

Ultramafic association of minerals (garnet-ureyite diopside-chromspinelid) in micaous kimberlites of Yakutian province.

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Diamond-bearing kimberlite fields of Yakutian province are mainly basaltoid type of kimberlite group 1, characterizing by a low alkalinity (K_2O content < 1). The exceptions are some pipes, located in the north and south margins of the Daldyn field. These are Zagadochnaya, Kusov (south cluster), Bukovinskaya, Gornyat'skaya pipes, D-57 anomaly (north cluster). The kimberlites of these pipes are marked by a low ferric oxides content, relatively high alkalinity (K_2O content $> 1\%$). In addition to olivine (pseudomorphs of carbonate-serpentine composition) the kimberlite contains phenocrysts of phlogopite and chromdiopside. A heavy fraction consists mainly of garnet, clinopyroxene and spinelids. The above pipes are unique in terms of a composition of deep inclusions, which are disthen eclogites and grosspydites (Sobolev, 1974). From our and literature data (Sobolev, 1974; Egorov et.al., 1991) the ultramafic association of mantle xenoliths is not found. In this connection a significant amount of red-violet and crimson garnet of ultramafic paragenesis present in a heavy fraction in addition to the orange-red garnet of eclogite paragenesis, is of great interest. Pyrope grains are of a round, angular-round shape, but relics of crystallographic shape can in cases be found. Sometimes, the garnets contain crystallic inclusions, which belong to two associations - 1) primary, including chromdiopside, chromspinelid; 2) secondary, which is usually confined to fractures in the garnet matrix and represented by amphiboles, aluminiferous spinel, titanium-magnetite and phlogopite. This contribution considers only primary mineral associations. Both single mineral and polymineral inclusions are found. Some garnet grains contain a great number of chromdiopside and cromspinelid inclusions. It provides an imitation of rock fragments. The chromdiopside as elongated grains of irregular flattened shape is usually found in the periphery pyrope zone, in cases it forms the discontinuous cover around pyrope grains. Spinelid inclusions are characterized by a greater idiomorphism as opposed to clinopyroxenes. They are round, in cases irregular. The inclusions with octahedron sides and smoothed edges can be observed.

The compositions of representative garnet collection as well as inclusions, which are contained in garnets have been studied. The analyses were done on an electron microprobe.

Garnets by the classification of Dawson, Stephens (Dawson, Stephens, 1975) belong mainly to 9 and partly 12 groups and are mainly of lherzolite paragenesis. When Cr_2O_3 and CaO contents vary in a wide range (1.33-9.57 and 1.86-10.99 wt%), garnets are marked by a relatively constant MgO and FeO contents. In minals the garnet composition variations due to the decrease of knorringite and uvarovite minals under a corresponding growth of pyrope minal. The majority of studied garnet grains turned out to have inhomogenous composition. The garnet zonal patterns is expressed in a decrease of Cr_2O_3 and CaO contents, which is directed to the grain periphery. Despite a common similarity of trends, garnets from different pipes differ in features of oxide distribution and average composition characteristics. So, trends of garnet composition in the triangle coordinates Ca-Fe-Mg for the Zagadochnaya and Kusov pipes turned out to be displaced towards a higher iron content as opposed to the garnets from Bukovinskaya and Gornyat'skaya pipes. On the other hand, distinctive difference is available between the garnets of two neighboring pipes (Zagadochnaya and

Kusov). This difference is in a maximum content of zonal garnets of the first pipe and a relatively small variations of Cr_2O_3 and CaO contents in the second pipe.

Clinopyroxenes from the inclusions in garnets belong to the ureyite diopsides (Stephens, Dawson, 1977), showing a significant variations of almost all oxides and primarily such as Cr_2O_3 , Al_2O_3 and Na_2O (1.13-5.19; 0.46-5.52; 1.0-6.17 mass %, correspondingly). Pyroxenes are marked by high $\text{Mg}/(\text{Mg}+\text{Fe})$ and $\text{Ca}/(\text{Ca}+\text{Mg})$ values, varying in ranges 87.71-95.31; 45.53-50.77, correspondingly. The latter values indicate relatively low temperature (nearly 800-1000C by Finnerty, Boyd, 1984) of clinopyroxene crystallization. The variation of composition of different inclusions within one garnet is not available or insignificant. Distinctive features of diopside composition distribution are found in different pipes. For instance, mainly high-temperature diopside varieties with the increased Cr_2O_3 , Al_2O_3 and Na_2O contents are found in Zagadocnaya pipe, while in Kusov pipe low-temperature varieties are predominant. A direct correlation of composition of clinopyroxenes and co-existing garnets is observed. There is a markedly high correlation from $\text{Cr}/(\text{Cr}+\text{Al})$ ratio.

Chromspinelids. Judging from a two-peak histogram of spinel composition distributions two groups are revealed: 1) high-chromous ($\text{Cr}_2\text{O}_3 = 50-61.6\%$) and 2) aluminiferous ($\text{Cr}_2\text{O}_3 = 20-47.7\%$). A higher correlation of compositions between spinelids of group I (as opposed to group 2) and the co-existing garnets and in particular clinopyroxenes, is observed. Within one garnet grain spinelids either preserve a constant composition or (in rare cases) insignificantly change from Cr/Al ratio. The heightened content of magnetite minal (mainly within 7-15% range) is common to both spinelids of group 1 and group 2. It indicates comparatively oxidizing conditions of crystallization.

Discussion. A significative feature of composition for the majority of garnet phenocrysts and containing inclusions is their inhomogeneity, suggesting the non-equilibrium of crystallization conditions. On the whole, zonal garnets are scarce, however in some pipes (Sobolev, 1974; Sobolev et al, 1997; Egorov, 1986) they exist. It should be noted that the maximum content of zonal garnets is found in high-magnesium kimberlites. As a rule zonal garnets are marked by a common trend of composition, indicating an increase of iron content from the center to the grain margin and coinciding with the trend of kimberlite crystallization differentiation. The change of composition of garnet zones is accompanied by a change of mineral parageneses. In the studied association a common trend of mineral composition follows towards the decrease of knorringite minal content in garnets and increase of $\text{Ca}/(\text{Ca}+\text{Mg})$ ratio in clinopyroxene. It suggests the crystallization of minerals when temperature and pressure fall.

The absence of orthopyroxene and olivine in the association hampers an exact evaluation of pressure. However, the features of composition for the studied minerals suggest their crystallization in high pressure. It is primarily true for the garnets of essentially pyrope composition, containing knorringite minal (up to 10%). The high pressure is confirmed by clinopyroxenes, containing high share of Al^{VI} , increased concentrations of jurite minal and by low titanium and relatively low-aluminiferous (7-10% Al_2O_3), high-chromium composition of major part of chromspinelids. Minerals of similar composition are frequently associated with diamonds (Sobolev, 1974; Stephens, Dawson, 1977).

The above high-chromium association is very similar to chromite-pyroxene-garnet intergrowths from Mir pipe, studied by N.V. Sobolev (1974). Such features of intergrowths as a common high chromium content of minerals and high oxidation of iron in chromites make them different from widely-spread peridotite xenoliths. However, high-chromium associaion of these minerals is also found (Sobolev et al, 1997) in the mantle xenolith of Mir pipe. According to authors opinion, the origin of this association is connected with metasomatism on the mantle deep as a result of kimberlite magmatism.

The non-equilibrium conditions of crystallization of the garnet-jurite diopside-chromspinelid association suggest phenocrysts origin. This conclusion is verified by the following arguments: a) absence of xenoliths of ultramafic composition in pipes; b) individual characteristics of association mineral composition for each pipe; c) presence of chromdiopside phenocrysts, which demonstrate trends of composition up to a complete disappearance of jurite and jadeite minerals (Egorov et al., 1992). The authors made a conclusion on crystallization of chromdiopside phenocrysts from kimberlite melt.

As this conclusion is of a principal significance for the material discussed, the argumentation, which was taken by the authors, is appropriate to be given. Some clinopyroxene varieties (ureyite diopside, chromdiopside, diopside, ferruginous diopside), which are characterized by a continuous trend, are found in Zagadochnaya pipe. The earliest high-temperature clinopyroxene generations, enriched in ureyite and jadeite minerals, compose relatively large phenocrysts (up to 5-8 mm long). The chromdiopside with the decreased Cr_2O_3 , Na_2O and Al_2O_3 contents form the phenocrysts up to 3-4 mm long, and diopsides have small size (0.5-1 mm). The diopside microlites composing the kimberlite groundmass are found. However they are completely replaced by carbonate-serpentine aggregate. Relics of crystallographic shape can be in cases found in all clinopyroxene varieties. Clinopyroxene phenocrysts frequently contain small inclusions of phlogopite, chromite and pseudomorphs of serpentine from olivine. The above minerals, occurring as independent porphyry insets in the kimberlite, frequently comprise isometric clinopyroxene inclusions. In addition, glomeroporphyritic intergrowths, out of 2-3 clinopyroxene grains and pseudomorphs after olivine are observed in the mesostasis of rocks. The above features of clinopyroxene occurrence and composition in kimberlites (when deep xenoliths of ultramafic composition, capable to provide a similar (in terms of composition) material under desintergration are absent) are strong arguments in favor of the conclusion on phenocryst origin.

The studied garnetiferous association is the beginning of kimberlite melt crystallization.

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