10IKC-057

^{40}AR/^{39}AR DATING OF PHLOGOPITE OF MANTLE XENOLITHS FROM KIMBERLITE PIPES OF YAKUTIA: EVIDENCE FOR DEEP ANCIENT METASOMATISM OF THE SIBERIAN PLATFORM

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Introduction

It is necessary to have a geochronometer, the mineral which keeps the information about the time of the rock formation, to estimate the rock age by some of radiologic method. Zircon or perovskite are used for the kimberlite dating normally (U-Pb dating). We didn't observe zircon in our mantle xenoliths. Perovskite grains are too small (first µm) and too rare for using this mineral. But some of the mantle xenoliths contain the potassium-bearing phase – phlogopite. So, at present ^{40}Ar/^{39}Ar dating is just one way for getting the information about mantle substance age. We have not numerous works about ^{40}Ar/^{39}Ar dating of xenoliths today (Pearson et al., 1997, Kelley and Warto, 2000, Johnson and Phillips, 2003, Hopp et al., 2008). In our investigation we applied conventional high stepwise heating technique (^{40}Ar/^{39}Ar dating) for the determination of the age of mantle xenoliths from Yakutian kimberlite pipes.

Samples

We studied 5 mantle xenoliths from the diamondiferous Paleozoic kimberlitic pipes Mir and Udachnaya (Yakutia) (Table 1).

Table-1. Tipe of rock and PT-conditions of last equilibrium for the phlogopite-bearing xenoliths M4/01, M5/01, M31/01 (Mir pipe) and UV300/09, UV162/09 (Udachnaya pipe). Ga – garnet, ol – olivine, sp – spinel. BK90 - Brey, Kohler, 1990, NT2000 - Nimis, Taylor, 2000.

Sample	Tipe of rock	P, GPa	T, ^{0}C
M 4/01	ga-sp-ol websterite	2.8±0.2(NT2000)	560(NT2000)
M 31/01	ga websterite	4±0.22(BK90)	871(BK90)
M 5/01	ga-ol websterite	2±0.22(BK90)	695(BK90)
UV 300/09	ol clinopyroxenite	3.7±0.2(NT2000)	895(NT2000)
UV 162/09	ga-ilm ultrabasite	*	*

*Values of PT-conditions for UV 162/09 have a big data scattering on different thermobarometers using different mineral suits. This rock is extremely non-equilibrium. Practically all its main minerals have a changeable composition. High Al-clinopyroxene (non-equilibrium with orthopyroxene) was found like small grains (first microns) in the rims around garnet.

The age of kimberlite eruption is estimated as 360-382 Ma for Mir pipe (Davis et al., 1980, Pearson et al., 1997) and 367-378 Ma (Kinny et al., 1997, Pearson et al., 1997) for Udachnaya pipe.

Phlogopites from studied xenoliths occurs as:

M4/01 – phlogopite plates reach 1mm in length and occur among basic minerals (fig. 1);

M5/01 – phlogopite plates reach 3 mm in length and are scattered randomly between the grains of other minerals (fig. 1);

M31/01 – phlogopite makes up large, often cut plates (up to 11 mm), flakes between the grains of other minerals (fig. 1);

UV300/09 – phlogopite makes up plates up to 6mm in length (fig. 1);

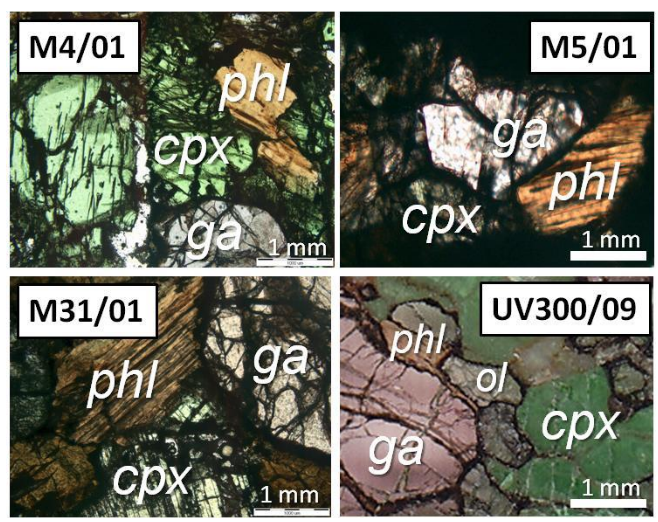

Fig. 1. Phlogopite morphology in xenoliths M4/09, M5/09, M31/09, UV300/09 from Mir and Udachnaya pipes. Ga – garnet, ol – olivine, cpx – clinopyroxene, phl – phlogopite.

UV162/09 – phlogopite flakes (up to 1mm) are scattered between the other minerals, they often form accumulations in different parts of the sample; cut plates and their intergrowths occur in small (1-2 mm) cavities of the sample together with K-sulfides, sulfates, carbonates, phosphates and perovskite (fig. 2).

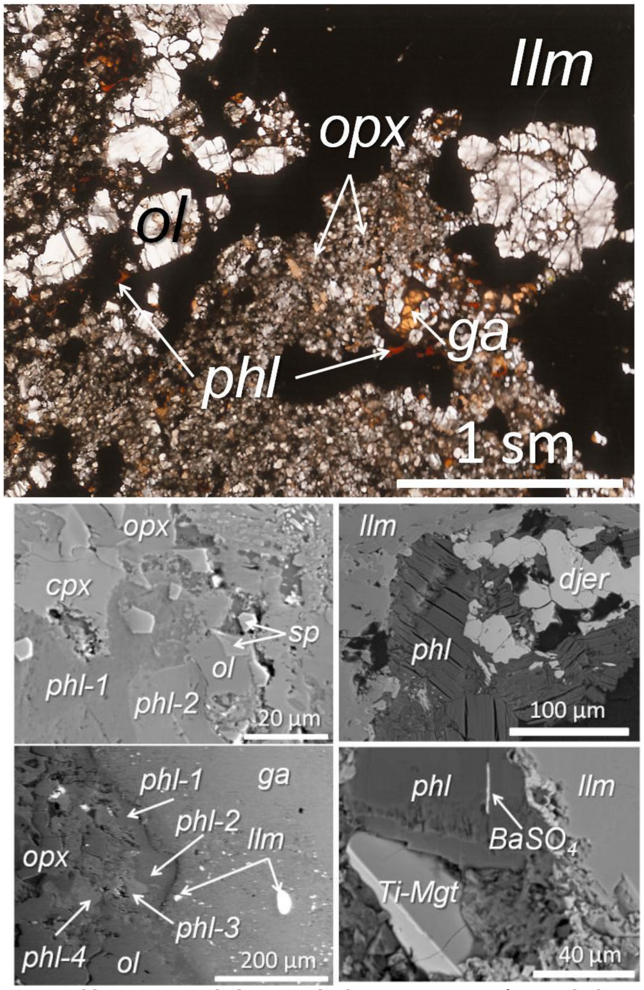

Fig. 2. Phlogopite morphology in ultrabasite UV162/09 from Udachnaya pipe. Ga – garnet, ol – olivine, cpx – clinopyroxene, opx – orthopyroxene, phl – phlogopite (changing composition), ilm – ilmenite, djer – djerfisherite, Ti-Mgt – Ti-magnetite, sp – spinel.

Thus, we supposed that at least two phlogopite generations are found in M31/01 and more than two ones in UV162/09. However, according to the criteria proposed by Winterburn etc. (Winterburn et al., 1990), the phlogopites from four studied xenoliths (M4/09, M5/09, M31/09, UV300/09) are in structurall equilibrium with other rock minerals. The chemical composition of phlogopites evidence to primary metasomatic origin. The phlogopite from UV162/09 has a very big data scattering of the values of main oxides. The extreme compositions test has confirmed the presence of a few generations of phlogopite in the rock.

Methods

Argon extraction was performed by conventional high stepwise heating technique, which has confirmed its viability and proven to be well for dating of phlogopites from mantle garnet-containing xenoliths from South African kimberlites (Hopp et al., 2008).

The mineral separates (grains were 250-125 μm size) after magnetic separation and final hand picking have been wrapped in Al foil, vacuum sealed in quartz vials and irradiated under Cd-shielding in the VEK-11 carrier of the VVR-K research reactor of the Politechnical Institute (Tomsk , Russia). K/Ar standard biotite MCA-11 calibrated with LP-6 biotite and MMhb-1 hornblende was put between every two samples for neutron gradient monitoring. The neutron gradient did not exceed 0.5% on sample size.

$^{40}Ar/^{39}Ar$ step heating experiments were accomplished in a quartz reactor heated by external furnace. For temperature monitoring thermocouple was used. Released gases were purified by exposure to a Ti-getter and two SAES getters.

The Ar isotope composition was measured in a Micromass 5400 static mass spectrometer. 1200ºC blank of ^{40}Ar deed not exceed n*10-9 STP.

Results of $^{40}Ar/^{39}Ar$ dating

Age spectrum, which begin from steps in the low temperature part, have been obtained for phlogopites from xenoliths from the Mir and Udachnaya kimberlite pipes. A flat 'plateau' has been observed in the high temperature parts of the spectrum of the samples M4/01, M5/01 and UV300/09. Maximal ages are 2568.5±17.7, 2429.8±17 and 2336.2±16 Ma, correspondingly (fig. 3).

A flat 'plateau'-like age of 2288±15.8 Ma is observed in the high temperature part of M31/01 phlogopite age spectrum after the steps (fig. 4). The age spectrum for UV162/09 with pronounced phlogopite heterogeneity is more complicated. Intermediate two-step 'plateau' of 697±7.1 Ma is observed here just after four steps up (the lowest is of 401.5±6.6 Ma) (fig. 2).

Discussion

Proper allowance must be made for a range of petrologic peculiarities of the studied rocks, phlogopite relationships with other minerals, chemical composition of phlogopites of different generations associating the obtained ages of phlogopites from mantle xenoliths with specific tectonic events or manifestations of ancient metasomatism. Phlogopies represented in the rock by large plates and tables with average size of 0,5 to 15 mm are referred to primary-textured phlogopites (Delaney et al, 1980). It is believed that they are related to the ancient enrichment of the continental lithosphere (Erlank et al., 1986). Two stages of mantle metasomatism are distinguished on the territory of the Siberian Craton. The earlier stage has been developed in the slowly cooling Archean lithosphere at the expense of addition of metasimatic fluids of KREEP-type (Solovjeva, 1986, Solovjeva et al., 1991). Mineralization is represented by phlogopite, sulfides, Cr-spinel, apatite and graphite (Galimov et al., 1989, Solov'eva et al., 1989). The later stage is considered to be a retreatment of the continental lithosphere mantle by oxidized asthenospheric fluids, which proceeded the development of kimberlite foci in the upper mantle. The reaction rims around pyroxenes and garnets are the manifestations of this stage (Solov'eva et al., 1994).

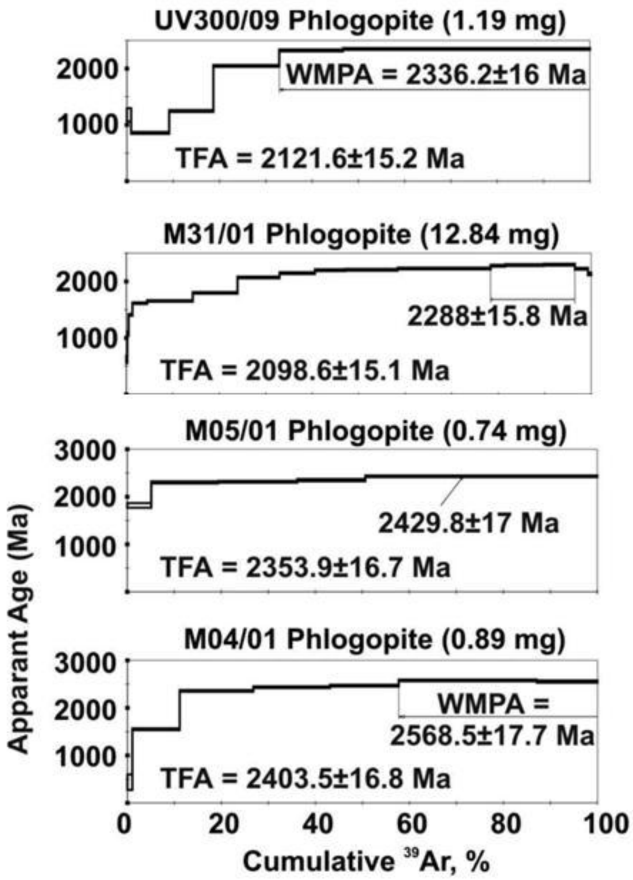

Fig. 3. Age spectrum for phlogopite from xenoliths M4/09, M5/09, M31/09, UV300/09 of Mir and Udachnaya pipes.

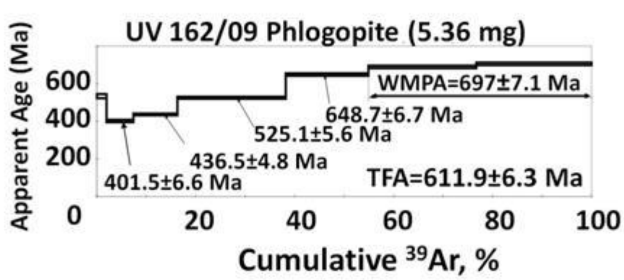

Fig. 4. Age spectrum for phlogopite from xenolith UV162/09 of Udachnaya pipe.

The ages 2.6, 2.4 and 2.3 Ga for phlogopite from xenoliths of different pipes correspond to the time of the cratons formation during the early Proterozoic time (and Siberian craton as well) and probably reflect the age of a large ancient widespread metasomatic event. This correlates well with the morphology of phlogopites from the studied samples M4/01, M5/01, M31/01, UV300/09 (fig. 1 – primary-texture phlogopites).

Hopp with co-authors (Hopp et al., 2008) suggested that the presence of several generations of phlogopite with different ages create mixed ages with a complex geochronologic meaning. Multistep spectrum of phlogopite from UV162/09 (fig. 4) illustrates this observation. The maximal age for this phlogopite estimated as 697±7.1 Ma is lower than measured maximal ages for phlogopites from other xenoliths (but higher than the age of kimberlite emplacement). It probably reflects manifestation of later metasomatic effect on the mantle block under the Udachnaya pipe. Thus, we can speak about more than one fixed stages of mantle metasomatism of different age and scale on the territory of Siberian craton.

Significantly lower age of the low temperature steps than the age of the high temperature steps of the age spectrum can be logically associated with the fact that xenoliths have stayed certain time in the high temperature kimberlite melt. The age about 400 Ma is fixed for phlogopites from UV162/09 (Udachnaya pipe) and M4/01, M31/01 (Mir pipe) in the low temperature part of the spectrum. It is much of an age of kimberlite emplacement. It can be age of the last metasomatic enrichment directly before the kimberlite explosion.

Conclusion

The obtained geochronological data consist with petrological particularities of studied rocks and confirm the existence of several stages of metasomatic enrichment of the lithosphere of Siberian craton in different time.

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