МІНЕРАЛОГІЧНИЙ ЗБІРНИК MINERALOGICAL COLLECTION
2007. № 57. Вип. 2. С. 35–45 2007. N 57 (2). P. 35–45

УДК 549

CRYSTALLOMORPHOLOGICAL FEATURES OF SOME SECONDARY MINERALS OF KIMBERLITES

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Crystallomorphological characteristic of some kimberlite secondary minerals, which were formed during postmagmatic stage of these rocks' transformation, is given by the results of complex investigations. Diversity of morphological forms of individual mineral-neoformations in kimberlites emphasizes complexity of postmagmatic minerogenesis processes in diatremes of this composition. Employment of complex research methods of crystallomorphological features of kimberlite secondary minerals made it possible to receive new information about their typomorphic properties, which enables much wider applied usage of the received materials.

Key words: kimberlites, secondary minerals, crystallomorphology, postmagmatic minerogenesis.

Earlier investigations revealed that significant changeability of material composition parameters is a characteristic feature of kimberlite rocks in various regions of the world. Changeability of material indications in the volume of kimberlite bodies in many respects is related with poligenous and heterochronous component properties of composing pipes rocks, which embrace the condition range of formation from upper mantle through pneumatolytic-hydrothermal stage to hypergenesis. Our investigations revealed that complexity and contrast character of mineralogical appearance of real kimberlite rocks were greatly conditioned by the development of secondary minerals complex. In our understanding neoformations of kimberlites include all minerals that were formed from thermal solutions which imply not only postmagmatic juvenile ones but the solutions which originated both in the period of pipe formation and at its much later stages. It should be noted therewith that the margin between primary and secondary minerals of kimberlites in some cases to some extent is relative [1–4].

Carried out investigations revealed [5–9] that serpentine and carbonates, which mostly compose these rocks, are the main secondary minerals of kimberlites. We [5] subdivided kimberlite formation into two sub-formations – proper kimberlitic (with fresh unaltered grains of primary minerals) and apokimberlitic (in which primary minerals nearly completely were replaced by mineral-neoformations) ones. Accessory ones include all other minerals which were formed at various stages of kimberlite pipes' formation. While studying in complex kimberlite rocks of Yakutia, Africa, Ukraine and other regions we noted and investigated silicates (serpentine, phlogopite, chlorite, vermiculite, talc, montmorillonite, sepiolite, thaumasite), carbonates (calcite, dolomite, aragonite, pyroaurite, shortite, strontianite, magnesite, hydromagnesite, khantite), oxides and hydroxides (magnetite, hematite, goethite, amakinite, quartz, chalcedony, chalcopyrite, tochilinite), sulfates (anhydrite, gypsum, celestine, barite, epsomite, metabasaluminite, brochantite), halogenides (halite), phosphates (francolite), borates (yekatirinite, ferrosibeliite) and bitumen. So far as individual secondary minerals have been noted in dense clusters or in a fine-dispersed form, then we shall pay essential attention in the present work only to well crystallized, amenable to crystallomorphological investigations neoformations of kimberlites. Investigation of crystallomorphological features of individual secondary minerals of kimberlites was carried out together with B.P. Antonyuk, S.S. Matsyuk and Y.M. Mel'nyk [1, 11–13].

Serpentines, constituting about half of Yakutian kimberlite bodies' volume, are most distributed in the class of silicates, which distinguishes them from similar formations of Africa and East-European platform, where the content of this group minerals does not exceed 10 % in average. The prevailing majority of serpentine particles is represented by individuals of submicroscopic size. Antigorite is the exception. The size of chrysotile particles and especially of lizardite is so small that is close to micron and aggregates become optically isotropic or sub-isotropic. And only X-ray photographs record availability of order in the arrangement of separate, composing these particles atoms. The shape of serpentine particles is determined by its crystalline pattern, which for all varieties at present is determined sufficiently precisely [3, 4]. Stronger interaction of atoms at some sites of individual and poor interaction at other sites in elongated along axis *a* wavy layers of antigorite result in the occurrence of additional cohesion. Lizardite, which practically always contains isomorphic impurities of cations, usually with smaller ion radius and larger charge, with unit cell consisting of one layer as a rule, crystallizes in the form of flat particles. In contrast to this purely magnesia chrysotile due to inconsistency of tetrahedral and octahedral patterns forms rolls the axis of which is always oriented in a certain direction of mineral structure, which manifests in the arrangement of optical indicatrix.

Phlogopite and products of its alteration are broadly distributed in individual kimberlite bodies of Yakutia and other regions, especially in micaceous kimberlites where this mineral plays the role of rock-forming one. On the whole not less than three generations of phlogopite [16] are distinguished in kimberlite rocks. The first generation is represented by phenocrysts of tabular and oval shapes with the size from several mm to 5 cm. The sizes of segregations in individual bodies are different. Phlogopite of the second generation forms in the basic mass of rocks fine (up to 2 mm) lamellar and scaly crystals. Isometric, idiomorphic, pseudohexagonal plates and elongated mica lamellae are distinguished. The third generation is represented by flaky phlogopite with the size of flakes not more than several mm. Contours of such flakes are irregular and the ends look like ragged. The first two generations of phlogopite are colored in gray, brown or greenish-brown color, the third one has gray, yellowish-gray, golden or whitish coloring. In contrast to phlogopite of the basic mass of kimberlites megacrysts of this mineral have 4–5 cm size. Dark-gray colouring and rounded shape with corroded edges are peculiar to them. Phlogopite is also included in composition of some type xenoliths – pyroxenites, peridotites, ilmenite-garnet ultrabasites, and also forms nearly monomineral rocks – glimmerites.

Sepiolite was found in a number of Yakutian kimberlite pipes in the form of macroscopic fine-fibre yellowish-greenish segregations with glassy luster, characterized by straight extinction and positive elongation. The mineral was found only in kimberlite breccia with massive texture of pipes International, Mir, Vostok, Snezhinka, Zapolyarnaya etc. It is usually confined to fissuring zones of kimberlite breccia where together with calcite it forms veinlets of zonal structure with thickness from 0,2 to 5,0 cm. The mineral composes endomorphs of veinlets and their central parts in the form of elongated lenticular nests of 3–5 mm size. Its fibers are oriented in parallel to veinlet contacts. In veinlets of larger thickness calcite is represented mainly by contacting crystals up to 2 cm size forming sometimes brushes on walls of fissures. Calcite crystals in separate cases are covered with envelope of sepiolite of twisted-fibrous structure the thickness of which often varies from 0,5 to 2,2 mm. In kimberlite rocks sepiolite is formed together with calcite during the final low-temperature stage of kimberlite bodies' formation. In kimberlites with massive texture therewith, characterized by prevalence of serpentine over carbonate minerals in the basic mass of rocks, sepiolite is deposited in fissures, and in autolithic texture kimberlites with prevalence of carbonates in the basic mass low-temperature secondary calcite develops along the fissures. In our opinion [3, 4] it is explained by the fact that low-temperature hydrothermal solutions in kimberlites with massive texture are more enriched with magnesium, which is leached from the rocks of this variety and is redeposited in the form of sepiolite in their fissures. And kimberlites with autolithic texture saturate hydrothermal solutions mainly with ions of calcium, which further is crystallized in veinlets in the form of calcite.

Calcite is one of the most general minerals of **carbonate** class in kimberlites of Yakutia [4, 9, 12]. The mineral is often observed in the form of irregular grains and their aggregates in the basic mass of rock. Calcite aggregates of irregular shape are also included in composition of pseudomorphs on olivine. Lath-like and columnar segregations of the mineral, confined to the basic mass of rocks, are of sufficient distribution. They often create certain fluidity. Rather often segregations of calcite in the form of veinlets or nests occur in kimberlite pipes, and in some pipes (Udachnaya, Yubileynaya, etc.) spherical segregations of calcite with 1 mm size of some spheres were revealed [9, 12]. Often concentrically zonal half-spheres are recorded, with grown crusts of other minerals (quartz, sepiolite, bitumen etc.) on their surfaces. Veins and nests of calcite in kimberlites are often infilled with well faceted crystals forming druses. We [4] have revealed that scalenohedra and rhombohedra were most frequently occurring simple forms of the mineral in kimberlites. Goniometric investigations carried out by B.P. Antonyuk indicated large variety of calcite crystallographic forms in kimberlites of different Yakutian pipes [1]. Sometimes veinlets of calcite pierce porous to different degree kimberlite. Calcite forms here elongated grains oriented perpendicularly to the surface of kimberlite with which it has sharp contact. The mineral in this case is colored in greenish hues of various intensities. We have noted acicular formations of calcite in kimberlites of deep levels of pipes Mir and International. The needles most often are represented by turbid calcite due to inclusion of ore minerals.

Basing on complex investigation one can distinguish [4]: a) early (abyssal) primarily magmatic calcite (inclusions in deep-seated minerals), being formed from primary water-silicate-carbonate magma; b) abyssal metasomatic calcite – product of upper mantle metasomatism of deep-seated rocks; c) proper "kimberlitic" calcite, crystallization of which is related with various processes of kimberlite bodies' formation. The latter can be subdivided, by method and time, into "kimberlitic" calcite composing the basic mass of rocks, "metasomatic" calcite – product of carbonatization of some minerals and rocks – and late hydrothermal calcite infilling cavity-fissure formations. On the whole calcite may be referred to "through" but polygenetic minerals of kimberlitic process, comprehensive investigation of which may give new information about nature and specifics of this process at its various stages. However it is important to ascertain whether calcite of this or that stage of kimberlite formation carries information about composition of abyssal water-silicate-carbonate fluid or it reflects only geochemical specialization of hosting the pipes rocks. It should be noted also that the process of calcite crystallization even within these formations was rather complicated and multistage. Quite often up to three generations of calcite can be revealed in one and the same geode, and they differ in size, morphological features, set of inclusions, type of zonality, colouring and, as it turned out later, in luminescent properties. Frequency of occurrence of the same associations in various kimberlite bodies, types of kimberlites, their different levels and sites may serve as convincing confirmation of calcite-bearing formations' stability (resistance). However quantitative relationship between mineral phases and form of segregations can substantially change at this.

Dolomite in kimberlites of Yakutia forms fine-grained aggregates in the basic mass of rock, as a rule, associating with calcite and serpentine. Dolomite has been found in vein formations of a leaching zone as well. Only in individual kimberlite pipes (Sytykanskaya, Yubileynaya, Molodost' etc.) the mineral is in such concentrations that allow considering it rock-forming. According to available mineralogical data formation of dolomite in time covers a rather wide interval: the beginning of metasomatism processes of upper mantle rocks (availability of dolomite inclusions in titanium-clinohumite and K-richterite) – final stages of hydrothermal processes in cavity-fissure formations of the cooling "kimberlitic" melt. According to classical conceptions about mechanisms of dolomite crystallization in nature various salts and sulphates may be peculiar catalysts of dolomite formation. It is by this in the first turn that one can explain the increased dolomite occurrence frequency in the form of finely aggregate intergrowths with anhydrite, celestine and calcite, as well as extremely rare cases of its proper segregations in kimberlites on the whole.

Aragonite forms veinlets, nodular aggregates of radial-beam and sheaf-like structure, druses of acicular crystals in kimberlites of individual pipes. Crystals of aragonite are usually well faceted. Goniometric investigations revealed [1] two approximately equally developed forms of mineral crystal; rhombic dipyramid and prism giving aragonite acicular habit. In individual cases (pipes Yubileynaya, Zapolyarnaya, Poiskovaya, Novinka etc.) fine veinlets are composed by aggregates of aragonite, close to spherical. Lumpy surface of such veins resembles wandering aggregates. The mineral is usually colorless, and in aggregates it is white with silky luster. Among separate spheres aggregates of serpentine, carbonates and other neoformations are recorded.

*Pyroaurit*e in kimberlite rocks of Yakutia is found [6, 14] in the form of veinlets and nests of fibrous and crystalline appearance. Besides the development in the basic mass of rocks within pseudomorphs on olivine in xenoliths of various rocks, bluish and bluish-green segregations of pyroaurite are often observed in veinlets (pipes Mir, Sytykanskaya, Zapolyarnaya, Poiskovaya, Prognoznaya etc.). Pyroaurite together with serpentine often composes large (up to 6–7 cm) greenish-gray geodes. On deep levels of many pipes (Mir, International, Udachnaya, Yubileynaya etc.) in association with calcite and serpentine pyroaurite is found in the form of individual bluish-green rhombohedral crystals and sometimes in the form of spherical and fibrous formations, composing thin veinlets and individual geodes. Besides fibrous pyroaurite lamellar variety, performing the loop cores of serpentinous olivine or cavity of leaching, is also common for kimberlites and xenoliths of deep-seated rocks. Pyroaurite is distinguished in kimberlite rocks of Yakutia in the form of crystals of two habits: rhombohedral and pinacoidal. Similar development of all facets (rhombohedra and pinacoids) is peculiar to the first type that is why crystals obtain pseudo-octahedral appearance. Facets of pinacoid prevail in crystals of the second type. Crystals of pyroaurite of both forms may occur in one and the same sample. Coloring of the mineral at this is usually non-uniform. Its fibrous diversity is colored mainly in pale-blue color and lamellar – in blue-green. Altered crystals obtain brown hue. On the whole broad distribution of pyroaurite is established in kimberlite rocks of Yakutia with pyroauritization typical for deep levels of deposits at this, where this mineral is often a rock-forming component.

Strontianite occurs in kimberlite rocks of many pipes of Yakutia and Africa. Quire often the mineral forms fan-shaped druses or entire accumulations of acicular crystals. Strontianite usually associates with celestine growing on its surface. The facets of Celestine crystals often discover features of partial dissolution. According to X-ray investigations the mineral from kimberlites of Yakutia is referred to calciostrontianite [4].

Magnesite is found in upper levels of many Yakutian pipes, as a rule with other neoformations [4]. It usually associates with khantite composing fine veinlets or occurs in brucitizated kimberlites. *Hydromagnesite* is noted in the form of white wandering porous aggregates on various minerals and neoformations in upper levels of many Yakutian pipes. Its crystals are noted [4] in geodes, as a rule aqueous-transparent elongated-tabular of lath-like appearance.

Khantite is discovered [4, 10] in a number of kimberlite pipes (Sytykanskaya, Zapolyarnaya, Marshrutnaya, Poiskovaya, Novinka, Molodost') where it infills multiple fissures in upper levels. Thickness of veinlets varies from sub-millimetre to 5 cm. In individual pipes (Zapolyarnaya, Novinka) the veinlets occur in large quantity down to the depths about 100 m from the surface. The mineral in veinlets is represented by thin-dispersed white powdery aggregate resembling chalk. It is coloured by hydroxides of iron in brownish and cream hues in near-surface parts of pipes.

In the class of oxides and hydroxides *magnetite* is a broadly distributed mineral in kimberlite rocks of many pipes, where it is scattered in the basic mass of rocks and is noted in the form of irregular segregations, concretions and geodes, as well as in individual serpentine pseudomorphs. It also forms fine (up to 2,5 mm) or branching (up to 5,0 mm) veinlets with illegible outlines. Octahedral crystals of this mineral associate with calcite, barite, and serpentine in geodes and concretions, as a rule. Pelitomorphic magnetite also usually deposits around phenocrysts and along edges of serpentine veinlets. One can observe mutual transitions of magnetite with sulphides of iron in most cases. Branching veinlets of magnetite-serpentine composition with 3–5 mm thickness prevail in individual pipes. Two most important morphological varieties of magnetite are distinguished in kimberlite bodies of most diamondiferous regions of Yakutia: coarse-grained aggregates (quite often of radial-beam structure) or growths of crystals, less frequently individual crystals; b) accumulations of fine-grained magnetite, which either form irregular nests in rock, bands and lenses, or are evenly distributed in it.

Quartz and chalcedony are the characteristic secondary kimberlite minerals of various regions in the world. These minerals are typical enough for kimberlite pipes of Yakutia. Thus, for instance, increased concentrations of quartz in pipe Udachnaya, as our investigations [3, 4] indicated, are confined not only to its most upper levels (especially to greatly weathered parts of western body) but to near-contact zones at much deeper levels as well. Quartz is often found together with calcite and other secondary minerals, forming brushes, veins and veinlets. Quite often one can observe crystals of quartz on quartz-opal-chalcedony substrate directly on altered to different degree kimberlite rock. The size, shape and morphology of quartz individuals are most different [4]. Characteristic feature of most investigated quartz crystals – sculptured nature of all facets, stipulated most probably by processes of dissolution and by availability of multiple inclusions of pyrite, marcasite, goethite and other secondary minerals. Both colourless and coloured in various brown, gray and purple tints quartz may be found. Brown and grey colours of the mineral are allochromatic and are stipulated by mechanical impurities of iron hydroxides (brown) or microinclusions of iron sulphides (grey). In all cases heads of crystals are coloured more intensively. Chalcedony is characteristic enough for kimberlites of pipe Udachnaya (especially its upper part). Quite often it is from chalcedony that crystals of quartz start growing, heads of which form druses. In case of pseudomorphs' formation the finest (pelitomorphic) particles of chalcedony are located on the surface of the first ones. The particles form a narrow, but of nearly constant thickness (up to 1 m) zone going in parallel to the facet surface of pseudomorphs. The colour of the zone is white in the result of significant isolation of particles. Towards the centre of pseudomorphs this zone gives place to the band of fibrous (acicular) chalcedony. The zone of fibrous chalcedony is colourless, which testifies about complete intergrowth of some individuals. The contact between the said zones is direct, sharp. The size of pseudomorphs in druse reaches 2 cm. "Crystals" of up to 1 cm size prevail. The surface of facets is weakly coarse. On the whole facets of pseudomorphs are developed very unevenly, in the result of which the crystals (and pseudomorphs correspondingly) are greatly distorted. Usually facets of octahedron prevail. The facets of other morphological forms have subordinate structure or are completely absent.

Brucite was noted [4, 17] in the form of asbestos-like veins of light-grey colour (nemalite). The mineral is revealed by us in individual blocks of pipe Udachnaya eastern body where it is often one of rock-forming minerals of the basic rock mass. The size of the blocks, enriched by brucite, reaches sometimes 50–60 mm in the central part of the eastern body. The content of this mineral in such sites often prevails 60 %. Crystals of the mineral are rare. In the thin section it is often noted in the form of parallel-fibrous aggregates, which, besides fibres, may represent crosscut front of broken according to cleavage tabular individuals. Brucite either develops on olivine directly or a narrow spacer of serpentine forms between them. Quite often brucite replaces not only grains of olivine but also partially other deep-seated minerals of kimberlite (garnets, pyroxenes), the basic mass of rock, and xenoliths of ultrabasic composition abyssal rocks as well. Individual veinlets of the mineral cross xenoliths of hosting carbonate and terrigenous-carbonate rocks and segregations of crystalline schists of the basement as well. Individuals of brucite are oriented, as a rule, in one direction. In contrast to serpentinization relic structure and texture practically do not preserve in the process of complete substitution of initial kimberlite minerals by brucite. Only relics of some stable minerals and also blurred outlines of olivine phenocrysts remain. All these testify about complete recrystallization of original rock accompanied by removal of silicic acid [4]. Despite the fact that brucite partially is formed during kimberlite serpentinization, brucitization represents a separate metasomatic process for which removal of silicic acid and iron is typical, as well as the appearance of purely magnesia hydroxide represented by aggregates from oriented individuals.

Sulphides are broadly distributed in kimberlite rocks of Yakutia and Africa. They are often found in veins and veinlets, as well as in the basic mass of rock. Besides sulphides of iron sulphides of other metals (sphalerite, galena, millerite) are widespread. Some of them are formed exclusively in the form of granular (chalcopyrite) or hair-like (millerite) aggregates. Most form druses or individual crystals in bulges of carbonate veins and veinlets. We have studied morphological features of sulphide crystals on the material from kimberlite pipes Mir, Udachnaya, Yubileynaya, Prognoznaya, Botuobinskaya, Nyurbinskaya etc.

Pyrite forms both entire masses and aggregates in kimberlite rocks and individual crystals and their druses. The mineral is mostly widespread in the tops of kimberlite pipes to different degree altered by hypergene processes. The mineral often infill veinlets in fissures associating with other formations. Druse aggregates of cubic crystals are present. Spherulite aggregates of the mineral directly in the basic mass of rock are noted. Quite often several generations of pyrite are distinguished: the first generation of cuboctahedral habit with mosaic-block structure is localized in fissures infilled with druses of light-brown calcite as well. Pyrite of the second generation is much smaller, growing on other minerals. Pyrite, sharply prevailing over other sulphides in terms of quantity and by the number of cut individuals, is represented by two habit forms – cube and octahedron. Facets of cube often blunt the tops of octahedral crystals. Crystals of cubic habit are seldom complicated by facets of octahedron, which as a rule have subordinate meaning. Crystals of cubic and octahedral habits are often met in one druse and their age relations are not always clear.

Sphalerite is discovered in some upper part levels of kimberlite pipes Mir, Novinka, Prognoznaya, Komsomol’skaya-Magnitnaya in associations with other sulphides. It was found together with calcite in individual veinlets and at much deeper levels of the same pipes. Sphalerite is noted in some types of inclusions of ultrabasic rocks as well. The mineral forms idiomorphic crystals on walls of fissures. It often composes solid masses and segregations of irregular form in altered kimberlites. Sphalerite has black or dark-brown colour with diamond shine. Parameter of a sphalerite unit cell (a_0 = 0,8411 nm) emphasizes its purity in individual monomineral segregations. Tetrahedral crystals of the mineral were noted in a small cavity in solid kimberlite of pipe Udachnaya. Besides tetrahedron facets other simple forms are present, which could not be identified due to corroded surface. Crystals of sphalerite with even shining facets have also been found. Positive and negative tetrahedra are the simple forms here.

Galena was found in small quantity only in upper parts of some kimberlite pipes (Mir, Krasnopresnenskaya, Yubileynaya, Sytykanskaya etc.). The following crystallographic types of galena were revealed: a) octahedral one with subordinate development of cube and rhombic dodecahedron; b) cubic, where facets of octahedron and rhombic dodecahedron are subordinate; c) cuboctahedron. Galena is usually in association with crystals and grains of calcite, segregations of pyrite and sphalerite. Among secondary formations of pipe Mir galena is often noted as forming well cut crystals of the same morphological types which were mentioned above, but cuboctahedral individuals with approximately similarly developed facets {100} and {111} are observed comparatively seldom. Besides, there are hexahedral crystals on which small in area facets {331} and {721} are developed. Octahedral and cuboctahedral crystals are the most widespread ones. Spikes of complicated outline within which there are always the sides parallel to one of the edges are usually developed on facets of octahedron. The facets of individual octahedron crystals are comparatively flat, less frequently concave, lustreless.

Millerite has been noted in many pipes in the form of impurity in neoformations of sulphides and sometimes forms tight intergrowths with some minerals. It occurs in serpentine-calcite pseudomorphs on olivine, in cavities of leaching, and in calcite veinlets as inclusions. The colour of the mineral is yellow, golden to brown-yellow, of metallic lustre. The length of its hair-like individuals constitutes usually 1–3 mm reaching in some cases 10–15 mm. Sometimes millerite forms bundles, radial-beam aggregates, less frequently twisted-fibrous felt-like crusts consisting of acicular or hair-like individuals.

Pyrrhotite usually develops in kimberlites in fine fissures. It often occurs in the form of fine-grained aggregates in calcite veinlets. Quite often pyrrhotite forms well-cut crystals being in association with calcite. Sometimes in selvages of calcite crystals of tabular, short-prismatic and barrel-like appearance represent veinlets pyrrhotite. Sometimes facets of hexagonal dipyramid and pinacoid are developed in crystals.

Tochilinite has been discovered [4] in many kimberlite pipes (Mir, Udachnaya, Yubileynaya, Sytykanskaya etc.), where its aggregates have black colour with bronze tint. In air this mineral in a fast way covers with a film of iron hydroxides. Tochilinite sometimes also develops on serpentine pseudomorphs giving them dark-grey colouring. Sometimes rosettes of leprose tochilinite associate with pyrite and pyroaurite in selvages of veinlet calcite. In separate cases tochilinite associates with small variable impurity of mackinawite.

Marcasite occurs both in the basic mass of rocks and in the form of veinlets and rims around phenocrysts of serpentine and other neoformations. Most frequently the mineral is observed in the form of cubic and octahedral crystals. Besides facets of pinacoid on crystals of marcasite one can note also facets of dipyramid giving the druses of such crystals plicated appearance. Mineral association analysis indicates that marcasite is a much later mineral with respect to pyrite.

Chalcopyrite has been revealed in upper levels of individual kimberlite pipes where it usually forms two generations. The first one replaces other sulphides (pentlandite in particular) and develops in fissures in kimberlite. Relic segregations of pentlandite replaced by chalcopyrite also occur; individual crystals of the mineral were noted. The second generation is represented by fine impregnation of chalcopyrite together with other sulphides.

Borates have been found among secondary vein formations in kimberlites of some Yakutian pipes. Basing on comprehensive mineralogical investigations one of them is referred to recently discovered [4] boron mineral – *yekaterinite*. The second borate is represented by established by us [13] for the first time ferriferous variety of szaibelyite – *ferroszaibelyite*. Borates were found in fine salt veins and veinlets where besides colourless, orange-red, and blue halite such minerals as anhydrite, calcite and serpentine with ophite structure (serpophyte) were noted. Boron minerals do not occur together in small veinlets, and in bulges they have no contact with each other. In bulges of small veins yekaterinite usually forms wandering inclusions in orange-red halite, and in veinlets it is observed in the form of aggregates in which individuals are located by long side in parallel to each other and transversely to substrate. Ellipsoidal segregations of light-grey serpophyte embraced by borate from two sides quite often border on yekatirinite. Ferroszaibelyite associates mainly with colourless fibrous halite and is arranged between individuals of the latter and also along its cleavage plane, which are located in fibres angularly to elongation, since their growth goes along axis of the third order. In uniformly granular salt ferroszaibelyite deposits also along cleavage planes of halite or in intergrain space where it forms radiant aggregates sometimes. Overfilled by ferroszaibelyite halite acquires greyish-light-brown colouring. Such halite in all cases directly contacts hosting rocks – altered kimberlite. Besides ferroszaibelyite and halite there is usually serpophyte in the veinlets.

Water-free ***sulphates*** in kimberlite rocks are represented by anhydrite, celestine, barite, thaumasite, and aqueous ones – by gypsum, epsomite, metabasaluminite and brochantite. Francolite was revealed from minerals of ***phosphate*** class, and halite – from ***halogenides***.

Anhydrite is most common for deep level kimberlite rocks of pipes Mir, International etc. Sometimes its tabular crystals cover fissures in kimberlites with a solid crust. Wandering (lumpy) aggregates of the mineral occur in places of rock dissolution.

Celestine is noted in kimberlites of many Yakutian pipes, as a rule in the form of complanate radial-beam aggregates. Its crystals are well cut. Prisms and pinacoid, forming short-columnar tabular and spear-shaped crystals, are the most frequently occurring simple forms.

Barite has been revealed during investigation of material composition of pipes Udachnaya, Krasnopresnenskaya, Yakutskaya etc. Its aggregates usually resemble roses composed by lenslike crystals. Facets of pinacoid and prisms dominate on barite crystals. Entire segregations of macrocrystalline barite occur comparatively seldom.

Thaumasite was found [15] in kimberlite rocks of individual pipes (Zapolyarnaya, Novinka, Udachnaya etc.) in the form of branchy monomineral veinlets or nests of up to 1,0–1,5 cm size. Individual crystals of the mineral were also found.

Gypsum very often occurs in upper levels of many kimberlite pipes of Yakutia. It forms numerous veins, veinlets, and irregular segregations including those that envelope phenocrysts of other minerals. One can find acicular and fibrous aggregates of the mineral. Druses of cut crystals occur less frequently in fissures.

Epsomite is noted in individual kimberlite blocks of some upper levels of investigated kimberlitic pipes (Udachnaya, Yubileynaya etc.), where it gives whitish colouring to the rocks.

Metabasaluminite was found in the form of insignificant impurity in altered kimberlites of pipes Sytykanskaya, Yubileynaya etc., where it is confidently diagnosed only during X-ray-diffractometer study.

Brochantite was confidently revealed only in individual investigated samples of altered kimberlites of pipes Udachnaya and Sytykanskaya, where only in some cases its concentration reaches 10 %.

Francolite was found in the basic mass of kimberlites of individual Yakutian pipes (Zapolyarnaya, Novinka etc.) and in other regions (Russian platform, Guinea-Liberian shield). In kimberlites of Guinea-Liberian shield francolite was diagnosed within neoformations around kelyphitic rims on garnets greatly altered by processes of weathering. In Yakutian kimberlites francolite associates with pyroaurite, calcite, serpentine and magnetite.

Halite – the only mineral of halogenide class identified by us in kimberlite rocks of Yakutia. It occurs most often in kimberlites of deep levels of pipes Mir, International and Udachnaya. Index of refraction 1,544 of the mineral confirms its purity.

Thus, carried out investigations indicate that precise diagnostics of many minerals-neoformations in kimberlites and relative to them rocks is possible only with the help of fine modern methods of investigations. The most important place in this complex of physical-chemical methods of investigations belongs to X-ray-structural studies, which allow performing precise identification of available mineral phases in investigated formations at once. Application of derivatography in combination with infrared-spectroscopy for studying the same samples and mineral segregations permits to make the forms and interrelations of aqueous and structural groups more precise. Composition of individual petrochemical components in neoformations, identified by the aforesaid methods, can be confidently determined with the help of X-ray-spectral and chemical analyses. Petrographic and goniometric investigations give important information for monomineral and well-crystallized neoformations. Wide crystallomorphological spectrum of individual secondary minerals points to a multipronged character of postmagmatic and hypergene alteration processes of kimberlites and relative to them rocks.

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КРИСТАЛОМОРФОЛОГІЧНІ ОСОБЛИВОСТІ ДЕЯКИХ ВТОРИННИХ МІНЕРАЛІВ КІМБЕРЛІТІВ

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Наведено кристаломорфологічну характеристику деяких вторинних мінералів, які сформувалися під час постмагматичних перетворень кімберлітів. Різноманітність морфології новоутворених мінералів кімберлітів свідчить про складність процесів постмагматичного мінералоутворення в діатремах. Використання комплексу методів дослідження кристаломорфологічних властивостей мінералів дало змогу отримати нову інформацію про їхні типоморфні особливості.

Ключові слова: кімберліти, вторинні мінерали, кристаломорфологія, постмагматичне мінералоутворення.

Стаття надійшла до редколегії 17.07.2007
Прийнята до друку 19.11.2007