Chemical-genetic classifications of oxides from kimberlite groundmass as a basis of a new technology of evaluation of diamond potential of kimberlite bodies (on an example of Yakutian and Arkhangelsk diamondiferous provinces)

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Introduction

Until now, for searching of diamondiferous kimberlites, the evaluation of their diamond potential were applied technologies, in the basis of which were fixed typomorphic features of minerals from inclusions in a diamond and diamondiferous xenoliths of mantle rocks of an ultrabasic assosiation (pyrope, olivine, pyroxene, chromite and ilmenite). As an example it is possible to recommend simple classifications for pyropes and chromites (graphs CaO - Cr_2O_3 for garnets and TiO_2-Cr_2O_3 for chromites with the allocated area pyropes and chromites from inclusions in a diamond and dunite-harzburgite diamond-bearing paragenesis, Sobolev, 1974).

The modern classifications were developed on the basis of a database of garnet chemical compositions from various types of mantle rocks and kimberlites (Dawson, Stephens, 1975) with allocation of group high chromium and low calcium garnet (G-10) of diamond-bearing paragenesis and on the basis of new offered chemical-genetic classifications of garnet, olivine, chromites and ilmenite from inclusions in a diamond, diamondiferous rocks and other types ultrabasic and basic rocks with allocation of groups these minerals of diamond-bearing paragenesis (Garanin et al., 1991).

As it is established now, among diamondiferous kimberlites were found such rocks, which have extremely a low output of minerals of heavy fraction (for example, Arkhangelskaya diamondiferous province). On the other hand, the minerals from the kimberlite groundmass can give a very important information about diamond potential of kimberlite bodies (Garanin et al., 1986, 1987; Garanin, 1991), because dynamics of kimberlite melt rising is reflected as on evolution of minerals from kimberlites, as a diamond.

The diamond deposit laboratory at MSU during many years large attention gave to study of oxides minerals from the groundmass of kimberlite bodies with a different diamond potential. Determination of ratio of different oxide minerals from the groundmass and their chemical composition features were a main goal of such investigations.

Main results of study and their applications for evaluation of diamond potential of kimberlite bodies

For kimberlite bodies of the Yakutian diamondiferous province, the most sensitive criteria of their diamond potential are spinels and ilmenites from the kimberlite groundmass, particularly quantative ratio between these minerals and relationships of such oxides with rockforming minerals of kimberlites.

Oxides minerals from the groundmass of 20 Yakutian kimberlite pipes (from 6 different kimberlites fields, from central parts of province to its northern edge) were studied. There are various evolutionary trends of spinels and ilmenites from the groundmass of kimberlites with different content of Mg in kimberlite melt. Established trend features precisely correlate with a of diamond potential of pipes.

The first is trend of spinels for high-magnesian kimberlites (with the low content of minerals of ilmenitic mantle rocks in heavy fraction). It is pipe Aikhal with high diamond grade and non-diamond-bearing pipe Obnazhennaya. They have uniform evolutionary trend from picrochromites

with 57-58 mas.% Cr_2O_3, 2% TiO_2 for Aikhal pipe up to Ti-containing picroferroferrichromites with 41% Cr_2O_3 and 7-8% TiO_2 for Obnazhennaya pipe. For magnesian-ferriferous kimberlites (Mir and Udachnaya pipes with high diamond grade; Dachnaya, Dal'nyaya, Leningradskaya pipes and others pipes with low diamond grade, Grenada pipe non-diamond-bearing), in which in heavy mineral concentrates are widely submitted chromites and ilmenite, are precisely allocated two equal trends: spinelic and ilmenitic ones. The spinelic trend begins from midium-chromium picroferrochromites with 49-52% Cr_2O_3 and 2,5-5,5 % TiO_2 for diamondiferous pipes; from midium-chromium picroferrichromites with 42-44% Cr_2O_3 and 5-7% TiO_2 for low diamond bearing pipes; from magnesian Cr-bearing ulvospinel (37-38% Cr_2O_3 and 9-10% TiO_2) for non-diamond-bearing pipes. All these trends are completed by titanomagnetite crystallization for picritic pipes (Velikan, Montichellitovaya) are typical Cr-bearing ulvospinels with 21-24% Cr_2O_3 and 10-13% TiO_2 are typical. Ilmenitic trend begins from picroilmenites for diamondiferous pipes. For non-diamond-bearing pipes is only characteristic Mn-containing ilmenite. Only one ilmenitic trend with predominantly distribution of Mn-containing ilmenite is established for magnesian ferrriferous-titanian non-diamond-bearing kimberlites with low contents pyropes and chromespinels and with high content of ilmenite (Morkokka pipe).

The database was created on the representative set of full electron-probe analyses (more than 1000) spinels and ilmenites from the groundmass of all studied kimberlites, objects with a different diamond potential and picrites. The claster analysis of these analytical data was done, and on allocated groups of ilmenites and spinels chemical-genetic classifications were developed for these minerals, some of them correspond to diamond-bearing kimberlites with different diamond grade and non-diamond-bearing rocks. With application of discriminate functions for all chemical-genetic groups new technology of evaluation of diamond potential of kimberlites on the basis of features of chemical composition of spinels and ilmenites from the kimberlite groundmass is offered .

The technology of diamond potential evaluation **of kimberlites bodies of the Arkhangelsk province** differs from developed for Yakutian one. Kimberlites of Arkhangelsk province are more magnesian, and an output of heavy mineral concentrates is very low for them. This province is more contrastic on zonal structure. In heavy mineral concentrates of pipes of diamondiferous Zolotitskoye field (M.V. Lomonosov deposit) are submitted minerals of an ultrabasic rocks: chromespinels and pyropes at complete absence of ilmenite. A following field is Verkhotinskoye one. It is similar on a composition and ratio of minerals of heavy mineral concentrate with kimberlites of Zolotitskoye field, but with more low diamond grade. From east edge these two fields neiboured by bodies of Kepinskoye and Soyanskoye fields, for which products of desintegration of ilmenitic ultrabasic rocks (ilmenite and red-orange garnet) are characteristic. In these fields, as well as from south are allocated the groups of melilitite bodies. These fields of kimberlites and melilitites are very low diamond-bearing or non-diamond-bearing ones.

Study of oxide minerals from kimberlite groundmass has specified well advanced differentiation of kimberlite rocks at transition from the bodies of Zolotitskoye diamondiferous field to the pipes of low grade or non-diamond-bearing Kepinskoye field. The kimberlite groundmass of the pipes of Zolotitskoye field have only Al-Ti-containing chromespinels (more than 70%), sometimes with thin rims of the chromium ulvospinel (30%),and the diamonds in the form of rombododechaedron form (about 50% of gem's quality). In pipes of Verkhotinskoye field all rare grains Al-Ti-containing chromespinels (5%) are unhomogeneous with the development of titanomagnetites in the rims. Separate grains of titanomagnetites are prevalence in the kimberlite groundmass (95%). All rare crystals of a diamond are resorbed ones, down to formation of the skeletal forms. In pipes of Kepinskoye and Soyanskoye fields there are rare zoning grains Al-Ti-containing chromespinels (2%); Mn-containing ilmenite (5%); rutile (43%), sometimes in aggregated with ilmenite;

titanomagnetite (50%). The rare grains of a diamond and their aggregates are resorbed and are submitted by fragments.

The claster analysis of a database of spineles (500 analyses) and the developed chemical-genetic classification have shown that only kimberlite rocks of diamondiferous Zolotitskoye field have group high-chromium picrochromite (56% Cr_2O_3, 2% TiO_2 and 6,5% Fe_2O_3). Thus, a typomorphic features of chemical composition of chromespinels are used in this classification as mineralogical criterion of evaluation of diamond potential, and the presence of titanomagnetite, ilmenite and rutile - as a negative attribute of diamond grade.

Complete evolutionary trends of chemical composition variation for spinels, a wide distribution of zonal grains and separate grains of titanomagnetite, the presence of ilmenite and rutile at a kimberlite groundmass are the indicators of high oxidizing potential, which at long process of kimberlite body formation in high-temperature conditions promotes solution and destruction of a diamond, that can sharply lower diamond potential in the object.

Thus, for estimation of potential diamond grade of kimberlites of Arkhangelsk province original technology is used, in the basis of which chemical-genetic classification of chromespinels lies, and for evaluation real diamond are involved yet the whole number of attributes of a chemical and phase composition variations of oxide minerals at increasing oxidizing potential during of all history of kimberlite rocks crystallization.

References

Garanin, V.K., Kudriavtseva, G.P., Mikhailichenko, O.A., 1986, Mineralogy of ilmenite from the kimberlite groundmass: Mineralogy of kimberlites and related rocks, VINITI, Moscow, # 6967-B86, p. 180-207.

Garanin, V.K., Kudriavtseva, G.P., and Mikhailichenko, O.A., 1987, Mineralogy of spineles from the kimberlite groundmass: Mineralogy and Petrology of kimberlites, VINITI, Moscow, # 7087-B87, p. 37-130.

Garanin, V.K., 1991, Mineralogical zoning of kimberlites: Izvestiya VUZov., Geology and Razvedka, # 9, p. 38-49.

Garanin, V.K., Kudriavtseva, G.P., Marfunin, A.S., Mikhailichenko, O.A., 1991, Inclusions in diamond and diamond bearing rocks: MSU, 240 p.

Sobolev, N.V., 1974, Deep-seated xenolithes in kimbelites and problem of upper mantle structure: Science, Novosibirsk, 264 p.

Dawson, J.B., and Stephens, W.E., 1975, Statistical analysis of garnets from kimberlites and associated xenoliths: J. Geol., Vol.83, p. 589-607.