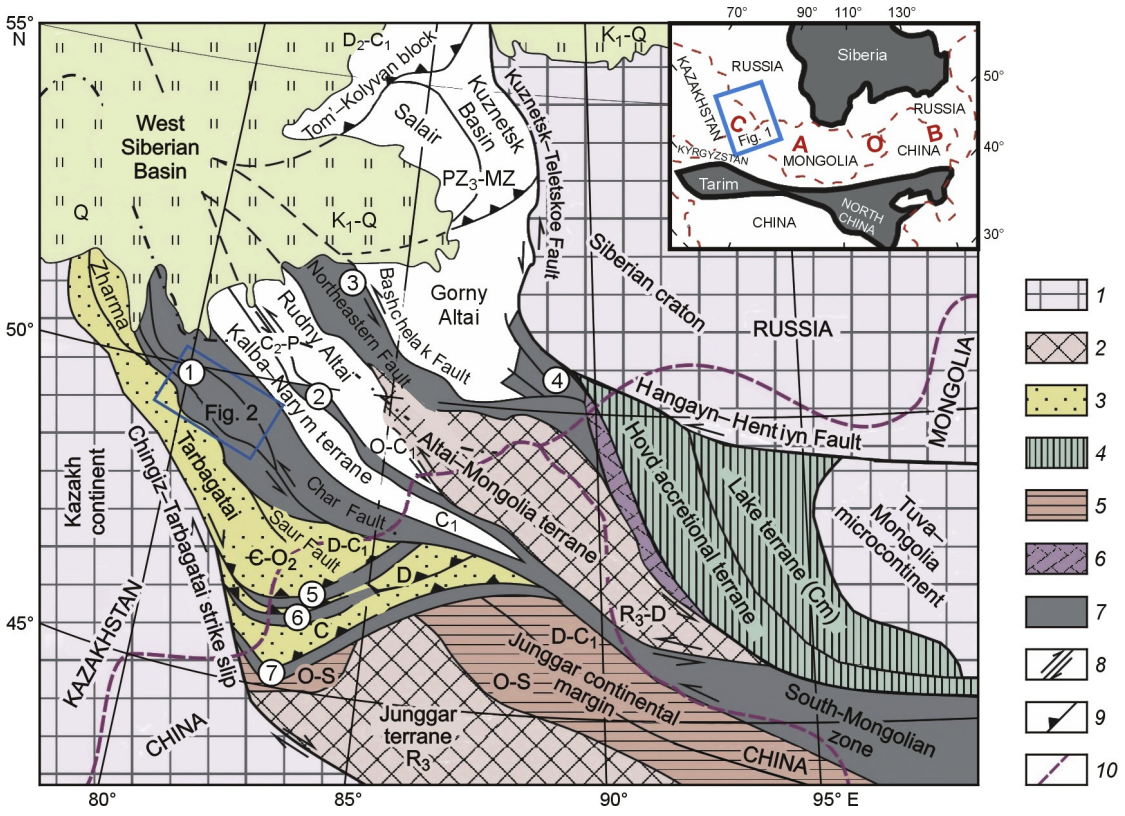

Fig. 1. Tectonic scheme of the western Altai–Sayan folded area (modified from Buslov et al., 2003), which is located in the western Central Asian Orogenic Belt (CAOB, see index map). *1*, cratonic blocks; *2*, terranes of disputable origin: Gondwana-derived vs. active margin; *3*, terranes of Kazakhstan affinity; *4*, West Mongolian terranes of different origin; *5*, continental margin units; *6*, Late Paleozoic sedimentary units; *7*, suture-shear zones reactivated in C_2–P_1; *8*, strike-slip faults; *9*, thrusts; *10*, state boundary. The numbers in circles show strike-slip zones reactivated during the Late Paleozoic: 1, Char; 2, Irtysh; 3, Charysh–Terekta; 4, Kurai; 5, Barlyk; 6, Maile; 7, Dalabute.

Study of the Char zone is very important for tracing the geodynamic evolution of folded structures occupying vast territories of eastern Kazakhstan, southern Siberia (Russia), northwestern China and western Mongolia. According to earlier conceptions, the Char zone formed as a result of evolution and closure of a paleo-ocean (Belyaev, 1985; Ermolov et al., 1981; Kovalev and Karyakin, 1975; Polyanskii et al., 1979). The subsequent evolution of the paleo-oceanic units was accompanied by the formation of magmatic arcs at convergent margins (Ermolov et al., 1981; Kovalev and Karyakin, 1975; Polyanskii et al., 1979; Rudnev et al., 2012, 2013), formation of subduction–accretion and collisional complexes and strike-slip faulting (Buslov et al., 2001, 2003; Metelkin, 2013). Thus, the Char SZ has a complicated structure and variable composition and includes terranes of diverse origin dominated by volcanogenic-sedimentary, magmatic and metamorphic units (Buslov et al., 2001, 2003; Dobretsov, 2003) (Fig. 2).

Previous researchers of the Char SZ have identified both oceanic allochthonous units (e.g., Buslov et al., 2001; Ermolov et al., 1981; Polyanskii et al., 1979) and autochthonous volcanogenic units (Belyaev, 1985) and have studied the chemical composition of basalts associated with oceanic sedimentary rocks (chert, carbonate) and recognized rock assemblages formed in mid-oceanic ridge and oceanic island/plateau settings (Safonova et al., 2004a, 2012a). Volcanic rocks of andesite-basaltic series (suprasubduction?) were mentioned in several publications (e.g., Belyaev, 1985; Kovalev and Karyakin, 1975; Polyanskii et al., 1979), but no their detailed studies, in particular, geochemical, have been ever done. The first limited data on the petrogenesis of suprasubduction (island-arc?) volcanic rocks were obtained from on the composition of clinopyroxene phenocrysts and their hosted melt inclusions and reported in Simonov et al. (2010). This paper presents first detailed geological, petrographic, major and trace element data from the Char SZ volcanic rocks of possibly suprasubduciton origin (Table 1) in order to determine conditions of their petrogenesis and geodynamic settings of their formation.

Geological outline of the Char Shear zone

The present-day geological structure of eastern Kazakhstan formed during late stages of Paleo-Asian Ocean closure in Late Carboniferous-Permian time (e.g., Buslov et al., 2001; Dobretsov et al., 1995, 2003; Safonova et al., 2004a). The Char SZ is extended over several hundred kilometers from northwest to southeast over the whole East Kazakhstan (Figs. 1, 2) and represents an axis of the Zaisan folded domain (Dobretsov and Ponomareva, 1969; Kovalev and Karyakin, 1975). It is bounded by the Zharma-Saur island-arc domain

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