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Pyroxenites and megacrysts from Vitim picrite-basalts (Russia): Polybaric fractionation of rising melts in the mantle?

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ABSTRACT

Picrite basalt tuffs and lavas from the Miocene basalt plateau of Vitim (Trans Baikal, Russia) contain abundant megacrysts and varied pyroxenite and mantle lherzolite xenoliths (spinel facies and upper part of the garnet-facies) and crustal cumulates. Black pyroxenites and megacrysts show decreasing temperatures from 1350 to 900 °C, and range from high-T dark green websterites and clinopyroxenites, to low-T black megacrystalline garnet clinopyroxenites and phlogopite–ilmenite-bearing varieties. Garnet-bearing Cr-diopside veins and zoned veins with mica and rare amphiboles cross-cut peridotite xenoliths. Veins consisting of almost pure amphibole are more common in spinel lherzolite xenoliths. *P–T* calculations for pyroxenites yield pressure intervals at 3.3–2.3, 2.2–2.0, 1.9–1.5 and 1.3–1.0 GPa, probably corresponding to the locations of dense magmatic vein networks in mantle.

Major and trace elements for clinopyroxenes from the black megacrystalline series can be modeled by fractional crystallization of a picrite-basalt melt. In contrast, green high-temperature pyroxenites and black giant-grained garnet pyroxenites with lower LREE-enrichment and variable LILE and HFSE concentrations probably result from AFC processes and mixing with partial melts derived from older pyroxenites and peridotites. Gray low-Cr garnet clinopyroxenites with highly fractionated and inflected trace element patterns may have been formed by remelting of metasomatic veins within peridotites. Multistage melting of metasomatic assemblages with selective removal of clinopyroxene in vein contacts produce the REE patterns with low MREE concentrations and usually with elevated HFSE contents. Cr-diopside veins were most probably formed by partial melting of phlogopite- and/or amphibole-bearing lherzolites. The trace element and Sr–Nd isotopic features of the megacrystalline pyroxenites suggest that they crystallized from magma volumes that evolved in separate systems during formation of pre-eruption vein networks and magma chambers, which together formed the feeding system for the host basalts.

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1. Introduction

Cognate relationships between suites of black pyroxenite (group II) xenoliths, megacrysts and their host basaltic lavas have been suggested by numerous authors (e.g., Beeson and Jackson, 1970; Wilshire and Shervais, 1975; Nixon and Boyd, 1979; Frey, 1980; Irving and Frey, 1984; Wilshire et al., 1980; Menzies et al., 1985; Liotard et al., 1988; Griffin et al., 1988; O'Reilly and Griffin, 1990; Liu et al., 1992; Righter and Carmichael, 1993; Dobosi and Jenner, 1999; Shaw and Eyzaguirre, 2000; Su et al., 2009, etc.), in part because of their geochemical features and similarity to experimental products (Knutson and Green, 1975; Edgar, 1987; Kogiso et al., 1998; Johnson, 1998; Yaxley, 2000). However, megacrysts tend to have less radiogenic $^{87}Sr/^{86}Sr$ ratios (e.g., Liotard et al., 1988; Akinin et al., 1997, 2005; Rankenburg et al., 2004, 2005) than their basaltic host rocks, which suggests that assimilation and fractional crystallization processes (AFC) (De Paolo, 1981; Neal and Davidson, 1989) or other types of interaction with mantle peridotite. Possible models of megacryst origin are: high pressure phenocryst crystallization; disintegration of high pressure coarse- and giant-grained pyroxenites (Irving, 1980) or growth in high pressure pegmatitic bodies (Rankenburg et al., 2005). Megacrystalline pyroxenites were probably formed during the ascent of the host magma to the surface (Lorand, 1989) and their crystallization may be a result of polybaric fractionation (Irving, 1984; Eggler and Mccallum, 1976; Neal, 1995) accompanied by AFC (Neal and Davidson, 1989).

Garnet peridotites and pyroxenite xenoliths and pyrope megacrysts are not frequent in alkali basalt (Beeson and Jackson,

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1970; Chapman, 1976; Kepezhinskas, 1979; Nixon and Boyd, 1979; Delaney et al., 1979; Kovalenko et al., 1987; Mukhopadyay and Manton, 1994; Ashchepkov et al., 1996; Stern et al., 1999; Upton et al., 2003; Bjerg et al., 2005). The picrite-basalt tuffs from Vitim (Russia) and closely located volcanic centers (Ashchepkov et al., 2003) contain a nearly complete set of megacrysts, peridotites and pyroxenites as described in the literature. Thus their genetic relations and position in the mantle section can be deduced.

Megacrystalline pyroxenites are considered to be the source of the megacrysts found in the Vitim picrite-basalts (Ashchepkov and Andre, 2002). In this study we have investigated the origin of pyroxenites and megacrysts using a large collection of xenolithic material from Vitim (Ashchepkov et al., 1989, 1994; Ashchepkov, 2002; Ashchepkov et al., 2003; Ionov et al., 1993). Mineral grains from >400 pyroxenite xenoliths were analyzed by electron microprobe; about 50 monomineralic separates were analyzed by solution ICP-MS for trace elements, and several clinopyroxene separates were analyzed by TIMS for Sr–Nd isotope compositions. Glasses and minerals from the host picrite-basalts were also studied by LA ICP-MS for comparison.

2. Location and geology

Miocene to Pliocene basaltic plateaus and fields cover a huge area of Central Asia, Mongolia and Trans Baikal (Kiselev, 1987; Kepezhinskas, 1979; Dobretsov and Ashchepkov, 1991; Ionov et al., 1992, 1995; Ionov and Hofmann, 2007; Ashchepkov et al., 2003; Johnson et al., 2005). The Vitim basalt plateau was formed mainly in Miocene times, and is the largest of the Cenozoic plateaus in Trans Baikal. It is located in the loop of the Vitim river (Fig. 1), 250 km east of Lake Baikal (Ashchepkov et al., 1989; Ashchepkov, 2002). Most of the Miocene volcanoes, the basal flows of the Vitim plateau, and the Plio-Pleistocene cinder cones and post-erosion lava flows, contain mantle and crustal xenoliths (Ashchepkov et al., 1989, 1994, 2003; Ionov et al., 1993, 2005a,b).

The pyroxenite xenoliths analyzed in this study were all collected from picrite-basalt tuffs excavated in a road quarry 1.5 km NE of the Vereya stream at the 75 km marker (N 53.742, E 113.336). The age of the tuffs is uncertain (13.5–18.5 Ma) due to the presence of abundant debris of crustal rocks, but they may be related to basalts and tuffs exposed nearby that were dated at 13–14 Ma (Ashchepkov et al., 1989, 2003). The tuffs contain mantle xenoliths up to 40 cm in diameter and abundant xenocrysts. The xenolith suite consists of garnet lherzolite (65%), spinel lherzolite (15%), black megacrysts and their giant-grained intergrowths (∼15%), green Cr-diopside websterites (5%), gray pyroxenites that are transitional between the black and green varieties, black fine-grained pyroxenites and lherzolites veined by pyroxenites (∼1–3%). The nearby (Fig. 1) Pliocene and Pleistocene volcanoes Kandidushka (N 53.834, E 113.357) and Yaksha (N 53.719, E 113.339), dykes at Bulykhta (N 53.725, E 113.258) and associated lava flows (N53.771, E 113.249) along the Dzhilinda river also contain mantle xenoliths (Ashchepkov et al., 2003) but these are not described in this paper.

3. Petrography

The general division into green Cr-diopside-bearing pyroxenite suites (group I) and black Al-augite-dominated suites (group II), advocated by Wilshire and Shervais (1975) and Frey and Printz (1978), allows us to separate the Vitim megacrysts and pyroxenites into two large groups. However, below we present a more detailed division, taking into account their petrographic features, and major and trace element mineral chemistry (Table 1). The samples were first divided using varimax factor analyses using major element compositions as described by Ashchepkov et al. (1994). Division into the groups was later supported by trace element data that show correlations between PT parameters and degree of differentiation (Ashchepkov et al., 1995b; Litasov et al., 2000; Ashchepkov and Andre, 2002), using the same set of major element analyses,

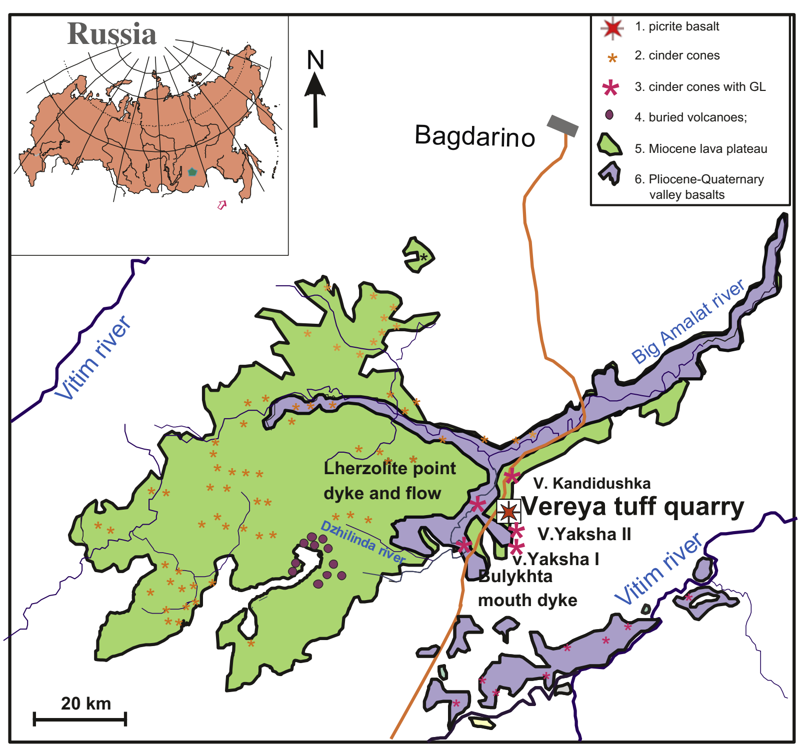

Fig. 1. Schematic map of the Vitim plateau basalts. (1) Buried volcanoes; (2) cinder cones; (3) Miocene lava plateau; (4) Pliocene-Quaternary valley basalts.

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