U/Pb dating of rutile from eclogite xenolith from Udachnaya kimberlite pipe (Yakutia)

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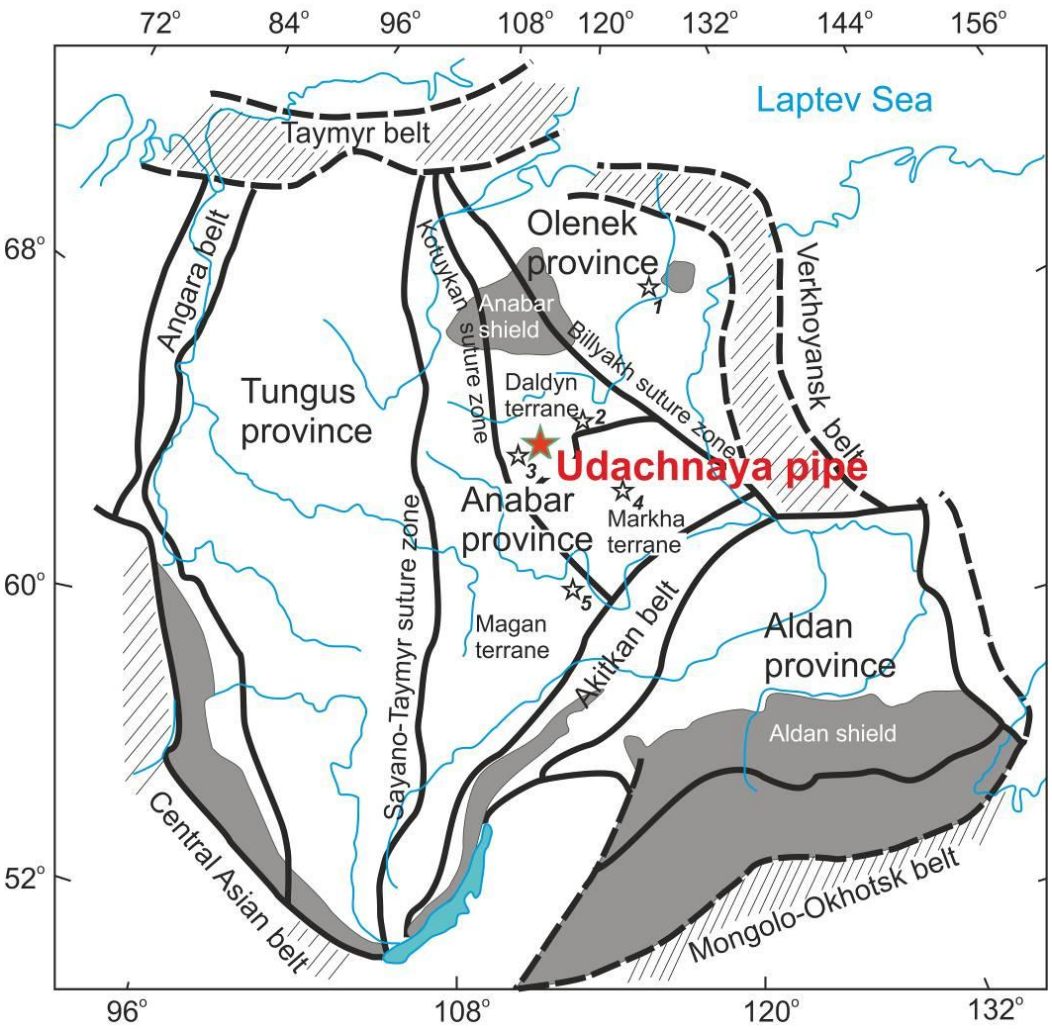
Udachnaya kimberlite pipe

Geological sketch map of Siberian platform showing locations of kimberlites and the main features of geology (after Rosen et al., 2006).

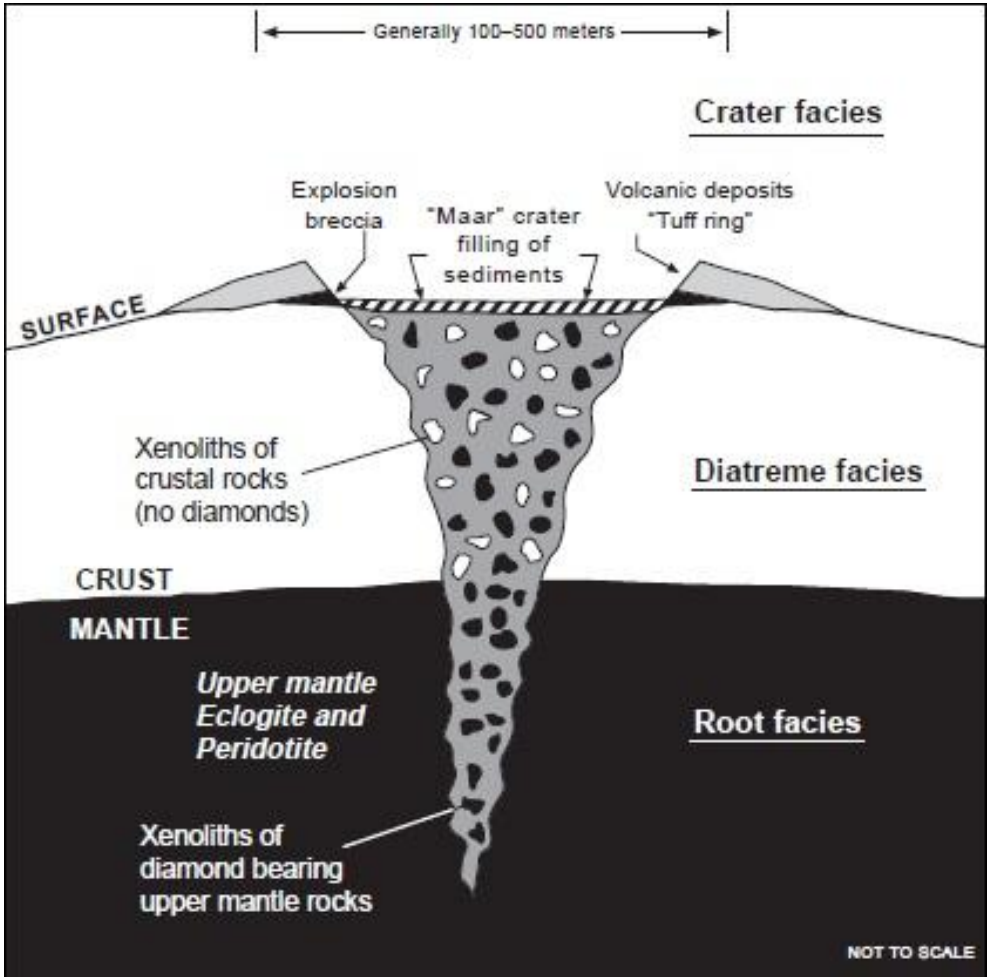


Shaded areas are outcropping Precambrian rocks, white area is post-Riphean sedimentary cover, dashed areas are Phanerozoic mobile belts.

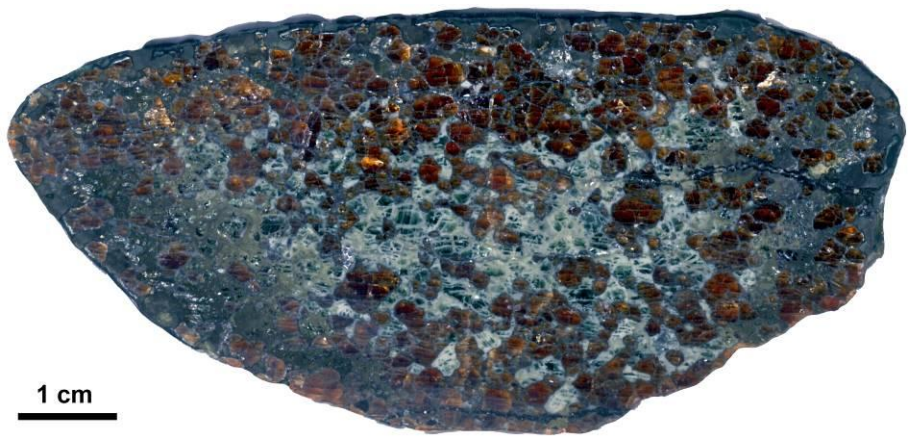
☆ kimberlite pipes (1 - Obnajennaya pipe; 2 - Novinka and Zapolyarnaya pipes; 3 - Aikhal, Komsomolskaya, Yubileinaya and Sytykanskaya pipes; 4 - Nurbinskaya and Botuobinskaya pipes; 5 - Mir pipe.

The Siberian platform is located between the Yenisey River and the Lena River. The Siberian platform is an ancient structure with Precambrian roots. Outcrops of basement occur in the Anabar and Aldan shields, and in a small area of the Olenek uplift. Anabar Province is divided by Rosen into two terranes, the Daldyn and the Markha. Udachnaya kimberlite lies within Daldyn terrane and have the age of near 350-360 Ma. Zircon ages of exposed rocks and crustal xenolith's from Udachnaya indicate crustal formation at ca. 3.0 Ga, with metamorphic events down to ca. 1.9 Ga.

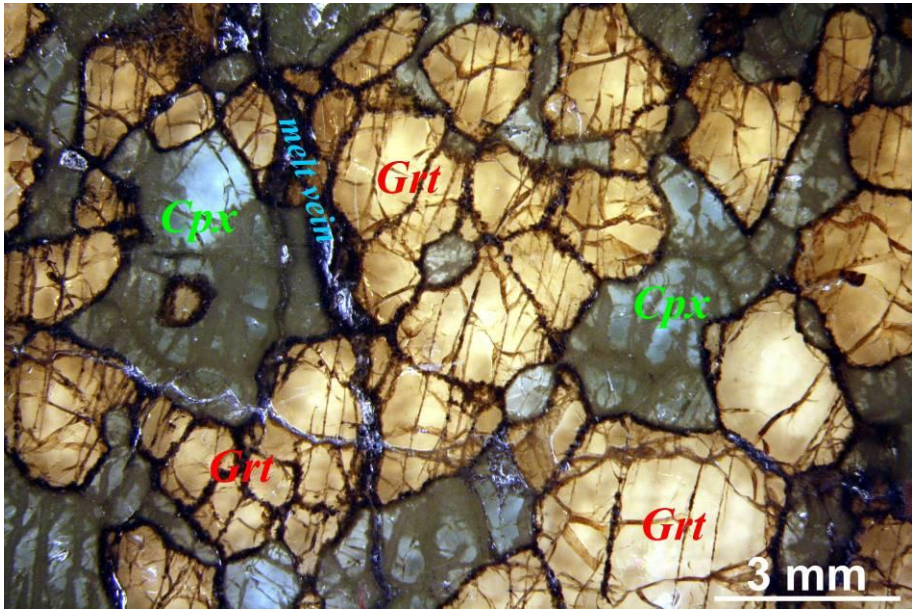
Mantle xenoliths



Deep seated xenoliths of mantle rocks in kimberlite pipes are represented by a wide spectrum of peridotites, pyroxenites and eclogites. Eclogites are rare in comparison with peridotites. Numerous studies of peridotites and especially of eclogites provide evidence of mantle metasomatism and its relation to the origin of diamonds. However, the age of these processes has been not well identified.



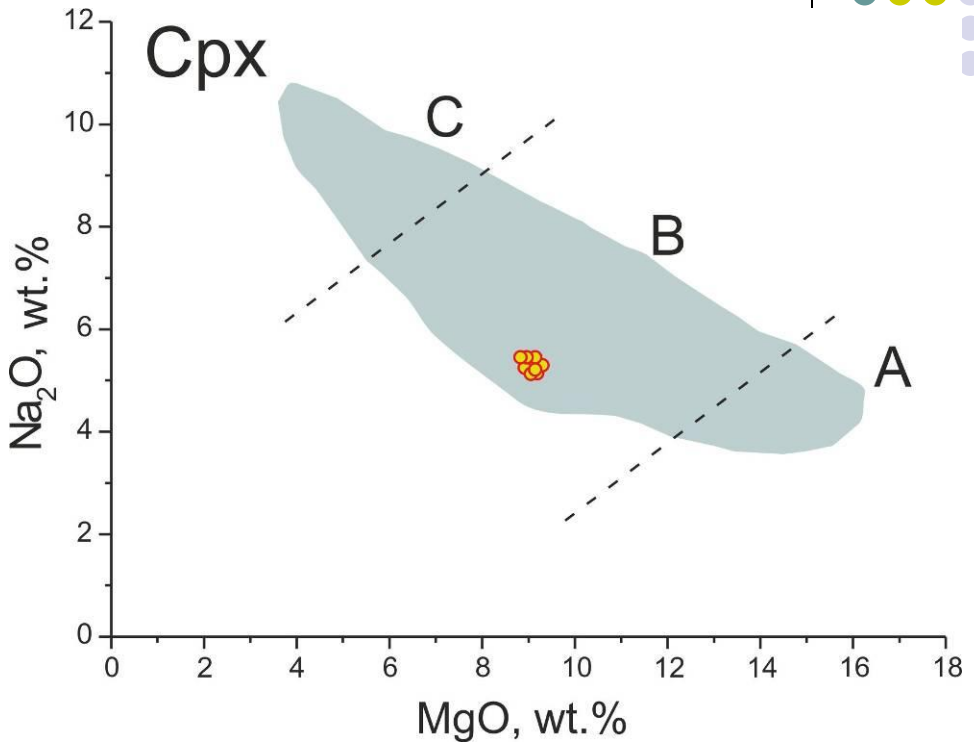
UD-208-05 - bimineral eclogite composed of dark green xenomorphic clinopyroxene (3–6 mm) and rounded garnet (2–5 mm) grains reaching ~55 and ~44 vol %, respectively + accessory minerals (1 vol. %)

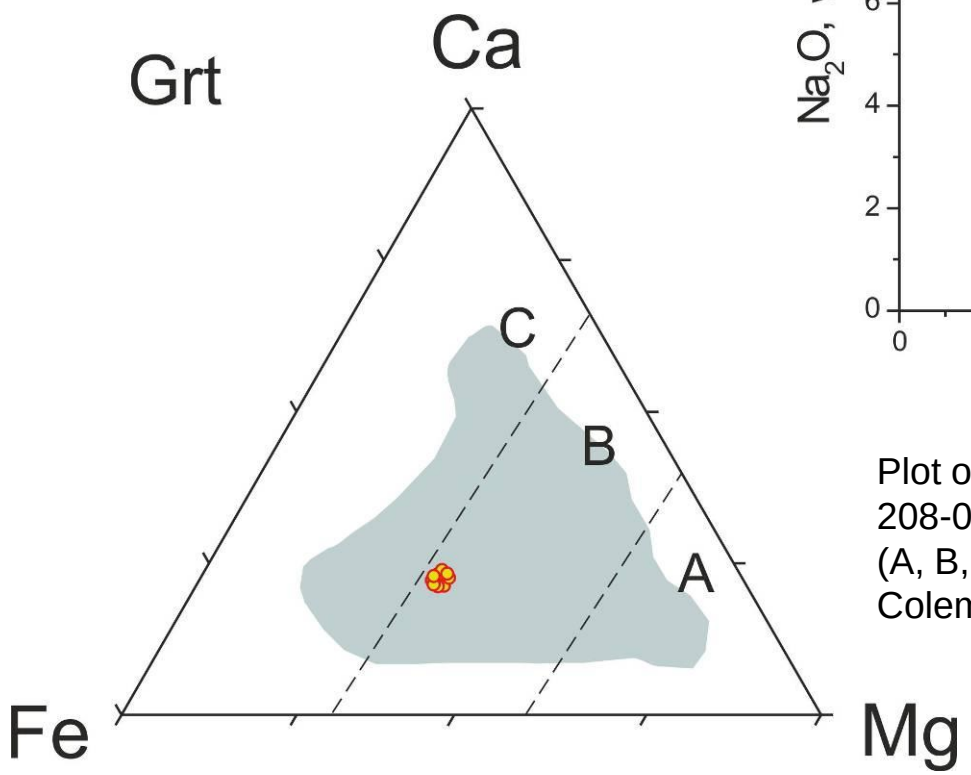


In the present study we have dated the rutiles in one eclogite xenolith from Udachnaya. Studied eclogite is about 9 cm across. This eclogite is coarse granular rock mostly composed of garnet and clinopyroxene with accessory rutile, ilmenite and sulfides. The xenolith contains the areas of partial melting including veins crossing rock forming omphacite and garnet.

Compositions of rock forming minerals

Plot of omphacitic clinopyroxene of xenolith UD-208-05 from Udachnaya pipe, showing the threefold (A,B,C) classification of eclogites according and Taylor&Neal (1989).

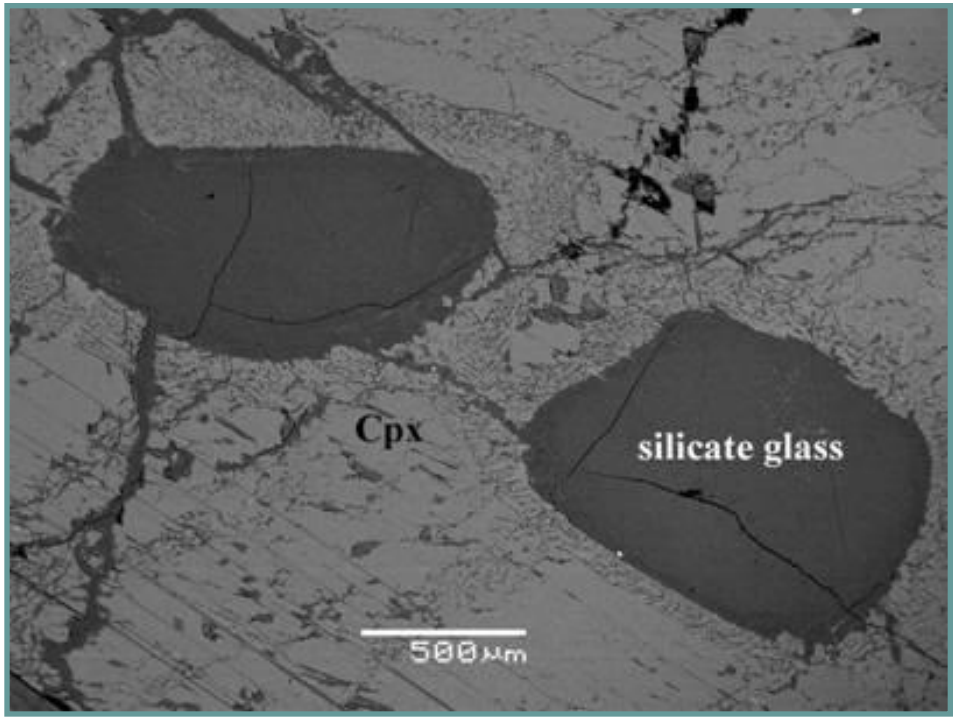


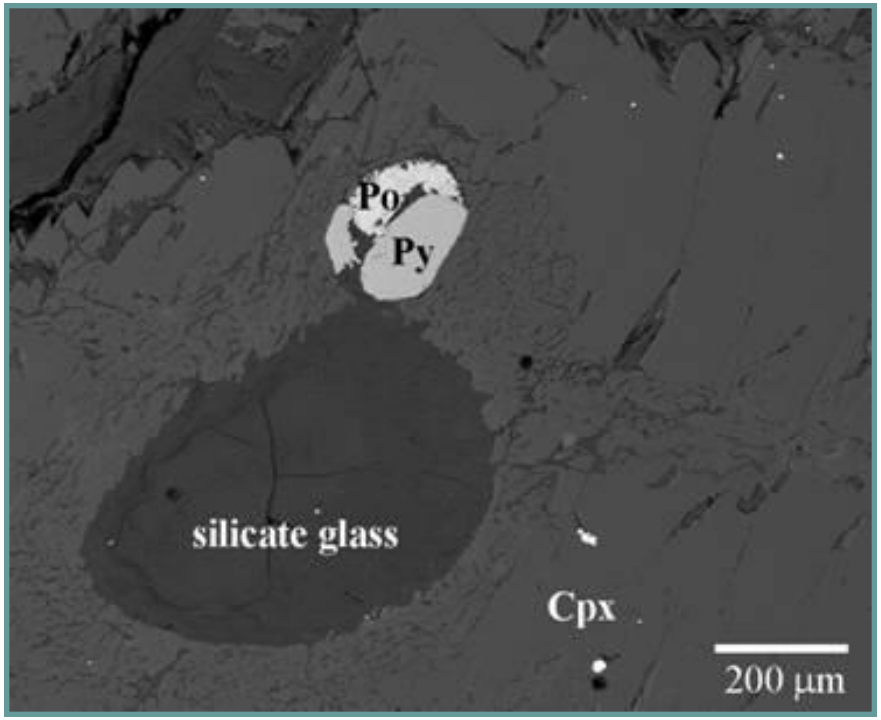


Plot of Mg - Fe - Ca of eclogitic garnet of xenolith UD-208-05 from Udachnaya pipe, depicting the three-fold (A, B, C) classification of eclogites, according to Coleman et al. (1965) and Taylor&Neal (1989).

Garnets are presented by mixture of pyrope-almandine-grossular components. Clinopyroxenes are omphacites. Compared with all worldwide eclogites Grt and Cpx in this sample are characterized by medium MgO content. According to classification Coleman et al. and Taylor&Neal they plot into the Group B.

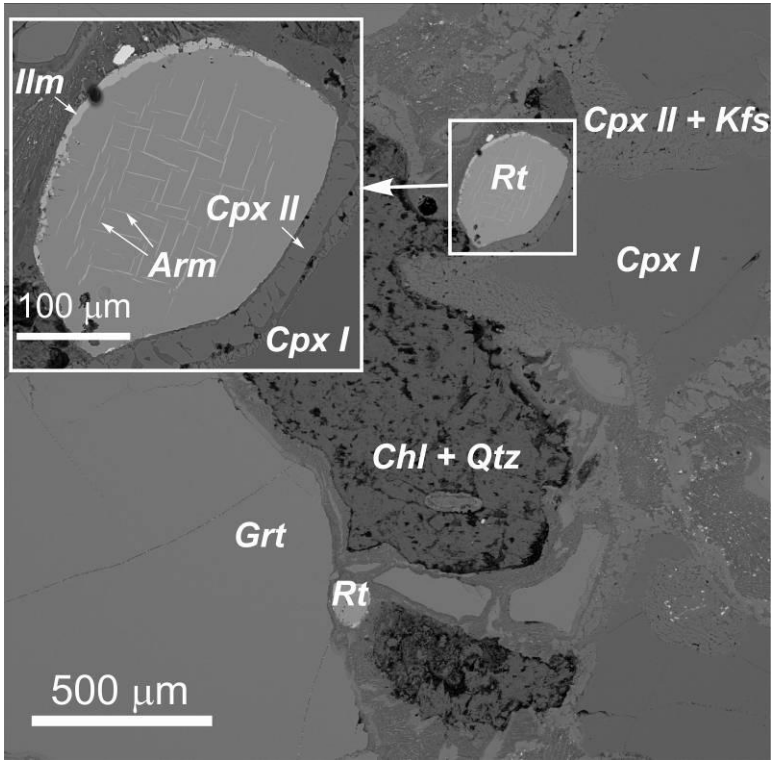
Back-scattered electron (BSE) image showing a partial-melting

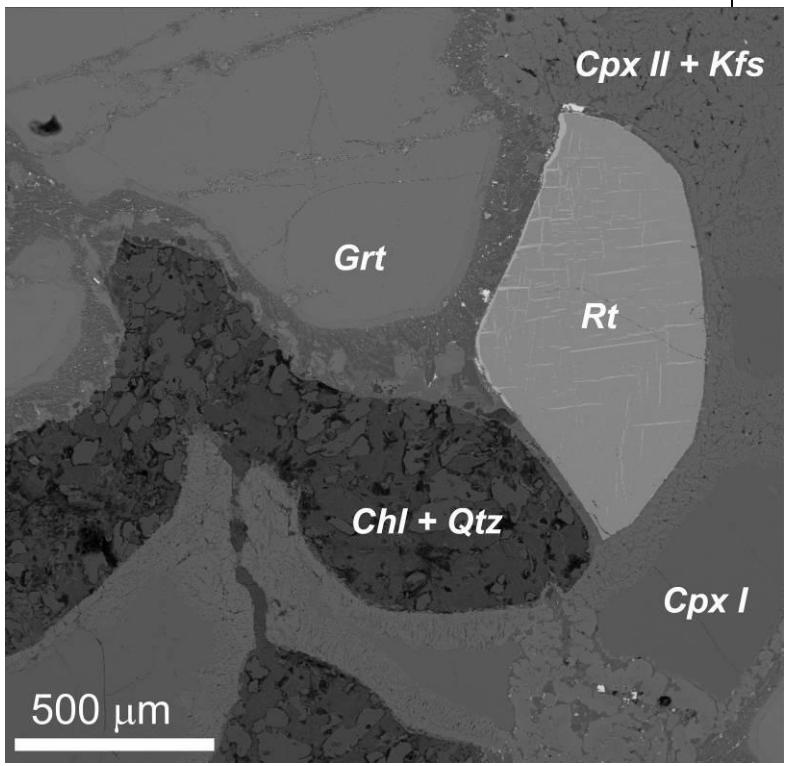




The primary assemblage of the eclogite has experienced metasomatic alteration seen as symplectites known as so called ‘‘spongy texture’’ around clinopyroxenes and kelyphitic rims on the garnets. The xenolith also contains the areas of partial melting including veins crossing rock forming omphacite and garnet. These veins consist of amorphous material (silicate glass) and its secondary products (chlorite and quartz). Some veins and melt pockets are surrounded by “spongy textures”

BSE images of textural relationships of rock forming garnet, clinopyroxene, and rutile bearing accessory mineralization in the eclogite xenolith UD-208-05



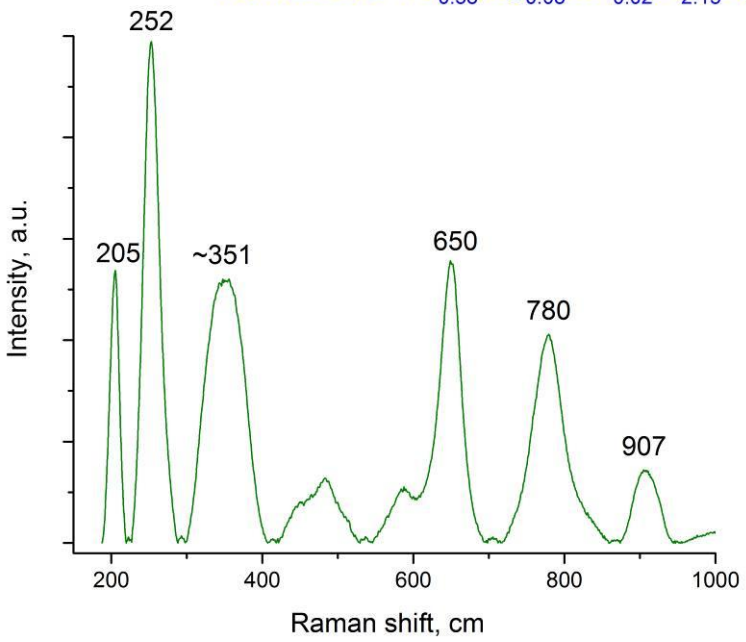


Grt - garnet; Cpx I - primary clinopyroxene; Cpx II - secondary clinopyroxene in symplectite; Chl - chlorite; Kfs - potassic feldspar; Qtz - quartz; Rt - rutile; Arm - armalcolite; Ilm - ilmenite.

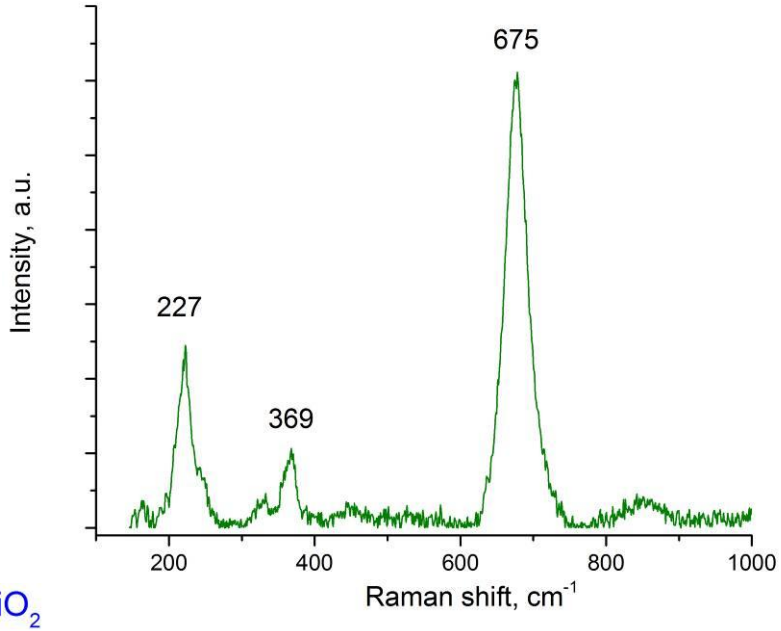
The mineralogical and petrographic features provide evidence for overprinting of rutile bearing mineralization in eclogite, Ti mineralization observed in the intergranular space and sometimes crosses rock forming garnet and clinopyroxene. In addition to rutile, this association includes potassic feldspar, newly formed clinopyroxene, products of silicate glass replacement (chlorite and quartz), and Ti oxides (rutile, ilmenite, and armalcolite). Rutile is the most abundant Ti oxide in veins and usually forms subidiomorphic crystals with a size up to 1.5 mm. Ilmenite sometimes forms individual elongated crystals (up to 100 μm), but veins usually contain rutile grains with ilmenite replacing it from the periphery. Armalcolite is observed as regularly oriented inclusions in rutile probably formed as a result of exsolution.

Raman spectra of Ti-bearing minerals from xenolith

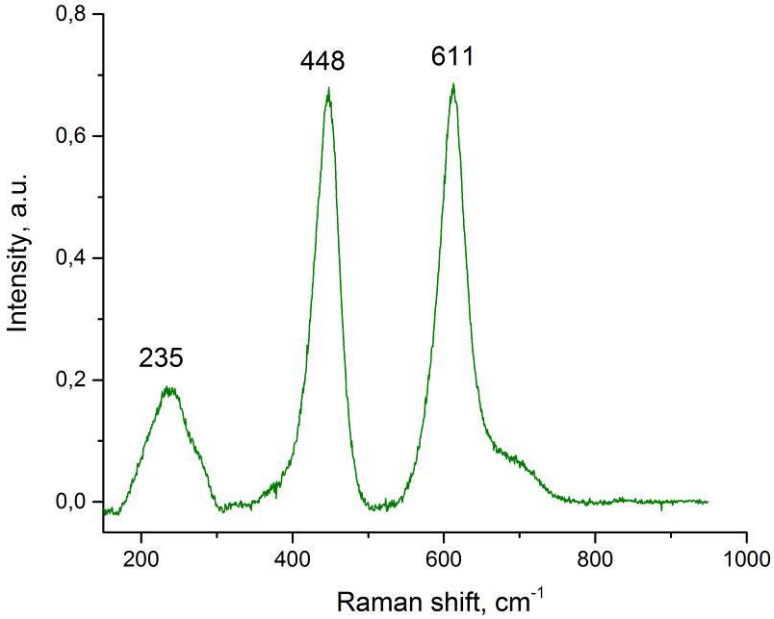
Armalcolite $Fe_{0.58}Mg_{0.08}Mn_{0.02}Ti_{2.15}O_5$



Ilmenite $Fe_{0.85}Mg_{0.08}Mn_{0.07}TiO_3$

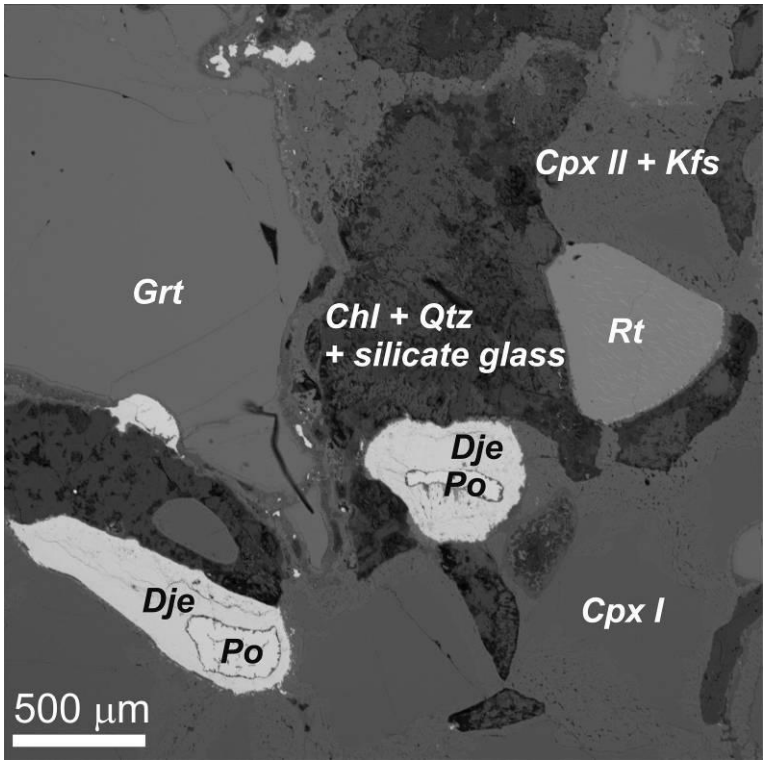


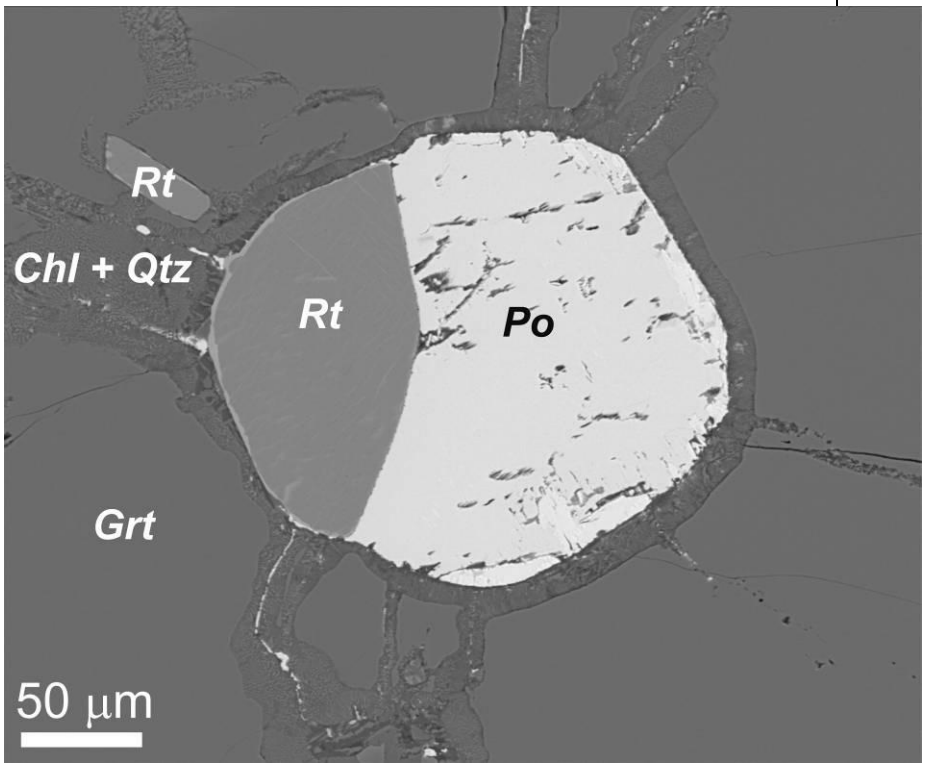
Rutile TiO_2



Ti bearing minerals such as armalcolite, ilmenite and rutile were confirmed by the Raman spectroscopy. The chemical composition of minerals was analyzed by energydispersive spectrometry on electron microscope. Chemical compositions of Ti-bearing minerals are shown on the figures.

BSE images of textural relationships of rock forming minerals, rutile-bearing and sulfide accessory mineralization



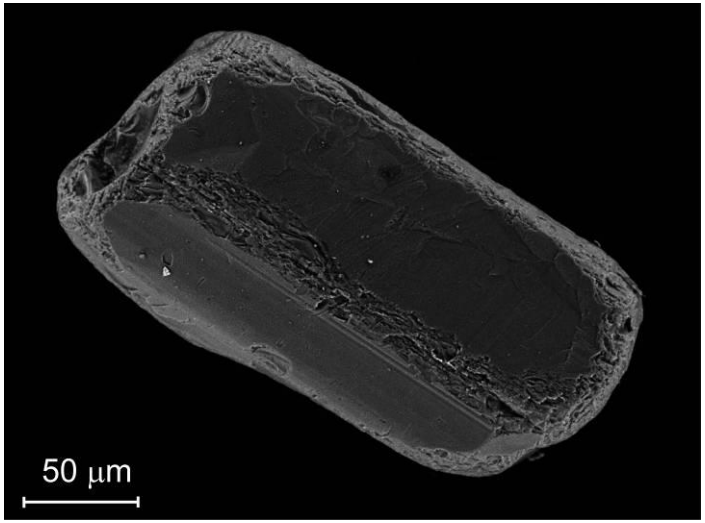


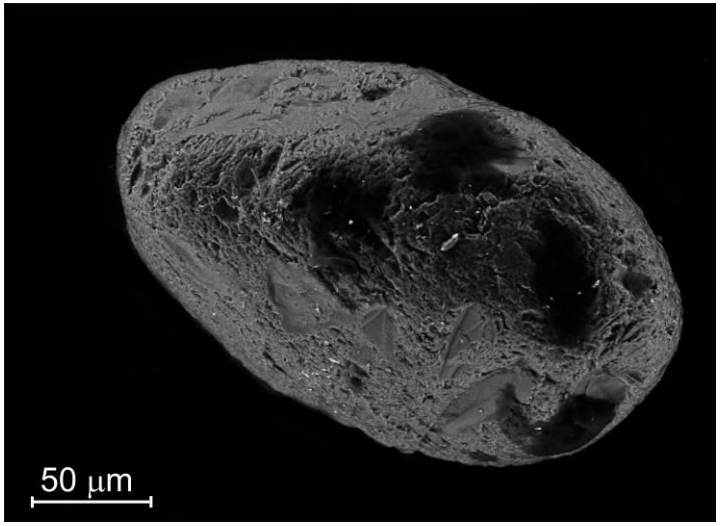
Dje - djerfischerite $K_{5.93}Co_{0.26}Ni_{2.89}Cu_{1.24}Fe_{19.70}S_{27.22}Cl$

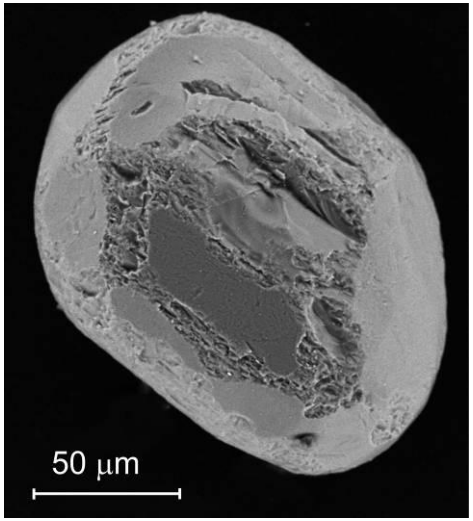
Rt – rutile, Po - pyrrhotite

In addition to Ti mineralization, veins contain pyrrhotite and djerfischerite, which replaced pyrrhotite. Sulfide grains occur in veins either as isolated grains or in some cases as intergrowth's with rutile. We believed that high temperature mineral association in veins represents stage of mantle metasomatism resulting from the influence of a high potassium fluid/melt enriched in Fe and Ti on eclogitic mantle rocks in the continental lithosphere.

SEM images of rutiles from xenolith







Isometric and elongated prismatic rutile crystals extracted from xenolith. They have a dark brown color and relics of crystal habit. Rutile is characterized by low concentrations of admixture. Rutiles were pressed into a epoxy resin and polished using 3 mkm diamond pastes and rinsed in acid .

LA-ICP-MS

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Original Article

U-Pb Age Determination for Seven Standard Zircons using Inductively Coupled Plasma–Mass Spectrometry Coupled with Frequency Quintupled Nd-YAG (λ = 213 nm) Laser Ablation System: Comparison with LA-ICP-MS Zircon Analyses with a NIST Glass Reference Material

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Abstract

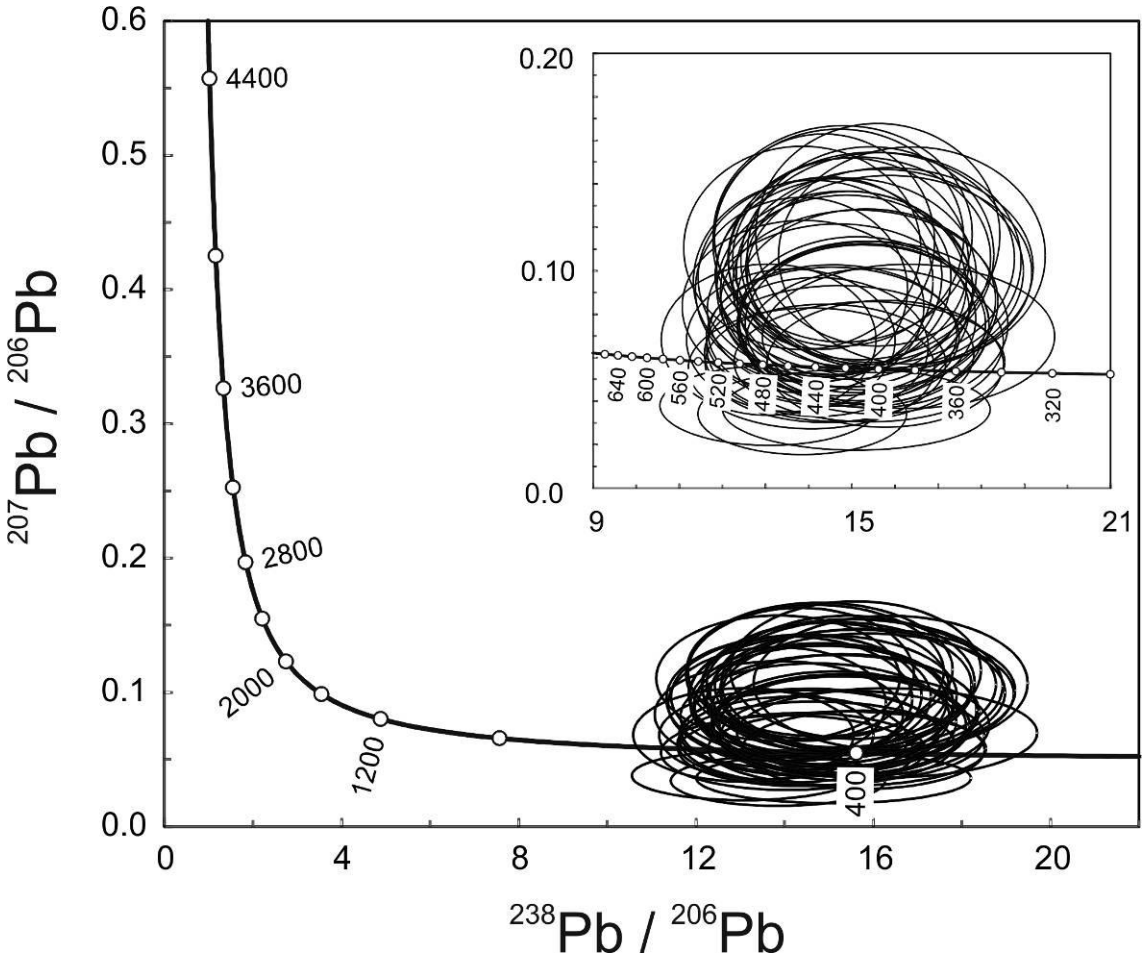
This paper evaluates the analytical precision, accuracy and long-term reliability of the U-Pb age data obtained using inductively coupled plasma–mass spectrometry (ICP-MS) with a frequency quintupled Nd-YAG (λ = 213nm) laser ablation system. The U-Pb age data for seven standard zircons of various ages, from 28 Ma

Isotopic analyses were performed by using quadrupole based ICP-MS (ThermoFisher XSeriesII) coupled with New Wave UP-213 laser ablation system installed in the University of Tokyo.

Analyses of the U and Pb isotope ratios in rutile grains were performed by ICP with laser ablation. The analytical studies were performed by Orihashi at the University of Tokyo. The detail of the analytical protocol followed after Orihashi et al. (2008). The diameter of the laser beam was 30 μm. He gas instead of Ar was used as the carrier gas, which resulted in higher transport efficiency of the sample aerosol into the ICP.

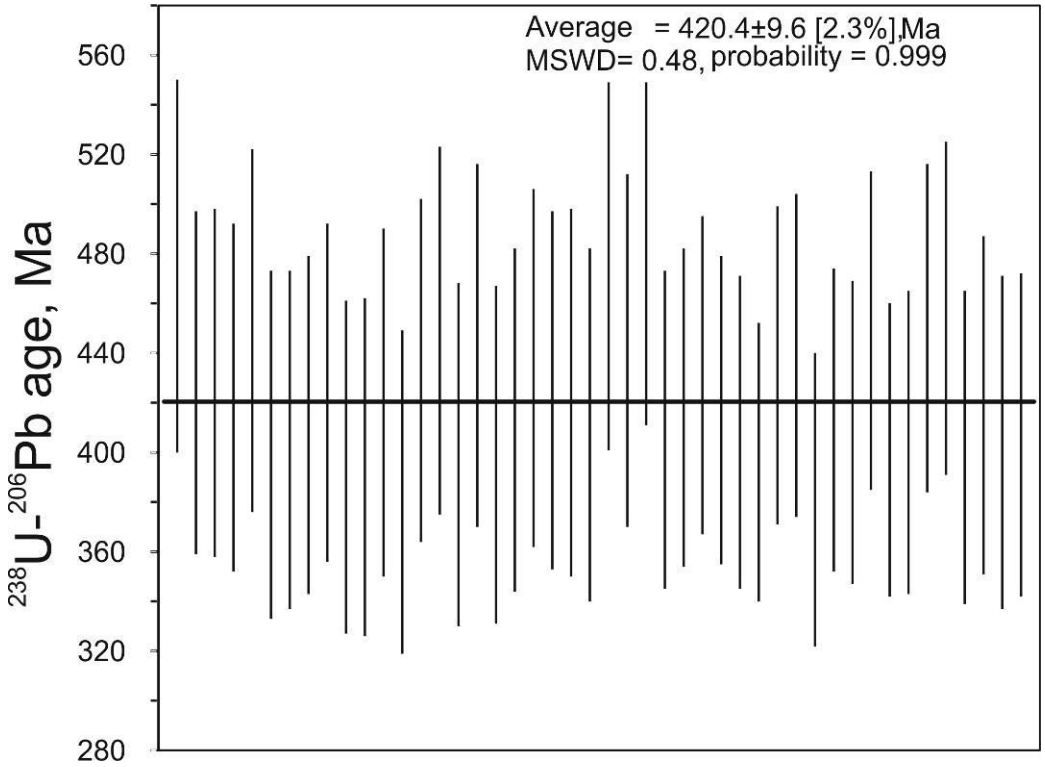
U/Pb dating

Terra–Wasserburg diagram $^{238}U/^{206}Pb$–$^{207}Pb/^{206}Pb$ ratios in rutile.



In total, 13 rutile crystals were studied. Three to five individual analyses were performed in each grain with a total of 46 measurements. The points of rutiles on the Terra–Wasserburg diagram plot near concordia, which provides evidence for the absence of a significant portion of common lead. The points on concordia correspond to the range from 381 to 475 Ma.

Weighted mean ^{238}U-^{206}Pb ages of rutile from the eclogite xenolith (46 analyses).



The weighted mean age within the 95% confidence level is 420.4 ± 9.6 Ma.

Conclusions

•**The accessory rutile in the studied eclogite xenolith from the Udachnaya pipe represent the component of high-T secondary metasomatic mineralization. The U-Pb age of rutiles obtained in this study reflects the Silurian event of mantle metasomatism (420.4 ±9.6 Ma).**

•**The age of rutiles (420.4 ±9.6 Ma) demonstrates significantly younger process in comparison with suggested age of eclogites in the lithospheric mantle of Siberian craton (2.9 ±0.4 Ga [Pearson et al., 1995]).**

•**The U-Pb dating of rutiles (420.4 ±9.6 Ma) from eclogite suggests their formation not earlier than ~60 Ma before the formation of the Udachnaya kimberlite pipe (~350-360 Ma). This age do not correspond to any known epochs of kimberlite magmatism in Siberian craton.**

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GEOCHEMISTRY

U...Pb Age of Rutile from the Eclogite Xenolith of the Udachnaya Kimberlite Pipe

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The Udachnaya kimberlite pipe in the Daldyn kimberlite field (Daldyn...Alakit region) of the central part of the Yakutian diamond province is the largest diamond deposit in Russia and one of the largest in the world. The pipe consists of two conjugate bodies: Udachnaya-East and Udachnaya-West. As is evident from the U...Pb dating of perovskites from kimberlites, the ages of the Udachnaya pipe formation are 367 ± 3 and 367 ± 5 Ma (Udachnaya-East); 361 ± 4 and 353 ± 5 Ma (Udachnaya-West) [1].

Deep-seated xenoliths of mantle rocks in kimberlite pipes are represented by a wide spectrum of ultrabasic rocks, as well as pyroxenites and eclogites. Eclogites are coarse-granular rocks mostly composed of garnet and clinopyroxene with accessory rutile. In addition to bimineral eclogites, the most abundant forming omphacite and garnet, which consist of amorphous material (silicate glass) and products of its replacement (chlorite and quartz). These areas are surrounded by replaced omphacite with the typical "sponged textures" (symplectites) [3]. Among the accessory minerals are rutile, ilmenite, and pyrrhotite. The chemical composition of minerals was analyzed by energy-dispersive spectrometry on a Tescan MYRA 3 LMU electron microscope with an EDS detector (Oxford Instruments) and using a JEOL JXA 8100 X-ray microanalyzer at the Institute of Geology and Mineralogy, Siberian Branch, Russian Academy of Sciences.

The mineralogical and petrographic peculiarities provide evidence for overprinting of rutile-bearing