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Research paper

Comparison of mantle lithosphere beneath early Triassic kimberlite fields in Siberian craton reconstructed from deep-seated xenocrysts

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ABSTRACT

Mantle xenocrysts from early Triassic kimberlite pipes from Kharamai, Ary-Mastakh and Kuranakh fields in the Anabar shield of Siberia revealing similar compositional trends were studied to estimate the superplume influence on the subcratonic lithosphere mantle (SCLM). Pressure-temperature (PT) reconstructions using monomineral thermobarometry for 5 phases show division of the SCLM beneath the Kharamai field into 6 units: pyroxenitic Fe-rich (1–2 GPa) and Mg-rich (2–3 GPa) layers; middle with two levels of Gar-Sp pyroxenites at ~3 and 4–5 GPa; Gar-dunite–harzburgites ~4.5–6.5 GPa subjected to Ilm-Px vein metasomatism; and a Mg-rich dunite lower part. In the Anabar shield (Ary-Mastakh, Dyuken and Kuranakh fields) mantle lithosphere is composed of three large units divided into two parts: upper part with amphiboles and phlogopite; two levels of pyroxenites and eclogites at 3 and 4 GPa, and a lower part composed of refertilized dunites. Diagrams showing P-Fe#Gar clusters for garnets and omphacites illustrate the differences between SCLM of these localities. Differences of Triassic SCLM from Devonian SCLM are in simple layering; abundance of Na-Cr-amphiboles and metasomatism in the upper SCLM part, thick pyroxenite-eclogite layer and lower part depletion, heated from SCLM base to 5.0 GPa.

Kharamai mantle clinopyroxenes represent three geochemical types: (1) harzburgitic with inclined linear REE, HFSE troughs and elevated Th, U; (2) lherzolitic or pyroxenitic with round TRE patterns and decreasing incompatible elements; (3) eclogitic with Eu troughs, Pb peak and high LILE content. Calculated parental melts for garnets with humped REE patterns suggest dissolution of former Cpx and depression means Cpx and garnets extraction. Clinopyroxenes from Ary-Mastakh fields show less inclined REE patterns with HMREE troughs and an increase of incompatible elements. Clinopyroxenes from Kuranakh field show flatter spoon-like REE patterns and peaks in Ba, U, Pb and Sr, similar to those in ophiolitic harzburgites. The PT diagrams for the mantle sections show high temperature gradients in the uppermost SCLM accompanied by an increase of P-Fe#Ol upward and slightly reduced thickness of the mantle keel of the Siberian craton, resulting from the influence of the Permian–Triassic superplume, but with no signs of delamination.

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1. Introduction

The evolution of the subcratonic lithosphere mantle (SCLM) has been widely discussed (e.g. Pokhilenko et al., 1999; Griffin et al., 2003; Tappe et al., 2007; Santosh et al., 2009; Lee et al., 2011; Ashchepkov et al., 2013a,b,c,d). Most investigations suggest destruction of mantle keel over time because of hydration and weakening (Yu et al., 2011), subduction tension (Yang et al., 2012) or delamination due to plume influence (Li et al., 2015). The latter

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mechanism suggested for the Northern part of Siberian craton (Griffin et al., 2005) was taken for the explanation for the low diamond grade of post-Siberian superplume kimberlites. Here we compare mantle sections of early Triassic kimberlites to examine the possible influence of superplume on the SCLM.

The structure of the lithospheric mantle sequences beneath the Siberian craton was originally formed in the early–middle Archean time. Initially separate micro-continents formed in early–middle Archean terranes were probably joined together into a large continent, variably named Kenorland, Arctica or Superia-Sclavia (Williams et al., 1991; Bleeker, 2003; Santosh et al., 2009), assembling around 2.7 Ga marked by two peaks of zircon ages at 2.5 and 2.7 Ga (Griffin et al., 2014; Roberts and Spencer, 2015) and a peak in Re-Os model ages for sulfides at 2.8–2.7 Ga. The final accretion to Siberia took place at ~1.8–1.6 Ga (Rosen, 1986, 2003; Rosen et al., 2005, 2007). After the Mesoproterozoic break-up stage of Columbia, at 1.1–0.6 Ga Siberia became part of the next supercontinent Rodinia (Griffin et al., 2002; Pearson et al., 2005; Rosen et al., 2006; Mints, 2007; Maruyama et al., 2013). A preliminary study of mantle layering and compositions supports the idea of differences of subcontinental lithosphere mantle (SCLM) (Ashchepkov et al., 2013a) beneath each tectonic terrane in Siberia (Gladkochub et al., 2006).

Northern kimberlite fields in Yakutia are mainly Mesozoic and their SCLM xenoliths are much less studied than in the central parts of the craton. Siberian the Kharamai kimberlitic field (Fig. 1A) (Cherenkov et al., 1987) is located in the northwestern part of the Siberian craton, 250 km west of the southeastern part of the Anabar shield which belongs to the Magan terrane. This field relates to the early Triassic stage of kimberlitic magmatism of the Siberian platform as well as most kimberlites in the northern part of the Siberian craton (Kostrovitsky et al., 2007), including the regions of Anabar shield and Prianabarie (Brakhfogel, 1984; Kinny et al., 1997; Griffin et al., 1999a,b; Griffin et al., 2005; Rosen et al., 2005, 2006; Kostrovitsky et al., 2007; Smelov and Zaitsev, 2013). The exceptions are some Devonian kimberlites in Starorechenskoe, Toluopskoe and Ukukite fields and late Jurassic kimberlites like the Obnazhennaya pipe common in Kuoyka (Taylor et al., 2003) and some northern kimberlite fields (Moralev and Glukhovsky, 2000; Zaitsev and Smelov, 2010). Mesozoic kimberlites in Siberia are of low diamond grade but numerous diamond placers in the northern part of Siberian craton (Afanasiev et al., 2011) suggest undiscovered sources. Diamond inclusions from placers in Cir Anabar are essentially eclogitic (Sobolev et al., 1998; Shatsky et al., 2015) while in the central part of the Siberian craton (Logvinova et al., 2005) both peridotitic and eclogitic inclusions are common.

The compositions of minerals and structure of the Kharamai field were given by Griffin et al. (2005) based on previous explorations (Cherenkov et al., 1987). Wide distribution of the high-chromium pyropes (to 14 wt.% Cr_2O_3) in the kimberlites in this field and other northern parts of the Siberian platform, and pressure estimates of the xenoliths at ~5.1 GPa (Brey and Kohler, 1990) or 6.2 GPa (McGregor, 1974), as well as the abundance of diamond placers in the northern Prianabarie (Sobolev, 1974; Afanasiev et al., 2011), suggest that the mantle keel in the northern part of Siberian platform was similar in thickness to that in the central part of the Yakutian kimberlite province. This is supported by geophysical mantle profiles (Koulakov and Bushenkova, 2010; Pavlenkova, 2011; Kuskov et al., 2014). Nevertheless using pressure estimates for garnets (Ryan et al., 1996) it was assumed that the lower part of the lithospheric mantle in the northern part of Siberian craton was delaminated (Griffin et al., 2005) after the Siberian Permian–Triassic superplume event. However recent work suggests that it was only slightly reduced, mainly in Jurassic time (Howarth et al., 2014).

In this study the heavy concentrate minerals from three kimberlitic pipes of Kharamai field were used to determine the geochemistry of minerals and their parental melts and the structure of the SCLM in comparison with data obtained for kimberlites from some fields in the Anabar shield. Kharamai field is part of the Magan terrane (Gladkochub et al., 2006; Smelov and Zaitsev, 2013) as well as Mir pipe and the Malo-Botuobinsky kimberlite field. According to Rosen et al. (2006), the nearest Ary-Mastakh field belongs to the (West) Daldyn terrane similarly to the Alakit and Daldyn kimberlite fields. But according to more recent divisions this field Starorechenskoe, Duken and Kuranakh fields are situated within the Khapchan terrane as described by Zaitsev and Smelov (2010).

The mantle layering reconstructions and general geochemical characteristics of the minerals provide the typical features of the different terranes and their distinct parts (Ashchepkov et al., 2013a). By comparing the PTXf(O_2) diagrams used for reconstructions of SCLM beneath the studied fields, we investigate the similarity of the mantle structure within the Magan terrane and differences with the SCLM in other tectonic units of the Siberian craton.

The geochemical characteristics of Kharamai field kimberlites are close to those of the Devonian kimberlites of Siberian platform (Kostrovitsky et al., 2007).

2. Data set and analytical methods

Mineral grains (~3100) of mantle xenocrysts of orthopyroxenes (Opx), clinopyroxenes (Cpx), garnets (Gar), olivine (Ol), chromite (Chr), ilmenite (Ilm) and amphiboles (Amph) from the Kharamai, Ary-Mastakh and Kuranakh kimberlites were analyzed in Analytic Centre of IGM SD RAN, Novosibirsk. Mostly the material was panned from the drilling mud.

Compositions of ~950 grains from three kimberlite pipes Evenkiyskaya, Malush and Tuzik from Kharamai field (Fig. 1B) were determined using the Jeol Superprobe electron microprobe (EMPA). In addition ~450 grains from the same pipes in Kharamai field, ~550 grains from Ary-Mastakh field (Fig. 1C) (Khardakh, Bumerang, Nebaibyt, Vympel and Bargadymalakh pipes) and ~1100 grains from Kuranakh field (Universitetskaya, Trudovaya, Losi, Malokuonamskaya pipes) (Fig. 1D) were determined using a CamebaxMicro electron microprobe (Ashchepkov et al., 2007, 2010) using 15 kV acceleration voltage and 15 nA beam current in epoxy mounts of the polished mineral grains according to the common procedure of Lavrent'ev and Usova (1994). For the constructions of the mantle transect we used additional data from some pipes in Duken field (Ashchepkov et al., 2001) and unpublished data for Malokounamskaya pipe provided by S. Babushkina and for the ilmenites from N.S Tychkov.

Minerals from Kharamai field (31), Ary-Mastakh field (Khardakh pipe, 17) and Kuranakh field (Universitetskaya, 9; Trudovaya, 20) pipe were analyzed by an LA-ICP-MS method using Finnigan Element I mass spectrometer with a Nd YAG 193: UV New Wave system laser. The laser spot diameter did not exceed 10–20 μm. Scanning time for each grain was about 2.5–3 min. The concentrations of 32 trace elements were obtained and normalized to ^{40}Ca using EPMA values for silicate minerals and to Ti and Cr for the ilmenites and chromites (Supplement 1).

3. Mineralogy

Pyropes of the Kharamai field, analyzed in this work, belong to the lherzolite field (Sobolev et al., 1973) reaching 11.5 wt.% Cr_2O_3 (Fig. 2A); reported values for the other pipes (Cherenkov et al., 1987; Griffin et al., 2005) are higher (14.5 wt.% Cr_2O_3).

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