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Alkaline magmatism of the Vitim province, West Transbaikalia, Russia: Age, mineralogical, geochemical and isotope (O, C, D, Sr and Nd) data

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ABSTRACT

In this paper, we study the geochronology, mineral chemistry, and whole-rock elemental, stable (O, C, D) and Sr-Nd isotopic data for alkaline ultrabasic–basic massifs of the Vitim alkaline province (Sayzhenski complex) in the Central Asian Orogenic Belt, near the boundary with the Siberian craton, to evaluate their petrogenesis and geodynamic significance. U-Pb zircon dating results in Early Paleozoic (520–486 Ma) and Late Paleozoic (306–294 Ma) stages of alkaline rock formation. The mineralogy and geochemistry exhibit a wide range of SiO_2 (38–73 wt.%), enrichment in Sr, Ba, LREE and Ta and, most significantly, in Na and Al. The rocks crystallized from a parental CO_2- and H_2O-rich silica-undersaturated melt. Isotopically, the rocks are highly variable, with $(^{87}Sr/^{86}Sr)i$ – 0.705595–0.707729 and $(^{143}Nd/^{144}Nd)i$ – 0.512237–0.512643. The geochemical and isotope data suggest that the rocks were derived from a source composed of three distinct components: PREMA, EM II and marine carbonate. Additionally, stable (O, C, D) isotope data display the shifting influence of assimilated organic sediments in the source of melts and a partial secondary isotope exchange between the late-magmatic fluids and minerals.

1. Introduction

The Vitim alkaline province (Sayzhenski complex) is located in western Transbakalia (Vitim plateau) within the Central Asian Orogenic Belt (Fig. 1), near its boundary with the Siberian craton. This fold belt is a collage of terranes (e.g., Precambrian microcontinents, fragments of oceanic crust and island arcs) that were accreted onto the craton in the Neoproterozoic and Early to Late Palaeozoic (e.g., Logachev and Zorin, 1992). The province is 50 km wide and over 450 km long and consists of more than twenty massifs of alkaline ultrabasic–basic rocks. The massifs display a broad array of rocks, including pyroxenite, members of the ijolite-urtite series, nepheline syenites and alkaline syenites. The massifs are economically significant as a source of Al, and they offer important insight into deciphering the composition of the mantle, regional tectonic settings and geodynamic reconstruction. In recent years, the alkaline ultrabasic–basic massifs have been genetically attributed to mantle hot spots (Kuzmin et al., 2010; Yarmolyuk and Kovalenko, 2003; Yarmolyuk et al., 2000, 2003).

Until now, there have been no precise geochronological and geochemical investigations of the Vitim alkaline province. In this study, we present here new geochronological, petrological and mineralogical information and the first geochemical (major and trace-element) and isotope (O, C, D Sr and Nd) data on the main rock types to describe the ages of emplacement, magmatic processes and characteristics of the mantle sources.

2. Geological background

The Vitim plateau is composed predominantly of Late Paleozoic granitoids of the Angara-Vitim batholith (Tsygankov et al., 2007) with Neoproterozoic (?) xenoliths of limestones. All the rocks are partly covered by Cenozoic basalts (Johnson et al., 2005). The massifs of the Vitim alkaline province have been extensively reviewed by Andreev et al. (1969), Konev (1982), and Sharakshinov (1984). The massifs are multiphase intrusions with circular, elliptical exposures or sheet-like bodies that contain pyroxenites, ijolite-urtites, nepheline syenites and alkaline syenites. The distribution and association of the rock types of the various complexes are shown in Table 1.

The massifs, composed of ultrabasic rocks and silica-undersaturated feldspathoidal rocks, are Gulkhen, Innolokta, Nizhne-Burulzayski and Sayzhenski. Pyroxenites are the early-formed rocks. They are composed of pyroxene and amphibole, with apatite and pyrrhotite as accessory phases. The rocks are medium-grained, massive (granular?) or with trachytoid texture. The ijolite-urtite series forms lenses and vein-like bodies in the pyroxenites and, in some cases, entire massifs, as at Mukhalski. Those rocks are fine- and medium-grained with banded and trachytoid textures. They are composed of nepheline, pyroxene and amphibole, with accessory garnet, apatite, pyrrhotite, magnetite, zircon and minor titanite, biotite, cancrinite and calcite; the proportions of the major minerals vary widely. Calcite fills the interstices and also

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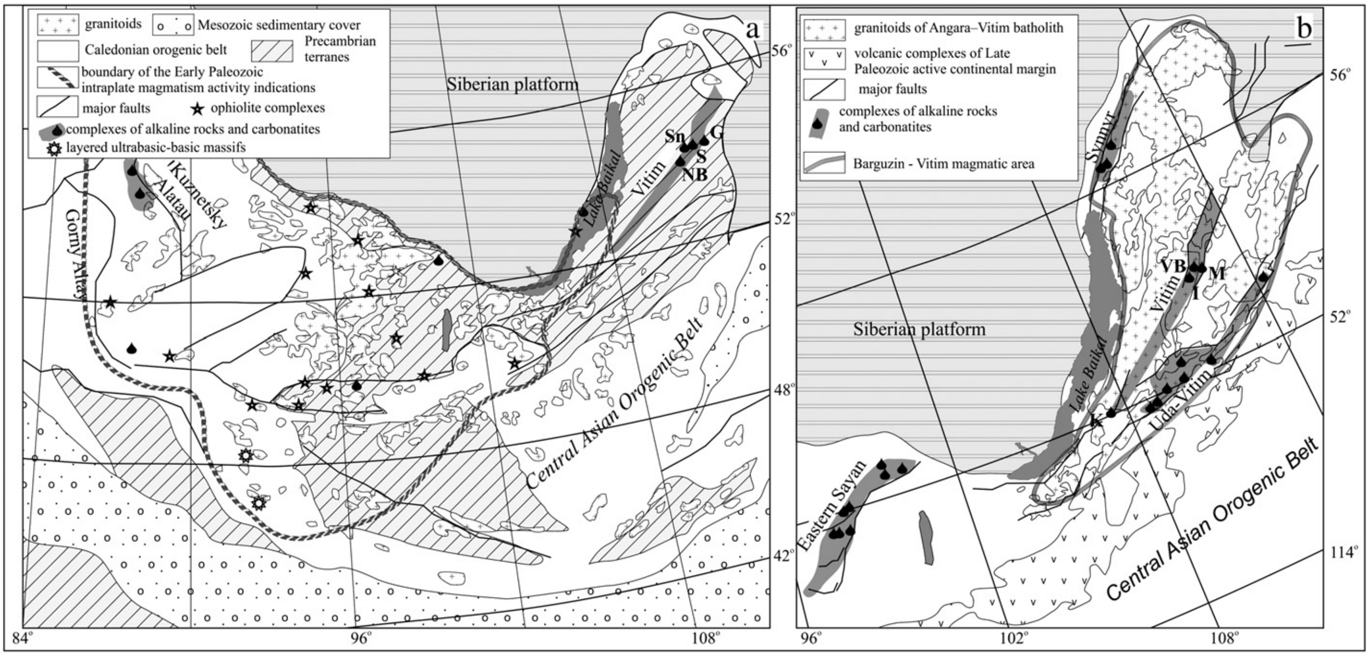

Fig. 1. (a) Location of the Early Paleozoic alkaline massifs of the Vitim province (Sn – Snezhny, G – Gulkhen, S – Sayzhenski, NB – Nizhne-Burulzayski) and the Early Paleozoic magmatic areas in the Central Asian Orogenic Belt (after Kuzmin et al., 2010). (b) Location of the Late Paleozoic alkaline massifs of the Vitim province (I – Innolokta, M – Mukhalski, VB – Verkhne-Burulzayski, K – Koma) and the Late Paleozoic magmatic areas in the Barguzin-Vitim area (the Central Asian Orogenic Belt) (after Kuzmin et al., 2010).

occurs as drop-shaped inclusions in pyroxene, amphibole and nepheline, indicating that it is a primary igneous mineral in equilibrium with the major minerals Nepheline syenites and alkaline syenites represent a third phase and usually form dykes or stocks cutting the early phases. Some massifs, such as Koma, Altan, Zimov'echi, Sirikta and Sayzhekon, consist only of nepheline syenites and alkaline syenites with gradational contacts. Feldspar and nepheline dominate the mineral assemblage, which also contains pyroxene, biotite, amphibole, and cancrinite as minor minerals, and zircon, magnetite and titanite as accessory minerals. The massifs exhibit sharp contacts with the country rocks, which are predominantly limestones. Magnesian and calcic skarns developed along the contact between igneous and sedimentary rocks and consist mainly of diopside, forsterite and tremolite. In some cases, limestone has been modified to brucite marble along the contact, which, according to Konev (1982), attests to the high temperature of the magmas and the shallow depth of emplacement. Contacts between the massifs and granites are rare but sharp in all cases. Late granite dykes crosscut some massifs, such as Nizhne-Burulzayski and Sayzhenski. Postmagmatic processes leading to metasomatic albite, nepheline, cancrinite and garnet are intense and widespread in the massifs (Sharakshinov, 1984; Vrublevskaya, 1988, 1992).

3. Analytical methods

The whole-rock compositions were determined by atomic absorption (Perkin-Elmer) and conventional chemical methods. The amount of CO_2 was determined by titrametric chemical decomposition. We used an ICP-MS apparatus (Finnigan MAT, Bremen, Germany) to measure levels of the trace and REE elements under standard operating conditions (an open acid digestion using the HF, HNO_3 and $HClO_4$ mixture). The precision of analytical results, characterized by the relative standard deviation (RSD), was assessed based on the repeated analyses of samples. For various geological samples, the values of RSD ranged between 5 and 15% for the elements with concentration above detection limits. Poor precision was obtained for elements with low concentration. The investigations were carried out in Geological Institute SB RAS, Ulan-Ude, Russia and Tomsk State University, Tomsk, Russia. The minerals were analysed using electron-probe microanalysis (EPMA): a MAR-3 WDS microprobe with an accelerating voltage of 20 kV, a beam current of 40 nA, a beam size of 3 to 4 μm, a 20 s counting time and a LEO-1430 scanning electron microscope with an IncaEnergy-300 energy-dispersive system (SEM-EDS) operated at 20 kV and 0.5 nA. The mineral analyses were carried out in the laboratories of the Geological Institute SB RAS (Ulan-Ude, Russia). The $\delta^{13}C$, $\delta^{18}O$ and δD values were acquired in the isotope laboratory of the Analytical Center FESC RAS (Vladivostok, Russia) using a Finnigan MAT 252 sensitive mass spectrometer. The analytical errors for the $\delta^{18}O$ determination were $\pm 0.05‰$ or less for carbonates and $\pm 0.3‰$ for silicates and oxides. The analytical errors for the $\delta^{13}C$ determination were $\pm 0.1‰$ for carbonates. The isotopic composition of Nd and Sr was measured on a Triton multichannel mass spectrometer in a static regime at the Institute of Precambrian Geology and Geochronology RAS, St. Petersburg, Russia. The method of preparation for the Nd and Sr

Table 1
Rock-types occurring in massifs of Vitim alkaline province.

	G	I	NB	M	S	VB	A	Sn	K	Al	T	Z	Sr	Sa
Exposed area (km^2)	1.2	0.5	0.9	4.5	20	20	5	18	5	1	1.8	10	1.9	3
Pyroxenites	+	+	+		+									
Ijolite-urtite series	+	+	+	+	+	+	+	+			+			
Nepheline syenites	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Alkaline syenites					+	+	+	+	+	+	+	+	+	+

G – Gulkhen, I – Innolokta, NB – Nizhne-Burulzayski, M – Mukhalski, S – Sayzhenski, VB – Verkhne-Burulzayski, A – Amalat, Sn – Snezhny, K – Koma, Al – Altan, T – Tuchinski, Z – Zimov'echi, Sr – Sirikta, Sa – Sayzhekon.