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Petrology of foiditic and meymechitic volcanism in the Maimecha–Kotui province (*Polar Siberia*)

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Abstract

Comparative analysis of ultramafic meymechites of the Maimecha Suite and alkaline volcanics of the Ary-Dzhang Suite (foidites (nephelinites, analcimites, limburgites, etc.) and melilitites) has shown their consanguinity, which indicates their relationship with the same magmatic system periodically producing large amounts of alkaline ultramafic melts. We have studied the petrogeochemical and mineralogical compositions of rocks and melt inclusions in the hosted olivines. The rocks of the Maimecha and Ary-Dzhang Suite differ considerably in MgO content, which is well explained by the accumulation of olivine. The inclusions in olivines from the meymechites and the rocks of the Ary-Dzhang Suite correspond in composition to foidites. The trace and rare-earth element patterns are similar both in the foidites and meymechites and in the melt inclusions: They show negative anomalies of Rb and K and positive anomalies of Nb and Ta. The ratios of indicator elements (Nb/Ta, Ba/La, Ta/La, etc.) in the rocks of the Maimecha and Ary-Dzhang Suite are constant and almost independent of their Mg# values. The La/Yb ratio in the foidites is significantly higher than that in the meymechites and in the melt inclusions from their olivines, which indicates that the rocks of the Ary-Dzhang Suite resulted from the fractionation of highly magnesian alkaline picritoid melt.

Keywords: foidites; meymechites; melt inclusions; Arctic Siberia; Maimecha–Kotui province

Introduction

The Maimecha–Kotui mafic–ultramafic magmatic province located in the north of the Siberian Platform differs from other similar provinces of the Earth's stable zones in having a unique complex of intrusive and volcanic rocks. Dating and geological study of the Permo–Triassic mafic–ultramafic magmatism in the province showed the following temporal sequence of formation of volcanic and intrusive rocks: Ary-Dzhang Suite, composed mostly of ultramafic and mafic foidites, lies in the lower section of a thick volcanic rock unit, which, in turn, is intruded and thermally metamorphosed by the Guli pluton dunites. Meymechites terminating the volcanic processes in the province rest upon the eroded surface of the Guli alkaline ultramafic pluton and underlying volcanics (Basu et al., 1995; Burgess and Bowring, 2015; Dalrymple et al., 1995; Egorov and Surina, 1976; Kamo et al., 2003; Vasil'ev and Gora, 2012; Vasil'ev and Zolotukhin, 1975). Some researchers (Egorov, 1991; Malich et al., 2015; Panina and Motorina, 2013; Rass, 2000) believe that the ultramafic and alkaline rocks of the Maimecha–Kotui province are heterogenesous, and others (Fedorenko et al., 2000; Mamaeva, 2006; Ryabchikov and Kogarko, 2016; Vasiliev and Zolotukhin, 1995) suggest their genetic relationship.

We think that the large manifestations of mafic–ultramafic magmatism in the province, first of all, volcanic deposits, are, most likely, the result of the periodical activity of the same magmatic system and must be genetically interrelated. Therefore, the goal of our research was to reveal common chemical compositional features of meymechite-picrites of the Maimecha Suite and foidites of the Ary-Dzhang Suite and their relationship with the same magmatic system, using our and voluminous literature material (petrochemical, geochemical, and isotope data and results of study of primary melt inclusions in olivines of volcanics).

Geologic location

Volcanic deposits of the Maymecha–Kotui province occur in its northern part, stretching as a 20–25 km wide and

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~250 km long band along the southeastern edge of the Yenisei–Khatanga Rift. The volcanic unit is 4.0–4.5 km thick and is made up of rocks of different compositions, from ultramafic meymechites and foidites to basalts, trachybasalts, and andesite-basalts. It is divided into six suites according to the geologic position and composition (from bottom to top): Pravaya Boyarka (mafic pyroclastics), Ary-Dzhang (ultramafic and mafic foidites, melilitites, and alkali picrites), Onkuchansky (tholeiites), Tyvankit (tholeiites and trachybasalts), Delkansky (foidites, trachybasalts, andesite-basalts, etc.), and Maimecha (meymechites) (Fig. 1). All suites are of unconformable bedding and form laterally separated fields, which hampers to follow their mutual correlation. At the Maimecha–Kotui watershed, the volcanic unit is intruded by the Guli volcanic pluton composed of different ultramafic–mafic rocks (dunites and clinopyroxenites), alkaline rocks (melilitolites, rocks of the jacupirangite–urtite series, etc.), and carbonatites. Earlier geological and geophysical studies (Butakova and Egorov, 1962; Egorov, 1991; Gusev, 1970; Shikhorina, 1970) showed that a major part of the Guli pluton and volcanic unit is faulted toward the rift and is overlain by Jurassic–Cretaceous deposits.

The Ary-Dzhang Suite is localized in the lower section of the volcanic unit. It rests unconformably upon Permian and Carboniferous rocks and the Pravaya Boyarka Suite rocks and is overlain by the tholeiitic basalts of the Onkuchan Suite. The rocks of Ary-Dzhang Suite occupy an area of ~800 km^2 (Butakova and Egorov, 1962). The suite bedrocks outcrop on the left bank of the Kotui River, 3–4 km downstream from the mouth of the Medvezh'ya River, its right tributary, and along the latter, where they form the Ary-Dzhang conform hill. Small occurrences of the Ary-Dzhang Suite were found during prospecting drilling at the exocontact of the Krestovskaya alkaline ultramafic intrusion located ~50 km southwest of the Guli pluton (Gertner et al., 2009; Sazonov et al., 2001). The geologic, petrographic, and petrochemical characteristics of the formation rocks were described in detail elsewhere (Butakova and Egorov, 1962; Fedorenko et al., 2000; Gladkikh et al., 1965; Laguta, 1993; Leont'ev et al., 1965; Shikhorina, 1970: Zhuk-Pochekutov et al., 1965). The thickness of the Ary-Dzhang Suite is estimated at 250 to 600 m. Its section is made up predominantly of lava sheets (flows) 3–5 to 20 m in thickness. Pyroclastic rocks form 0.5–10 m thick intercalates, and scarce local lava breccias form up to 30 m thick horizons.

The suite is composed mostly of ultramafic and mafic foidites (melanephelinites, nephelinites, melaanalcimites, analcimites, augitites, limburgites, etc.), melilitites, and, seldom, alkali picrites. Some of the latter are highly magnesian, similar in composition to meymechites. Three horizons are recognized in the suite section along the Kotui River according to petrographic composition and structure. The lower horizon, ~150 m thick, is formed mostly by melanocratic foidites with melilitite and picrite sheets. Pyroclastic rocks here amount to 20–25 vol.%. The Permian and Carboniferous terrigenous and coaly deposits of the section bottom are overlain by a member of pyroclastic rocks with 25–50 m thick intercalates of ultramafic foidites (Laguta, 1993). The middle horizon, 110 m thick, is made up mostly of melilite nephelinites, nepheline melilitites, and nephelinites. Melanocratic rocks are scarce. The upper horizon, 30–40 m thick, is composed predominantly of limburgites and alkali picrites alternating with tuff intercalates. The section is terminated with a melilite nephelinite sheet and is crowned with outcrops along the Medvezh'ya River, where the rocks of the Ary-Dzhang Suite are unconformably overlain by the basalts of the Onkuchan Suite. The $^{40}Ar/^{39}Ar$ age of melanephelinites from the bottom of the Ary-Dzhang Suite is 253.3 ± 2.6 Ma (Basu et al., 1995), and the $^{206}Pb/^{238}U$ age of perovskite from these rocks is 251.7 ± 0.4 Ma (Kamo et al., 2003). Recent $^{206}Pb/^{238}U$ dating of perovskites from the Ary-Dzhang Suite lavas yielded an age of 252.27–252.2 Ma (Burgess and Bowring, 2015).

Rocks of similar composition and structure are widespread in the southwest of the lava field and are assigned to the lower half of the Delkan Suite (Butakova and Egorov, 1962; Shikhorina, 1970; Zhuk-Pochekutov, 1965).

The Maimecha Suite, occupying the upper part of the volcanic-unit section, is located in the Maimecha River basin as separate fields, the largest being 60 km^2 in area. Meymechites are predominant lavas and subordinate pyroclastic rocks as well as dikes and diatremes. The thickness of the lava flow is estimated at 600 to 1400 m (Butakova and Egorov, 1962; Egorov and Surina, 1976; Fedorenko and Czamanske, 1997; Vasiliev and Zolotukhin, 1995). The lava flows and dike bodies are characterized by the nonuniform (jet- or band-like) distribution of olivine crystals and an increase in the degree of groundmass crystallization toward their cores. The time of meymechite eruption is evaluated from the $^{40}Ar/^{39}Ar$ age of the hosted biotite at 245.5 ± 1.2 Ma (Dalrymple et al., 1995). Based on geological observations and available dates, we think that meymechite volcanism terminated alkaline ultramafic magmatism in the Maimecha–Kotui province (Vasil'ev and Gora, 2012).

Methods

The contents of major and trace elements in olivines and glasses of melt inclusions (MI) were measured on Jeol JXA 8200 Superprobe at the Max Planck Institute for Chemistry, Mainz (Germany). Analysis of olivines was performed by a special technique (Sobolev et al., 2007, 2009b) ensuring high-accuracy determination of the contents of trace elements. The analysis was carried out at long integration time and high probe current, which ensured a detection limit of 10–15 ppm and an analytical error of 20–30 ppm. Operation conditions: accelerating voltage of 20 kV, probe current of 300 nA, and integration time of 120–180 s at the signal peak and 120 s on the background for trace elements (Al, Ti, Mn, Ca, Cr, Co, and Ni) and of 40 s at the signal peak and 40 s on the background for major elements (Si, Mg, and Fe).

The rocks under study were powdered and sintered to glass with the use of an Ir heater (Stoll et al., 2008). The contents of major elements in homogeneous glasses of MI and rocks