

An evidence for the composition of the Ordovician upper mantle beneath West Sangilen (Southeast Tuva, Russia)

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Introduction

Ultramafic xenoliths in alkaline basaltic rocks are major source of information on the structure and composition of the lithospheric mantle beneath the continents. Although many studies have been carried out on xenoliths from Tertiary and Quaternary magmatic host, far fewer studies have been undertaken on xenolith suites from older magmatic events of orogenic belts. In this paper, we present a study of ultramafic xenoliths from Ordovician lamprophyre dikes of the West Sangilen Highland (Southeast Tuva, Russia).

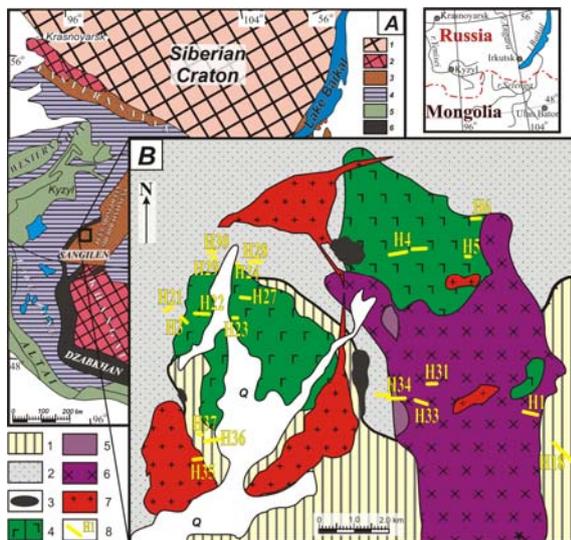


Fig. 1. **A** – Simplified tectonic scheme of the central part of the Central Asian Orogenic Belt (modified after Vladimirov et al., 1999). 1 – Siberian craton; 2 – Precambrian microcontinental megablock; 3 – Riphean microcontinental blocks; 4 – Neoproterozoic mobile belts; 5 – Paleozoic mobile belts; 6 – ophiolites. **B** – (modified after Egorova et al., 2006) Location map of the lamprophyre dikes. 1 – Precambrian metamorphic rocks; 2 – Cambrian volcanogenic – sedimentary rocks; 3 – serpentinites; 4 – gabbroids; 5 – porphyritic monzodiorites; 6 – nonporphyritic monzodiorites; 7 – Ordovician granites; 8 – lamprophyre dikes.

Geological setting

The West Sangilen is a fragment of highly metamorphized structure of Cambrian-Ordovician orogen, which has been formed as a result of Tannuola island arc, Agardag back-arc basin and Sangilen microcontinent piling-up (Gibsher et al., 2000). Recently, a number of mantle-derived xenoliths have been found in the lamprophyre dikes. The dikes correspond to the last stage of magmatic activity within the region, which belongs to the Late Ordovician orogeny. Ar-Ar dating of amphibole and biotite megacrysts from the lamprophyres provides an age of 441.3 ± 1.1 Ma (Izokh et al., 2001).

Sample description

Lamprophyres contain numerous xeno-, mega-, and phenocrysts, as well as abundant xenoliths of lherzolites, harzburgites, clinopyroxenites, and gabbro. The megacryst assemblage includes kaersutite, Al-Ti-augite, anorthoclase, biotite, apatite, and Ti-magnetite.

Peridotite nodules reach up to 50 cm in diameter and are significantly dominant among the mantle-derived xenoliths. They are very fresh, well-preserved rocks. According to the Frey-Prinz classification (1978), the group I xenoliths are presented by spinel lherzolites, of which the some contain the grains of phlogopite and amphibole, and spinel harzburgites; the group II xenoliths are spinel clinopyroxenites with amphibole and plagioclase-spinel-garnet clinopyroxenites. The textures of group I are protogranular (Mercie & Nicolas, 1975). The textures of group II are cumulative.

Whole rock chemical composition

The bulk rock analyses of most peridotites reveal negative correlation between MgO content and TiO_2 , Al_2O_3 , and CaO. It is consistent with traditional concept of partial melting degree of

primitive mantle lherzolite. Correspondingly, the harzburgites contain less amount of TiO_2 , Al_2O_3 , CaO , and higher MgO content.

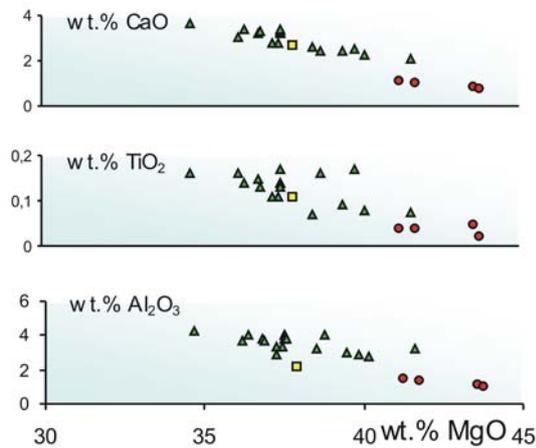


Fig. 2. A plot of MgO versus some major oxides content in bulk rock peridotites. Symbols: triangles – lherzolites; square – phlogopite-amphibole-bearing lherzolite; circles – harzburgites.

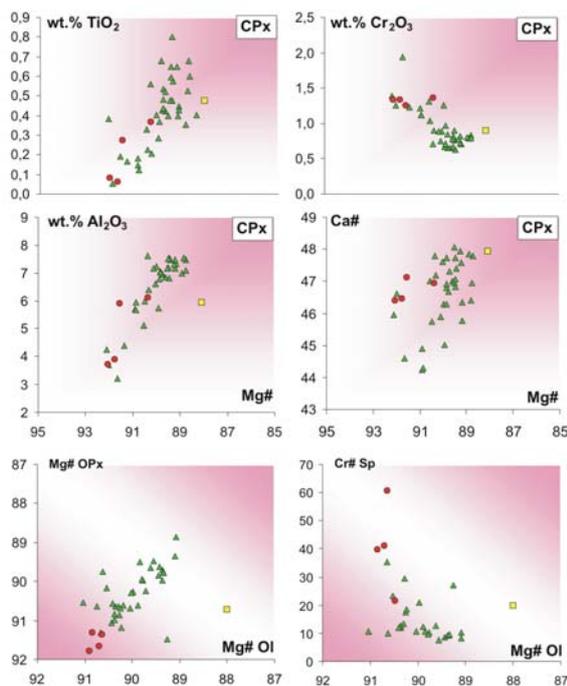


Fig. 3. Compositional variation of major elements in peridotitic minerals. $\text{Mg\#} = 100 \text{ Mg}/(\text{Mg}+\text{Fe})$, $\text{Ca\#} = 100 \text{ Ca}/(\text{Ca}+\text{Mg})$, $\text{Cr\#} = 100 \text{ Cr}/(\text{Cr}+\text{Al})$; CPx – clinopyroxene, OPx – orthopyroxene, Sp – spinel, Ol – olivine. Symbols: triangles – lherzolites; square – phlogopite-amphibole-bearing lherzolite; circles – harzburgites.

Mineral chemistry

Composition of minerals gradually changes from fertile lherzolites to harzburgites. Peridotitic olivine composition fits the mantle array. It has Mg\# values

89-91 %. NiO contents plot within 0.3-0.4 wt %. Orthopyroxene from peridotites has $\text{Mg\#} = 87-91 \%$, $\text{Al}_2\text{O}_3 = 2.3-5.5 \text{ wt } \%$, $\text{Cr}_2\text{O}_3 = 0.28-0.86 \text{ wt } \%$. Clinopyroxene from peridotites has $\text{Mg\#} = 86.8-92.3 \%$, $\text{TiO}_2 = 0.01-0.95 \text{ wt } \%$, $\text{Al}_2\text{O}_3 = 3.5-7.5 \text{ wt } \%$, $\text{Cr}_2\text{O}_3 = 0.63-1.94 \text{ wt } \%$. Clinopyroxene from clinopyroxenites has $\text{Mg\#} = 79-89 \%$. Clinopyroxene composition differs for spinel clinopyroxenites and plagioclase-spinel-garnet clinopyroxenites (correspondingly, 8.4-9.4 and 8.0-11.2 wt. % of Al_2O_3 , 0.87-1.75 and 0.02-0.26 wt. % of TiO_2 , and 0-0.03 and 0.05-0.25 wt. % of Cr_2O_3). Spinel from peridotites has $\text{Mg\#} = 60.6-80.3 \%$ and bears $\text{Cr}_2\text{O}_3 = 7.2-47.2 \text{ wt. } \%$, $\text{Al}_2\text{O}_3 = 20.4-59.9 \text{ wt } \%$. Spinel from clinopyroxenites has $\text{Mg\#} = 70.2-80.1 \%$, $\text{Cr}_2\text{O}_3 = 0-2.2 \text{ wt. } \%$, $\text{Al}_2\text{O}_3 = 64.4-69.7 \text{ wt } \%$. Garnet from plagioclase-spinel-garnet clinopyroxenites (Py_{65-73} , Alm_{15-23} , Gross_{12-15}) has $\text{Mg\#} = 73.9-82.7 \%$, $\text{Cr}_2\text{O}_3 = 0.08-0.19 \text{ wt. } \%$, $\text{TiO}_2 = 0.01-0.1 \text{ wt } \%$. Phlogopites of lherzolite have $\text{Mg\#} = 73.8-88.7 \%$, $\text{Na}_2\text{O} = 0.4-0.9 \text{ wt } \%$, $\text{K}_2\text{O} = 8.7-9.5 \text{ wt } \%$, $\text{Al}_2\text{O}_3 = 15.4-17.0 \text{ wt } \%$, $\text{TiO}_2 = 3.7-5.9 \text{ wt } \%$. Amphibole belongs to pargasite with $\text{Mg\#} = 87.3-87.6 \%$, $\text{TiO}_2 = 2.6-4.6 \text{ wt } \%$, $\text{Al}_2\text{O}_3 = 15.3-14.6 \text{ wt } \%$, $\text{Na}_2\text{O} = 2.8-3.1 \text{ wt } \%$. Plagioclase from plagioclase-spinel-garnet clinopyroxenites corresponds to labradorite (An_{52-66}).

Geothermometry

According to mineral geothermometry, calculated temperatures for spinel lherzolites range from 970 to 1100 °C (Ca-OPx, Brey, Kohler, 1990) and from 1040 to 1160 °C (2-Px, Brey, Kohler, 1990), for spinel clinopyroxenites – from 1024 to 1032 °C (Mercier, 1980), for plagioclase-spinel-garnet clinopyroxenites – from 1110 to 1243 °C (Ellis, Green, 1979).

Trace elements characteristics of clinopyroxene

Trace element composition for clinopyroxenes in West Sangilen Highland xenoliths is comparable with those for typical primitive mantle peridotites, which have primitive trace element patterns or minor depletion in LREE, Th, U, and Nb. All clinopyroxenes of fertile spinel peridotites have small negative Zr-Hf-Ti anomalies in chondrite-normalized plots. The La/Yb ratios in the clinopyroxenes vary from 0.06 to 0.98.

Clinopyroxenes from several peridotites are slightly enriched in LREE, Sr and depleted in HREE and HFSE. They have La/Yb ratios in the clinopyroxenes from 0.72 to 40.02.

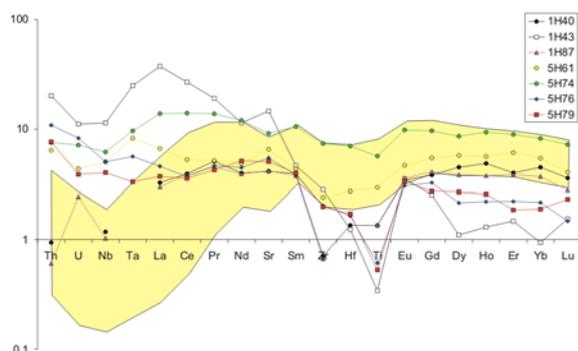


Fig. 4. Chondrite-normalised trace element patterns for clinopyroxene from fertile spinel peridotites. Individual trace elements patterns are shown for spinel peridotites with features of cryptic metasomatism.

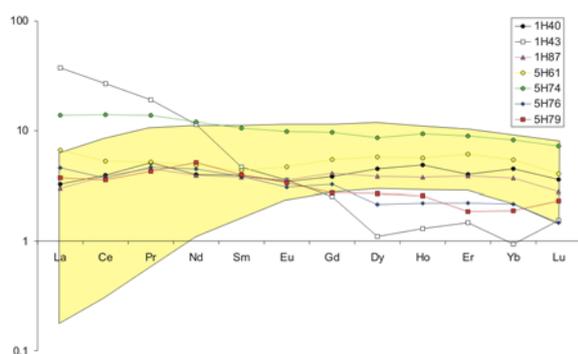


Fig. 5. Chondrite-normalised REE patterns for clinopyroxene from fertile spinel peridotites. Individual trace elements patterns are shown for spinel peridotites with features of cryptic metasomatism.

Results

The Ordovician lamprophyre dikes of the West Sangilen Highland are of special interest, because they sampled and carried up some pieces of most the ancient mantle under orogenic belts.

The chemical and mineralogical data obtained for the lherzolite nodules from Western Sangilen lamprophyre dikes allow us to suggest following:

- (1) The upper mantle domain beneath the Western Sangilen at a depth of the spinel facies consisted of mainly 'dry' lherzolite varieties in the Late Ordovician.
- (2) At that time, the local upper mantle column was heterogeneous ranging from fertile to depleted compositions.
- (3) Locally, mantle metasomatism occurred under volatile influence (preferably CO₂).
- (4) High geothermal gradient beneath the Western Sangilen during the capture of xenoliths is assumed from relatively high calculated temperatures for the depth of spinel facies.

One of important thing is, that a majority of the Ordovician mantle peridotites, in terms of major element compositions, resembles those from numerous xenolith localities of all over the Quaternary basalts of neighboring Baikal Rift System.

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