GENESIS AND TYPOCHEMISM
OF LAMPROPHYLLITE-BARYTOLAMPROPHYLLITE SERIES MINERALS
FROM LUJAVRITE-MALIGNITE COMPLEX OF Khibiny MASSIF

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The detail analysis of chemical composition and character of postmagmatic alteration of lamprophyllite-barytolamprophyllite series minerals from luja-vrite-malignites of Khibiny massif was made by local roentgenspectral and electron-microscopic methods. It is determined that in luja-vrites high-barium lamprophyllite is a typomorphic accessory mineral. In malignites two stages of lamprophyllite alteration are ascertained, which correspond to two stages of their formation: 1) at the stage of primary rocks [luja-vite or titanite trachyoid melteigite-urites] transformation in result of K, Si-metasomatosis the recrystallization of primary Ba-lamprophyllite without change of chemical composition (in case of luja-vrites) and enrichment of primary strontium lamprophyllite by barium and potassium (in case of melteigite-urites) take place; 2) at the stage of low-temperature rocks transformation by action of solutions enriched by strontium and/or calcium the replacement of Ba-lamprophyllite by strontium analogue (in malignites genetically connected to luja-vrites) and development of titanite after Ba,K-lamprophyllite (in malignites connected to ijo-lite-urites) occur.

It is detected that the character of postmagmatic alteration of primary strontium lamprophyllite in «porphyrocraceoe malignites» is also the evident of primary rocks (trachyoid ijolites) transformation during K, Si-metasomatosis.

4 figures, 1 table and 16 references.

Lamprophyllite, \((Sr,Ba,K)_2Na(Na,Fe,Mn)_2Ti_3(SiO_4)_6(O,OH,F)_{b}\) is one of the most characteristic accessory minerals of Khibiny alkaline massif. It occurs in rocks of almost all this massif complexes: nepheline syenites, melteigite-urites, apatite-nepheline rocks, ristochorrites, luja-vite-malignites. A whole number of works was devoted to lamprophyllite, however, the systematical study of accessory lamprophyllite from rocks of Khibiny massif, in particular, the study of genetic aspect of its mineralogy, was not practically undertaken till now. The minerals of lamprophyllite-barytolamprophyllite series from rocks of luja-vite-malignites complex have become the object of present study.

The crystal structure of lamprophyllite has a layered constitution, which allows free entering of large cations (Sr, Ba, K, Ca, Na) into inter-layer space and significant variations of their ratios (Rastsveteva et al., 1993a, Rastsvetaeva, Dortman, 1995b). This crystal structure peculiarity makes lamprophyllite perspective from the point of view of use as one of the mineraloggeochemical indicators of changes of minerogenesis environment conditions.

General characteristic of research objects

Luja-vrites and malignites in Khibiny massif are spatially connected to trachyoid melteigite-urites of Central Arc. Their alternating bed bodies are traced in upper part of this complex along contact of Kukisvumchors-Rasvumchorr apatit-nepheline deposit with overlapping ristochorrites up to the upper course of Kuniok. The luja-vrites from Khibiny are the late melanocratic phase of nepheline syenites; they consist of orthoclase, nepheline, and dark-colored minerals, are characterized by clear trachyoid texture, being the result of orthoclase lab orientation. The question about malignites genesis remains disputable. According to opinion of one researches group, they are the late phase of melteigite-urites or ristochorrites (N.A Elisseev, T.N. Ivanova, S.I. Zak et al.). Others, LAZotov, B.Ye. Borutzky, A.I. Serebritskii, consider them as a product of metasomatic alteration (orthoclazization) of melteigite-urites or ijolites at their contact with luja-vrites, khibinites, and iyavochorrites. In present research malignites are considered as rocks of metasomatic genesis, according to analysis of earlier works and features, determined by us. On their mineral composition they are divided into three types: 1) malignites (below denoted by us as «malignites-L») formed as a result of metasomatic alteration of luja-vrites and confined to endocontact zone of luja-vrites with trachyoid melteigite-urites; they have mineral composition similar to that of luja-vrites, but with poikilitic structure caused by large poikiloblasts of orthoclase and amphibole; 2) malignites (denoted as «malignites-U») confined to eocxontact zone of luja-vrites with titanite trachyoid melteigite-urites and formed as a result of metasomatic alteration of the latter; they are also characterized by poikilitic structure, but according to their composition, are closer to melteigite-urites; these rocks contain
### Table 1. Chemical composition of lamprophyllite-barytolamprophyllite series minerals from lujavrite-malignites complex rocks of Khibiny massif

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<th>Phases</th>
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<th>Mn</th>
<th>Fe</th>
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<th>TiO2</th>
<th>Nb2O5</th>
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</tbody>
</table>

**Note:**
- Phase 1 — primary lamprophyllite of the rock; I-a — barytolamprophyllite (in lujavrites); II-a — lamprophyllite, formed during K, Si-metasomatism; II-b — lamprophyllite, formed by influence of the late more low-temperature solutions. Analysts: an. 1-4, 6, 7, 9, 13 — V. V. Khangulov ( Camebax SX-50, IGEM RAS); an. 5, 8, 10-12, 14 — N. Y. Trubkin (electron microscope JSM-5300 with X-ray spectrometer Link Isis, IGEM RAS). An. 9, 14 — average on two analyses; an. 2, 3, 5, 8 — on three; an. 12, 10, 11 — on five; an. 6, 13 — on seven; an. 1, 7 — on ten analyses.

Table 1 shows the chemical composition of lamprophyllite-barytolamprophyllite series minerals from lujavrite-malignites complex rocks of Khibiny massif. The rocks are classified into three main categories: 1) lujavrites, 2) ‘malignites-L’, and 3) ‘porphyric malignites’. Each category is further divided into subcategories based on their mineralogical characteristics.

**Note:**
- Phase 1 — primary lamprophyllite of the rock; I-a — barytolamprophyllite (in lujavrites); II-a — lamprophyllite, formed during K, Si-metasomatism; II-b — lamprophyllite, formed by influence of the late more low-temperature solutions. Analysts: an. 1-4, 6, 7, 9, 13 — V. V. Khangulov (Camebax SX-50, IGEM RAS); an. 5, 8, 10-12, 14 — N. Y. Trubkin (electron microscope JSM-5300 with X-ray spectrometer Link Isis, IGEM RAS). An. 9, 14 — average on two analyses; an. 2, 3, 5, 8 — on three; an. 12, 10, 11 — on five; an. 6, 13 — on seven; an. 1, 7 — on ten analyses.

Significantly more nepheline and dark-coloured minerals than ‘malignites-L’, and less potash feldspar; titanium enrichment is also their characteristic feature; 3) ‘porphyric malignites’, according to S.I. Zak terminology (Zak et al., 1972), which are traced in lower part of trachytoid melteigite-urtitess series at the contact with underlying khibinites and among ristschorrites, and apparently, represent the small-grained trachyeldolite jilites altered by metasomatic processes. They are characterized by porphyritic structure caused by the poikilocrystals of lamprophyllite or feldspar, which stand out among more small-grained matrix, composed by dark-coloured minerals and nepheline, and the trachydolite texture caused by orientation of aegirine-hedenbergite needle-shaped crystals and laths of metasomatic potash feldspar replaced nepheline. Outcrops of these rocks are noted at Mt. Poachvumchorr.

Bedrocks of ‘malignites-L’ and ‘malignites-U’ are traced at Mt. Kukisvumchorr.

**Morphology, typical assemblages and chemical compositions of lamprophyllite from lujavrite-malignites**

In lujavrites lamprophyllite forms prismatic crystals of goldish-brown colour from some millimeters up to 1 cm in size and their growths disposed between high-barium (up to 3.0 – 3.5 % BaO) orthoclase laths, among magnesio-alfvedsonite and aegirine. Lamprophyllite is associated with euclialyte (proper euclialyte, according to (Johnsen et al., 2003)), titanite, rarely rinkite and apatite. Here lamprophyllite is one of the latest mineral phases: it forms later than dark-coloured and most of accessory minerals, i. e. rinkite, apatite, which inclusions are observed in the crystals of lamprophyllite, ti-
tante (sometimes replaced by lamprophyllite), and eudialyte.

Primary lamprophyllite from lujavrites, according to its chemical composition, is high-barium, although there are perceptible variations in content of both BaO, in most of cases from »10 – 11 to »15 %, and SrO, from »8 to 11 % (Table 1); the ratio (in atoms per formula unit) Ba/Sr = 0.7 – 1.4. Continuous isomorphous series between Sr- and Ba-dominant specimens is traced (Fig. 1). Potassium and calcium are contained in lamprophyllite in subordinate amounts. The content of manganese is also insignificant.

At the late mineral formation stages barium lamprophyllite are replaced by varieties with yet higher content of barium right up to barytolamprophyllite (the content of BaO increases to 20 – 21 %, the content of SrO is near 4 – 5%; Ba/Sr = 2.5 – 3.7, in Table 1), growing at the grains edges. Apparently, this phenomenon is caused by accumulation of barium in residual mineral forming environment because of its non-cogeneracy.

The appearance of high-barium lamprophyllite in lujavrites of Khibiny is their distinctive typomorphic peculiarity. The predominantly strontium lamprophyllite with significant content of manganese is spread in the analogous rocks from Lovozero massif (Kola Peninsula): lujavrites from differentiated complex of lujavrites-foyaites-urtites; eudialyte, lamprophyllite, and porphyric lujavrites (Busen, Sakharov, 1972; Vlasov et al., 1959). Strontium lamprophyllite is observed also in leucocratic nepheline syenites of Khibiny; khibinites, foyaites etc. Barium lamprophyllite and barytolamprophyllite till now are noted practically only in pegmatites and late cross-cutting veins, which occur among apatite-nepheline rocks and nepheline syenites in Khibiny (Dudkin, 1959; Png Tze-Chung, Chang Chien-Hung, 1965; Kapustin, 1973; Rastsveteva, Dorfman, 1995a) and Lovozero massifs, Kola Peninsula (Semenov, 1972; Kapustin, 1973; Bussen, Sakharov, 1972; Bussen et al., 1978), and also among albitized fennites at Turii cape (Kola Peninsula), metasomatites in Inagli and Murun massifs (South Yakutia) (Rastsveteva et al., 1995b; Lazebnik et al., 1998), syenitized schists in Botogol'skii massif (East Sayran) (Kapustin, 1973). Moreover, high-barium lamprophyllite is described in a number of other massifs in the world (Zaitsev, Kogarko, 2002).

«Malignites-L» are characterized by irregular distribution of lamprophyllite. Here there are its large (up to 2 – 3 cm and larger) poikilocrystals (with inclusions of aegirine, nepheline, apatite, sometimes fersmanite), growing among poikilocrystals of high-barium orthoclase and Na-Ca-amphiboles of magnesioarfvedsonite — richterite series. Rarely lamprophyllite forms small tabular crystals. In a number of cases lamprophyllite is corroded by high-barium orthoclase. The mineral assemblage, coexisting with lamprophyllite, is close to «lujavrite» one: it contains eudialyte, titanite, rarely rinkite, later Sr-apatite (6 – 10% SrO), taseqite, growing after proper eudialyte (Johnsen et al., 2003), fersmanite, sometimes pectolite, which accumulations are noted into interstitions between other minerals grains.

The chemical composition of early lamprophyllite from «malignites-L» is in whole identical to barium lamprophyllite and barytolamprophyllite from lujavrites: BaO — from 10 to 17 %, SrO — 5 – 10 %; Ba/Sr = 0.7 – 2.2 (Table 1, an. 5 – 7). However, here barium lamprophyllite is, as a rule, changed. In the most of cases in its poikilocrystals there are, together with Ba-dominant parts, the areas with gradually decreasing barium content (up to 4% BaO) and increasing content of strontium (on average »12 % SrO, Table 1, an. 8). These areas are traced parallel cleavage cracks of lamprophyllite poikilocrystals (Fig. 2). The ratio Ba/Sr in these zones is decreased up to 0.25, on chemical composition they corresponds to proper lamprophyllite, i.e. strontium lamprophyllite.

In the levels of «malignites-U» lamprophyllite, in contrast to above-mentioned rocks, is noted enough rarely. Its prismatic crystals are nearly 0.3 – 0.5, seldom 1 cm in length. They are located together with dark-coloured minerals (mainly aegirine, rarely magnesioarfvedsonite are noted) between poikilocrystals of potash.
The development of strontium lamprophyllite after poikilocrystal of high-barium lamprophyllite in «malig- nites-L» (image in reflected electrons, scanning electron microscope JSM-5300, IGEMRAS). Ba-lamp — high-barium lamprophyllite; Sr-lamp — strontium lamprophyllite; Amph — magnesioarfvedsonite.

The replacement of primary strontium lamprophyllite by barium-potassium lamprophyllite during K,Si-metasomatosis in «malig- nites-U» (image in reflected electrons, scanning electron microscope JSM-5300, IGEMRAS). Ba-lamp — high-barium lamprophyllite; Sr-lamp — strontium lamprophyllite; Neph — nepheline; Aeg — aegirine.

Genesis of lamprophyllite in the rocks of lujaivrite-malignites complex

The analysis of the evolution of chemical composition of lamprophyllite-barytolamprophyllite series minerals from the studied complex rocks and the character of their alteration as a result of postmagmatic processes, compared with peculiarities of general evolution of accessory mineralization of lujaivrite-malignites, allows in significant degree reconstructing the history of lujaivrite-malignites formation. The analysis of alterations, detected for lamprophyllite from malignites of this complex, is high informative in genetic relation.

Barium lamprophyllite from «malig- nites-L».

«Malig- nites-L» is seems to be mainly the product of lujaivites transformation as a result of K,Si-metasomatosis, and barium lamprophyllite is here inherited from initial rock. This assumption is confirmed by following: 1) in malignites of these levels there are the mineral relics of primary assemblage, parts reaches 2.7% (Table 1, an. 11) in primary lamprophyllite of above-mentioned rocks, this ratio fluctuates from 1.0 to 1.7%, and in late lamprophyllite it achieved 1.9%, Table 1). On the diagram, showing the ratios of barium, strontium, and potassium in apfu (contained in Table 1), the points of its chemical compositions are slightly displaced in «potassium» area (Fig. 1). At yet later stages Ba,K-lamprophyllite is, in its turn, replaced by titanite (Fig. 4).

In «porphyric malignites» lamprophyllite forms large poikilocrystals (up to 2 — 4 cm in size) among matrix, consisting of fine-needle-shaped crystals of aegirine-hedenbergite and magnesioarfvedsonite and small grains of nepheline. Here lamprophyllite is corroded by po- tash feldspar and often replaced by microgra- ined aggregates of feldspar and aegirine. Except lamprophyllite, the typical accessory minerals here are eudialyte group minerals (high-sodium and potassium-sodium eudialyte is most widespread), forming large accumula- tions in these rocks, and also tinkle, lorenz- ite, titanite, apatite, and others.

On its chemical composition lamprophyllite in «porphyric malignites» is stratoni (Table 1, an. 12). However, also as in «malignites-U», it is often replaced in significant degree by lamprophyllite, enriched by barium and potas- sium. In late lamprophyllite the content of BaO achieves 19%, K2O — 2.6% (Table 1, an. 14). On Fig. 1 the points, corresponding to chemical compositions of this lamprophyllite, lies in the area close to chemical composition of late Ba,K- lamprophyllite from «malignites-U».
which is analogous to «lujavrite» one; 2) early postcrystallization changes, i.e. recrystallization of mineral grains, formation of poikilitic structure, corrosion of primary minerals by orthoclase; 3) gradual transition between lujavrites and «malignites-L», existing of «transitional» varieties with composition, corresponding to lujavrites, but combining trachytoolite («lujavrite») and poikilitic («malignite») parts of rock. On this stage barium lamprophyllite is exposed to recrystallization and forms poikilocrystals.

The later transformation of lamprophyllite in «malignites-L» is a gradual replacement of barium lamprophyllite by significant stronont tonite, which, apparently, was influenced by late solutions, enriched by strontium and Calcium. Formation of late Ca-Sr-mineral assemblage, containing Sr-apatite, pektolite, pyrochlore, taseqite, and is practically distinguished from the later one by wide prevalence of late titanite, forming pseudomorphs after lamprophyllite.

In «malignites-U» as well as in «malignites-L» the more low-temperature lamprophyllite alteration takes place because of influence of late solutions. Here the character of lamprophyllite alteration is different: in contrast to «malignites-L», the development to titanite pseudomorphs after Ba,K-lamprophyllite is typical for these rocks. However, later transformation of «malignites-U», probably, was realized as a result of influence of the same solutions, enriched by calcium and strontium that solutions caused transformation of «malignites-L». The composition of late mineral assemblage, close to composition of «Ca,Sr-assemblage» of «malignites-L» indicates that. The former assemblage contains Sr-apatite, pektolite, pyrochlore, taseqite, and is practically distinguished from the latter one by wide prevalence of late titanite, forming pseudomorphs after lamprophyllite.

Lamprophyllite from «malignites-U». Most probably, early (strontian) lamprophyllite from «malignites-U» is also inherited from protorocks, in that case from trachytoolite melteigite-urtites, later undergone a K, Si-metasomatosis transformation. The relics of these rocks in a number of cases are noted in «malignites-U». Moreover, the absence of sharp contacts between these rocks (they are connected to each other by gradually transitions), indirectly indicates the existence of their genetic connection with trachytoolite melteigite-urtites. In trachytoolite melteigite-urtites accessory lamprophyllite is not enough widespread. According to data of Arzamastsev et al. (1987), its amount is not exceeding 0.9% from total rock mass, which, probably, explains the rarity of lamprophyllite in «malignites-U».

The character of postmagmatic alteration of lamprophyllite, the barium and some calcium enrichment and corrosion by potash feldspar (identical to character of lamprophyllite alteration in massive melteigite-urtites, undergone an intensive transforming with formation of ritschortorites complex rocks during K, Si-metasomatosis), indicates the significant role of K, Si-metasomatosis in formation of «malignites-U». The similar scheme of lamprophyllite alteration was, in particular, described (Ageeva, 2001, 2002) for massive urtites, which is a main «matrix» for ritschortorite formation. The rising alkalinity of mineral formation environment, which causes the increase of activity of most basic components (in this case barium) and the decrease of activity of less basic ones (i.e. strontium), is a reason of barium activity increasing during K, Si-metasomatosis, according to O.A. Ageeva data.

Conclusion

The data, observed as a result of detailed analysis of the chemical composition of lamprophyllite and the peculiarities of its postcrystallization alteration, allow determine following.

1. The enrichment by primary high-barium lamprophyllite is a typomorphic peculiarity of lujavrites from Khibiny. At present moment barium accessory lamprophyllite is noted neither in analogous rocks. Lujavrites of Lovozero massif, no in other (leucocratic) nepheline syenites of large high-alkali masses (Khibiny, Lovozero etc).

2. In «malignites-L» (genetically connected to lujavrites) and «malignites-U» (connected to melteigite-urtites) the character of alteration of lamprophyllite-barytolamprophyllite series minerals and minerals, associated with them, indicates two stages of their formation. The first stage is a transformation of initial rocks (lujavrites for «malignites-L» and trachytool titanite ijolites for «malignites-U») during K, Si-metasomatosis. In the case of «malignites-L» it
is accompanied by recrystallization of primary barium lamprophyllite, forming poikilocrystals, without change of chemical composition; in the case of «malignites-U» there is enrichment of primary strontium lamprophyllite by barium and potassium. The second stage is the more low-temperature transformation, connected to influence of late solutions, enriched by strontium and calcium. In «malignites-L» barium lamprophyllite and barytolamprophyllite are replaced by proper lamprophyllite (strontian), in «malignites-U» titanite replaces them at this stage. The influence of these solutions causes calcium-strontium character of late mineralization in «malignites-L» and «malignites-U».

3. In porphyric malignites the alteration of early strontium lamprophyllite, inherited from their protorocks (small-grained trachytoid iolites), caused by transformation of the latter during processes of K, Si-metasomatosis (as well as in «malignites-U»).

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