GARNET-CLINOPYROXENE ASSEMBLAGE OF MANTLE ROCKS FROM THE OBNAZHENNAYA KIMBERLITE PIPE (YAKUTIA)

Anna Nikiforova, Andrey Bobrov, Vitold Spetsius
Moscow State University, Russia

GEOLOGICAL STRUCTURE AND AGE

The Obnazhennaya kimberlite pipe is located on the Olenek uplift of the Anabar-Olenek area in the Yakutian diamondiferous province, on the bank of the Kuoika River (Fig. 1). A small pipe named by the rocky outcrops of kimberlite breccia became widely famous because of the abundance, variety and freshness of deep-seated rock xenoliths. By various estimations, the portion of xenoliths ranges from 0.1-0.3 to 30% of the breccia volume. The age of the Obnazhennaya pipe is considered to be Early Palaeozoic (416 Ma) according to 40Ar/39Ar method for phlogopite from kimberlite (Keller et al., 1999).

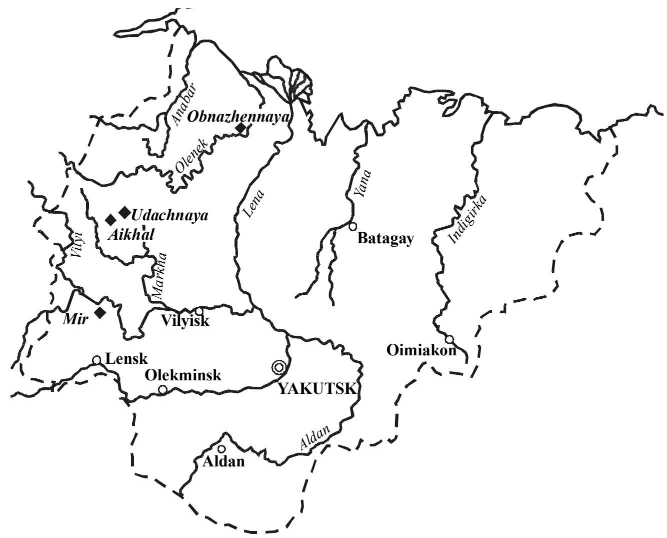

Fig. 1. Yakutian diamond province and location of the Obnazhennaya kimberlite pipe.

MINERAL VARIETIES AND CHEMISTRY OF MANTLE ROCKS

Mantle rocks of the Obnazhennaya kimberlite pipe comprise garnet-clinopyroxene paragenesis. In addition, ultrabasic rocks contain olivine, pyroxenite contains enstatite, and eclogites, aluminous minerals, such as kyanite and corundum. In some cases rocks contain phlogopite, which sometimes reaches the concentration of the rock-forming mineral.

We have distinguished several groups among the garnet-containing rocks using the petrochemical MgO - FeO+Fe2O3+TiO2 - Al2O3+SiO2 diagram (Fig. 2a), on which the fields corresponding to different rock types from kimberlite pipes are presented. The groups of ilmenite ultrabasite (VII) and websterite (IV) are the most abundant; the large group of ilmenite ultrabasite may be divided in to ferrugenous and aluminous varieties, the latters are similar to enstatitite (III) and websterite (IV). Almost all lherzolite rocks plot to the field of ilmenite ultrabasite (VII), except two samples (spinel and garnet lherzolites). Fig. 2b demonstrates Mg-Al and Fe-Ti magmatic series of the studied rocks from the Obnazhennaya pipe.

PETROGRAPHY

Xenoliths of garnet-clinopyroxene rocks have rounded, oval, rarely irregular angular shape. It's sizes don't axceed 8 cm along the long axis, xenoliths with 2-3 cm in size are mostly distributed. Rock colors contrast from green to grey-green, areas, with garnet composition, are lightly colored in red. Structures of most part of rocks are equigrained, medium- to coarsegrained, in some cases porphyraceous type is detected (TO-40a, TO-40a, TO-28, TO-42, TO-43, TO-208, TO-228). Porphyritic phenocrists are composed by garnet and olivine, rare by pyroxene (clino-, orthopyroxenes) with lamellas.

Garnet-websterites and garnet-clinopyroxenites are distinguished among the garnet-pyroxenite due to it's mineral composition. Rock structures are medium-grained and equigranular as usual, porphyraceous structures are rare. Major minerals in garnet-pyroxenite (by contrast to eclogites) comprise orthopyroxene, which is presented by individual grains, phenocrysts and oriented ingrowths in clinopyroxene. As a rule, clinopyroxene forms coarse (up to 5 mm and more) phenocrysts. Along the bounds of these phenocrysts and along the cleavage cracks of clinopyroxenes also, original "indrafts" of orthopyroxene and garnet were found (in some cases these two minerals grow at the same time) (Fig. 3). Formation of kelyphitic rims (appreciably of phlogopitic composition) is usual. Fibraceous grains of rutile in central areas, were found in garnets of ilmenite-rutile clinopyroxenites.

MINERALOGY

Results of microprobe analyses of minerals, composing garnet-clinopyroxene xenoliths from Obnazhennaya kymberlite pipe are given in this part. Because of wide-spread occur-

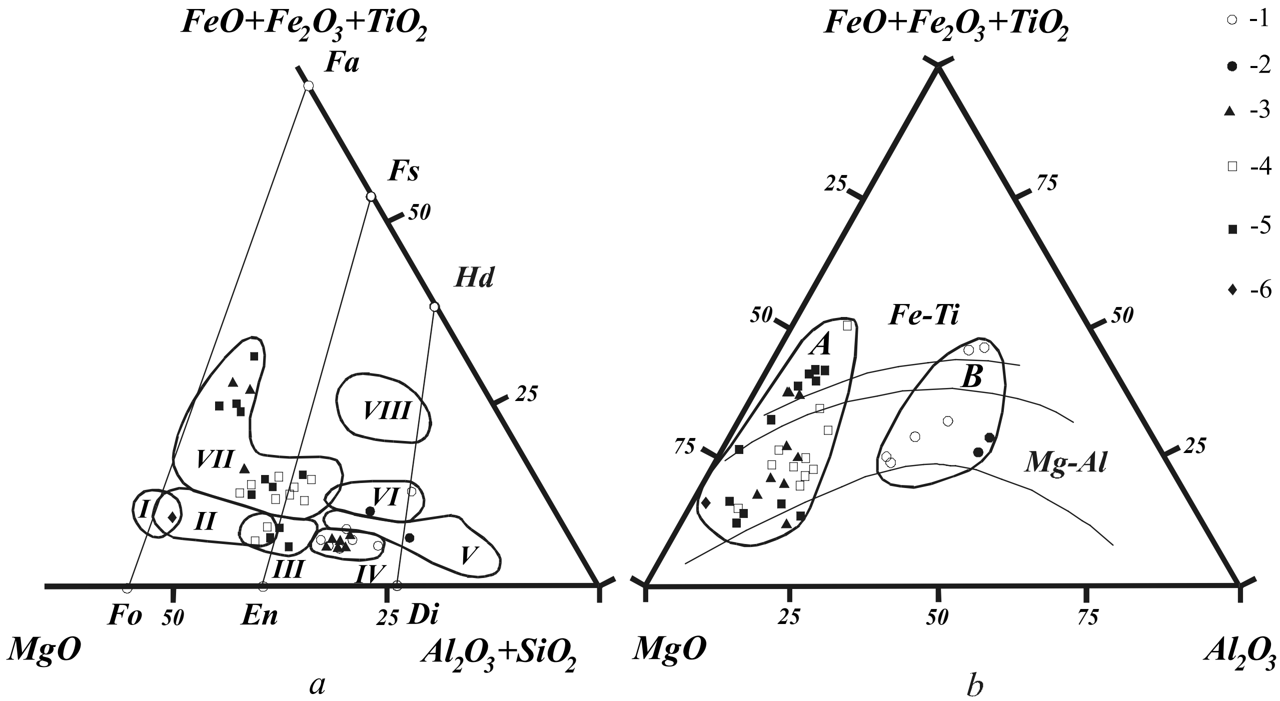

Fig. 2. MgO-Al2O3+SiO2-FeO+Fe2O3+TiO2 (a) and MgO-Al2O3-FeO+Fe2O3+TiO2 (b) petrochemical diagrams of basic and ultrabasic mantle rocks of the Obnazhennaya kimberlite pipe. I - dunite and harzburgite; II - lherzolite; III - enstatitite; IV - websterite; V - Mg eclogite; VI - Mg-Fe eclogite; VII - ilmenite ultrabasite; VIII - rutile eclogite; À - garnet peridotite; Â - garnet clinopyroxenite and eclogite. Magnesium-aluminous (Mg-Al) and iron-titanium (Fe-Ti) branches of rocks are distinguished. Analyses of garnet clinopyroxenite (1), eclogite (2), websterite (3), lherzolite (4), orthopyroxenite (5), harzburgite (6).

rence of garnet-clinopyroxene parageneses in different types of rocks (from pyrope peridotites to eclogites) and formations of different facies of depth (from inclusions in diamond to products of crustal consolidation) garnet and clinopyroxene were under the most detailed study.

Garnet is a major mineral in studied samples, which means that its content is always higher than 5% and in some cases comes close to 70-80%. Five types of garnet were distinguished according to its composition. These types are well performed on CaO-MgO-FeO diagram (Fig. 4). First type of garnet is a high-magnesium one, with high content of pyrope (up to 70 mol.% Mg3Al2Si3O12) with admixture of almandine component (up to 15 mol.% Fe3Al2Si3O12). That type is typical for pyrope peridotites (field I, Fig. 4). Garnet from clinopyroxenites can also be derived to that field (TO-109, TO-228).

Second type of garnet is also high-magnesium, but content of pyrope component is less than 65 mol.% and admixture of almandine component is up to 26 mol.%. That type is typical for garnet-pyroxenites (field II, Fig. 4) Third type of garnet is typical for high-ferrous garnet-pyroxenites. Content of almandine component is even higher (up to 38 mol.% Fe3Al2Si3O12). In samples with garnet of that type grains of ilmenite and rutile were found. That can be a matter for relating these rocks to a ilmenite-rutile varieties. As it's performed on the diagram (Fig. 4) in two cases both clino- and orthopyroxene are in paragenesis with garnet.

Garnets from eclogites are divided into two types: magnesium-ferrous (III) and calcium-aluminous (IV) varieties. Calcium-aluminous eclogites have a high content of grossular (up to 32,7 mol.% Ca3Al2Si3O12) and low content of pyrope 38 mol.% Mg3Al2 Si3O12) in garnet besides the magnesian-ferrous rocks (30 and 42 mol.% correspondingly). In studied garnets from eclogites and pyroxenites low admixtures of chrome (up to 0,6 mas.% Cr2O3) in compare with pyrope-peridotites (up to 2,9 mas.% Cr2O3)) were found.

Cinopyroxene in studied rocks can be recognized because of it's essential diopside composition (65-87 mol.% CaMgSi2O6) with admixture of jadeite component (up to 29 mol.% NaAlSi2O6). As it is performed on the diagram (Fig.

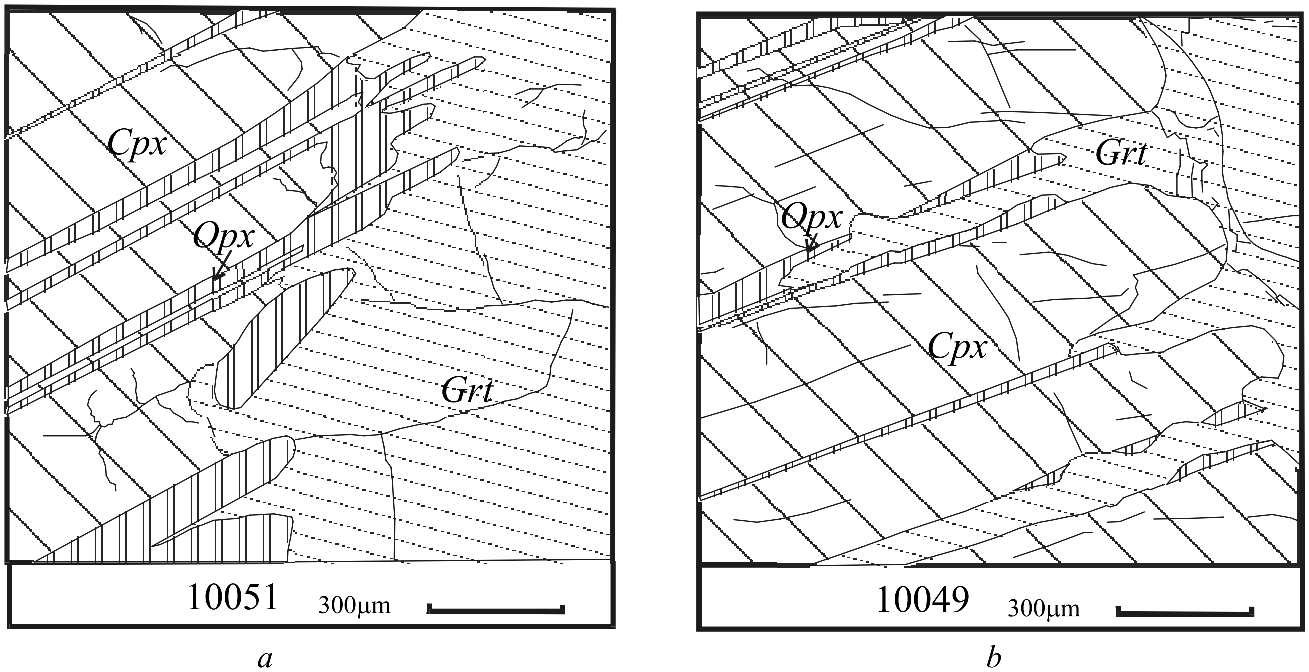

Fig. 3. Sketch of oriented orthopyroxene intergrowths in large clinopyroxene crystals from garnet clinopyroxenite of the Obnazhennaya pipe. Samples TO-40b (a), TO-13 (b).

4) there are two types of cinopyroxenes, derived by content of magnesium. The first one, represented in the corundum eclogite, (TO-15, field IV) has got lower magnesium (up to 9 mas.% MgO), other types has normal magnesium (up to 16 mas.% MgO) which is typical for cinopyroxenes from xenoliths of kimberlite pipe. There are many lamellas of orthopyroxene in cinopyroxene. As usual clinopyroxene consists of diopside minal (up to 87 mol.%) but in some cases (TO-15), content of jadeite in central area of a grain reaches 29 mol.%.

Orthopyroxene was distinguished for peridotites and pyroxenites according to its composition. In magnesium series orthopyroxenes are enstatites (up to 4,90 mas.% FeO for peridotites and up to 9,8 mas.% FeO for pyroxenites). But ilmenite-rutile pyroxenite (TO-42) with content of iron (from 13,48 to 13,98 mas.% FeO) was classified as bronzite.

Olivine in studied rocks is low in iron (up to 7,8 mas.% FeO). For pyrope-peridotites of magnesian-ferrous series (TO-281) low concentration of ferrum (9,88 mas.% FeO) is characteristic. Zonation is absent in olivine. There is a high degree of olivine serpentinezation on the contact of kimberlite.

Rutile and Ilmenite are presented as inclusions in grains of garnet and clinopyroxene. Rutile contains admixtures of iron, magnesium, silicium and chrome. Rutiles of other type (on the edges of garnet grains) contains silicon, magnesium, iron and chrome. These rutiles contain numerous oriented ingrowths of ilmenite. In grains of rutile up to 600mm in size so-called "worms" of ilmenite from 10 to 60mm in size were found. Ilmenite composites inclusions and rims on rutile. Such rutile consist of (mas.%): TiO2-52,84; FeO-38,51; MgO-7,16.

Chrome-spinellides are zoned in studied rocks. This zonation is a result of decreasing amount of Al2O3 (from 38, 70 to 32,92 mas.%), MgO (from 17, 64 to 16,19 mas.%) and increasing amount of Cr2O3 (from 30, 65 to 36, 02 mas.%) and FeO (from 12, 56 to 13, 97 mas.%) from centers to the edges. Chrome-spinel from veins is low in cilicium (28,27 mas.% Al2O3) and high in chrome (40,27 mas.% Cr2O3) in lager grains. Spains of chrome-spinel presented as oriented ingrowths in pyroxenes contains lowest amount of Cr2O3 (from 28,15 mas.%) and Al2O3 (1,26 mas.%).

PT-CONDITIONS OF ROCK FORMATION

Thermodynamical parameters of garnet-clinopyroxene rock formation were calculated with the use of three geotermobarometres (garnet-clinopyroxene, garnet-orthopyroxene and two pyroxenes).

For the formation of garnet-clinopyroxene rocks from the Obnazhennaya pipe temperatures from 800 to 1110 °C, and pressures from 30 to 40 kbar are characteristic, that is out of diamond stability field. Temperatures from 950 to 1110 °C are characteristic for eclogites, 900-1050°C, for peridotites, and 800-1100°C, for pyroxenites. Observation of minerals

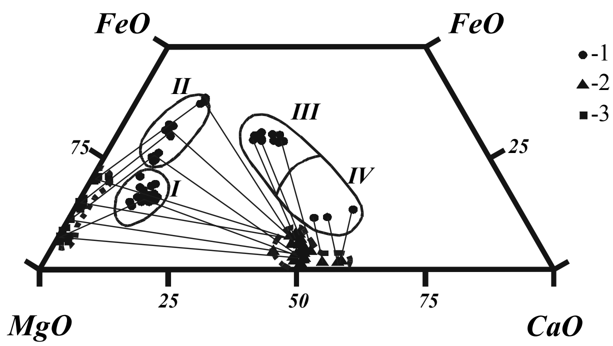

Fig. 4. Mineral paragenesis of mantle rocks from the Obnazhennaya kimberlite pipe. (1) garnet; (2) clinopyroxene; (3) orthopyroxene. Co-existing minerals are indicated by tie-lines. Fields of pyrope peridotite (I), garnet pyroxenite (II), Mg-Fe (III) and Ca-Al (IV) eclogite are shown.

along the growth zones and decomposition structures lets us see the range of crystallization of garnet-clinopyroxene rocks. For example (TO-40b): temperatures according to garnet-orthopyroxene thermometer are T=940-1000°C, and according to ganet-clinopyroxene and double-pyroxene temperatures are lower - from 800 to 870°C. This shows that crystallization began with temperatures not lower than 1000°C, and final consolidation took place at temperatures about 700-800°C.

POLYFACIAL NATURE OF MANTLE ROCKS

Major rock-forming minerals of eclogites are zonal, for garnet at first, which has direct and indirect zonation for different types of rocks. Formation of zonal garnet is related with changes of termodynamical parameters during crystallization. Indirect zonation can be a result of pressure decrease and displace of solidus line into magnesian field during the process of ascending intrusive invasion of partially crystallized magmas. Indirect zonation of garnet is a frequent occurence in mantle garnet-clinopyroxene rocks (in diamodiferous also), and can be used as one of main indicators of rock crystallization in deep-seated magmatic chamber.

Grains of rutile with oriented ingrowths of ilmenite, founded in specific rocks of Obnazhennaya pipe - ilmenite-rutile pyroxenites are related with early high-temperature stage of crystallyzation of peridotite-pyroxenite-eclogitic magmas. An important indication of complex evolution of garnet-clinopyroxene rocks is a presence of numerous lamellas of clinopyroxene in orthopyroxene and vice versa, it's formation took place during the temperature decrease. Results of calculation of temperatures of double-pyroxene balance of grains containing lamellas indicates that statement.

DISCUSSION OF THE RESULTS

Results of our observations show that range of garnet-clinopyroxene rocks of Obnazhennaya kimberlite pipe is corellated with most part of kimberlite pipes of Yakutian diamondiferous province, but in compare with other pipes volume of garnet-pyroxenites and eclogites is much higher. All of these can find it's corellation with the chemistry of rocks: Fig. 2 shows that rocks of Obnazhennaya kimberlite pipe have a wide range according to it's aluminium and ferrum content, at the same time for Udachnaya pipe low in ferrum hyperbasits of magnesian branch are most wide-spread. These observations, according to our point of view, indicate a high degree of differentiation (and low depth of seating) of magmatic chambers, from which garnet-clinopyroxene rocks of Obnazhennaya pipe crystallized. Besides that high in ferrum rocks - ilmenite-eclogites, pyroxenites and peridotites, characteristic for Mir pipe, have low spread in Obnazhennaya (and Udachnaya) pipe.

As in most part of kimberlite pipes between distinguished types of rocks straight boundaries were found, it's exsistance can be explained with two points of view. First considers kimberlite pipes to be an original natural wells along which material evacuated from different mantle levels is displaced to surface. Besides that, differences in petrografic composition of xenoliths from one pipe to another can be explained by heterogenity of lithospheric mantle.

Second point of view developed by A.A. Marakushev (and supported by authors) explains combination of different garnet-clinopyroxene rocks (pyrope-peridotites, garnet-pyroxenites and eclogites) as a result of layering of magmatic chambers under a high water-hydrogene pressure. Recently that model was confirmed by reveal of polyfacial nature of garnet-clinopyroxene rocks of kimberlite and lamproite pipes (indications of crystallization on different depth levels).

AKNOWLEDGEMENTS

Our study is supported by the Russian Foundation for Basic Research (project no. 01-05-64508).

REFERENCES

Garanin, V.K., Kudryavtseva, G.P., Marfunin, A.S. et al., 1991.Inclusions in diamond and diamondiferous rocks Moscow Univ., Moscow (in Russian).

Garanin, V.K., Kudryavtseva, G.P., Kharkiv A.D. et al., 1982. New variety of eclogite in Yakutian kimberlites. Doklady Earth Sciences. 262, 6, 1450-1455 (in Russian).

Garanin, V.K., Kudryavtseva, G.P., Kharkiv A.D. et al., 1985.

Mineralogy ilmenite ultrabasite of the Obnazhennaya kimberlite pipe. Izv. Acad. Sci., 5, 85-101 (in Russian).

Keller R.A., Remley D.A., Snyder G.A. et al., 1999. Mantle xenoliths from the Obnazhennaya kimberlite, Yakutia. Seventh Intern. Kimb. Conf. Ext. Abst. Cape Town. P. 402-404.

Nikitina, L.P., 1993. Concordant system of thermometers and baro-meters for basic and ultrabasic rocks and reconstruction of thermal regimes in mantle by xenoliths in kimberlites. Zap. Miner. Soc. 22, 5, 6-19 (in Russian).

Sobolev N.V., 1974. Deep-seated xenoliths in kimberlite the problem of upper mantle composition. Nauka, Novosibirsk (in Russian).

Pearson D.G., Kelley S.P., Pokhilenko N.P. et al., 1995. Laser 40Ar/39Ar analyses of phlogopites from kimber lites and their xenoliths: constraints on eruption ages of Southern African and Siberian kimberlites and mantle volatile compositions. Sixth Intern. Kimb. Conf. Ext. Abst. Novosibirsk. 424-426

Contact: Anna Nikiforova, Dept. of Mineralogy, Geological Faculty, Moscow State University, Leninskie gory, Moscow, 119992 Russia, E-mail: taptal@yandex.ru