Unusual metasomatites (phyolithites) in the Kolivtskiy gabbro-anorthosite rock mass: composition and structural position

Evgenii N. TEREKHOV1*, Aleksandr B. MAKEEV2, Aleksandr S. BALUEV1, Aleksandr N. KONILOV1, Konstantin V. VAN3
1 Geological Institute of the Russian Academy of Sciences, Moscow, Russia
2 Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, Moscow, Russia
3 Institute of Experimental Mineralogy of the Russian Academy of Sciences, Chernogolovka, Russia

How to cite this article: Terekhov E.N., Makeev A.B., Baluev A.S., Konilov A.N., Van K.V. Unusual metasomatites (phyolithites) in the Kolivtskiy gabbro-anorthosite rock mass: composition and structural position. Journal of Mining Institute. 2021. Vol. 248. p. 232-242. DOI: 10.31897/PMI.2021.2.7

Abstract. Complex mineralogical, geochemical, and geological-structural characteristics of a rare collection stone of violet color, phyolithite, in the southwestern part of the Kola Peninsula. This is a metasomatic rock formed under the conditions of brittle deformation on gabbro-anorthosites of the Paleoproterozoic Kolivtskiy rock mass. As a result of potassium metasomatic process, the plagioclase of the initial rocks was replaced by a fine-grained mica aggregate of muscovite-phenite composition with inclusions of Va-aluminoseladonite (up to 20–30 microns). Ba-aluminoseladonite contains 6.6–10.5 % by weight of BaO. Manganese is the only chromophore that accumulates in the rock during metasomatic process. It is manganese that provides the purple-violet color of pseudomorphs of mica according to anorthite. The phyolithites are depleted by REE and have a positive Eu-anomaly. The phyolithites are confined to the areas of fracturing of the north-eastern strike, located in the zone of dynamic influence of the north-western closure of the Onega-Kandalaksha rift of the Riphean age. Other formations (injection conglomerates and lamproites) are also associated with the formation of this structure, which owe their origin to an intense fluid flow.

Key words: phyolithites; muscovite; gabbro-anorthosite; Onega-Kandalaksha rift; accommodation zone; Riphean; injection conglomerates

Acknowledgement. The work was carried out in accordance with the plans of basic research of the Institute of the Russian Academy of Sciences with the financial support of the Russian Foundation for Basic Research, grant N 19-05-00256.

Introduction. In the southwestern part of the Kola Peninsula, among the gabbro-anorthosites of the Kolivtskiy rock mass, the age of formation and metamorphism of which is close to 2450 million years [13, 20], there are unusual purple rocks that compose metasomatic zones – phyolithites (Fig.1). This manifestation has not been the object of close attention by researchers, it is occasionally mentioned in popular science literature under the name “Kola charoite”, in a scientific article [6] and in the proceedings of the meeting [30]. The composition and genesis of these rocks, as well as their structural position, and, accordingly, the importance of phyolithites for understanding the geological evolution of this area remain unexplored. The fact that these formations are confined to the Onega-Kandalaksha graben of the Riphean age, as well as their secondary nature in relation to the rocks of the granulite complex, allows to link their formation with the evolution of the White Sea rift system of the Neoproterozoic age [25].

An important element of the continental rift systems in general [10, 12, 36] and the White Sea system in particular [25] is the presence of shallow discharges-detachments that determine both the structure-forming processes and the material transformations of the basement rocks caused by fluids that are mobilized during decompression and tectonic exhumation of the recumbent wings of large discharges [23, 35]. Such a model of the evolution of
the earth's crust during rift formation allows to take a new look at the problem of the structural-material relationship between the metamorphosed basement and the cover rocks and to link the development of new formations in the basement with the evolution of rift deflections.

The purpose of this work is to study the features of the composition and structural position of the phylolithites, as well as to compare them with other rocks that are the products of structural and material transformations during the evolution of the White Sea rift system.

**Research.** The main mass of phylolithites is found in the area of Cape Kataranskiy in the south-western part of the Kola Peninsula. Small manifestations are known in the western part of the Ilinskaya Bay and on the Srednyye Ludy Islands within the Kandalaksha Bay (Fig. 2). The phylolithites are confined to fractured zones (the azimuth of the strike is 30°-50° NE), which are well distinguished in the coastal cliffs, in the area of the exits of the gabbro-anorthosites of the Kolvitskiy rock mass with an age of 2.45 billion years [20]. The thickness of individual fracture zones varies from 0.5 to 15 m.

The process of phylolithization of the initial rocks affects the entire fracture zone and extends beyond it in massive rocks at a distance of up to 1 m. Phylolithization develops exclusively by plagioclase, while dark-colored minerals are almost unchanged. Gabbro-anorthosites in this place are large-gigantic-grained (Fig. 3, a, b). The size of individual hypersthene grains sometimes reaches 25 cm, and the most vivid samples of phylolithites are confined to the contacts of large crystals, while the pyroxene crystals themselves are often irizzatting differences, which additionally decorates this ornamental stone. The development of phylolithization zones is extremely uneven. The color of pseudomorphs varies from light lilac to inky purple, with the brightest color-near the grains of dark-colored minerals. In contrast, pseudomorphoses are lighter in the monomineral differences of anorthosites (Fig. 3, c, d). Phylitization is zonal: the most intense color is confined to the first meters of the fractured central part, along the periphery the purple color of the rocks gradually disappears, and in some cases the rocks remain massive without noticeable superimposed fracturing.

---

**Fig. 2.** Structural position of phyloliths (muscovite-phengite metasomatites) in the closure zone of the Riphean rift (according to [28] with additions).

1 – presumably Paleozoic (Devonian deposits); 2 – Riphean deposits: on land (a), in the White Sea (b); 3 – granite-gneiss; 4 – anorthosites (a), eclogites, and eclogite-like rocks (b); 5 – early Riphean lamproite distribution field; 6 – location of phyloliths; 7 – Devonian alkaline intrusions: rock masses (a), dikes (b), explosion tubes (c); 8 – shifts (a) and main discharge (b); 9 – structural lines and shallow faults; 10 – modern uplifts: rift shoulders (a), accommodation zones (b); 11 – suspected faults.

The inset shows the formation of ring structures at the end of a growing crack (experimental data) according to [14].
preserve the primary structures of igneous rocks. The newly formed aggregate is quite soft, so high-quality polishing of samples is achieved in rare cases.

Gabbro-anorthosites composing a lopolite-like structure, as well as underlying and overlapping garnet amphibolites and eclogite-like rocks, respectively, are considered in many works, which are mainly devoted to deciphering the conditions of granulite metamorphism and the age of formation of the initial rocks [3, 13, 32]. The regressive stages of the formation of these complexes associated with the exhumation and formation of Riphean and younger structural ensembles have not been practically studied, with rare exceptions [2]. Within the entire granulite belt, a large number of various small pegmatite veins are found, representing the stage of its exhumation, and in the area of the development of phyolithites, dikes of lamproites of Riphean age and Devonian lamprophyres are developed [1, 21, 29].

The initial rocks on which the phyolithites developed were anorthosites and gabbro-anorthosites. Most of them have a banded, gneiss-like look (Fig. 3, a), but some of them have massive textures with veins of gabbro-pegmatites (Fig. 3, b). Monomineral anorthosites are very rare in the Kolvitskiy rock mass. There are gradual transitions between anorthosites and gabbro-anorthosites, and according to petro-geochemical data, they also do not differ fundamentally. In melanocratic differences, there are more components such as FeO, MgO, K2O and Cr. Phyolithites develop on both sides, but in massive samples they are more spectacular. Taking into account that the rocks are large-gigantic-grained and unevenly colored, the sample of phyolithites has a composite character, i.e. several differences with the brightest color were selected, and after crushing the rob was quartered with further abrasion for chemical analysis.

Petrogenic elements in the phyolithite were determined in the laboratory of the Geological Institute of the Russian Academy of Sciences using the S4 PIONEER X-ray spectrometer (Bruker AXS, Germany), and trace elements were determined by the ICP-MS method using the Element 2 mass spectrometer (Thermo Fisher Scientific of GmbH, Germany). The mineral compositions (about 50 points) were determined at the Institute of Experimental Mineralogy (IEM) of the Russian Academy of Sciences using a Camebax electron microscope with an energy-dispersive spectrometer Link-860. In the Laboratory of Isotope Geochemistry and Geochronology of the Institute of Geology of Ore Deposit, Petrography, Mineralogy and Geochemistry of the Russian Academy of Sciences (performed
by V.A. Lebedev), the K-Ar age of the phylolithite was determined. The study of the radiogenic argon content in mica was carried out on the MI-1201 IG mass spectrometer by isotope dilution using $^{38}$Ar as a tracer; the determination of potassium was carried out by flame spectrophotometry. To determine the nature of the violet color of muscovite-fengite from the phylolithite of the Kola Peninsula, the capabilities of the collective research center of the Institute of Geology of the Komi Republic of the Scientific Center of the Ural Branch of the Russian Academy of Sciences (Syktyvkar) were used. Samples of muscovite-fengite preparations were studied by the following methods: X-ray phase, IR spectroscopy, and electron paramagnetic resonance.

**Results.** In most petrogenic elements, the phylolithites are very close to the gabbro-anorthosites, but they show a noticeable increase in MnO and K$_2$O compared to the initial rocks. The content of Li, Ni, Rb, and Ba – elements that are characteristic of mica-muscovite-increases from trace elements in phylolithites (Table 1).

### Table 1

| Oxides, elements | Gabbro-anorthosite | Phylolithite | Oxides, elements | Gabbro-anorthosite | Phylolithite |
|------------------|-------------------|-------------|------------------|-------------------|-------------|
|                  | 87/3 | 86/1 | TFin (bulk) | 87/3 | 86/1 | TFin (bulk) |
| SiO$_2$          | 50.25 | 48.38 | 50.15 | Sr   | 329  | 423  | 191 |
| TiO$_2$          | 0.41  | 0.23  | 0.14  | Y    | 9    | 9    | 2.4 |
| Al$_2$O$_3$      | 23.68 | 27.52 | 23.57 | Zr   | 51   | 22   | 9   |
| FeO$_3$          | 5.31  | 4.62  | 3.92  | Ba   | 198  | 131  | 665 |
| MnO              | 0.08  | 0.06  | 0.39  | La   | 5.8  | 6.2  | 1.36 |
| MgO              | 3.22  | 2.85  | 5.26  | Ce   | 9.7  | 7.3  | 2.81 |
| CaO              | 12.43 | 14.28 | 6.24  | Pr   | 4.9  | 3.6  | 0.36 |
| K$_2$O           | 0.45  | 0.11  | 3.89  | Nd   | 3.5  | 2.7  | 1.65 |
| Na$_2$O          | 3.48  | 2.27  | 2.09  | Sm   | 0.5  | 0.6  | 0.47 |
| P$_2$O$_5$       | 0.03  | 0.03  | 0.03  | Eu   | 1.2  | 0.68 | 0.44 |
| Fe,Na<sub>2</sub> | 0.65  | 0.71  | 3.86  | Gd   | 1.4  | 0.51 | 0.43 |
| Li               | 9.1   | 9     | 32    | Tb   | –    | –    | 0.07 |
| Sc               | 1.6   | 1.8   | 14.6  | Dy   | –    | –    | 0.43 |
| V                | 100   | 151   | 65    | Ho   | –    | –    | 0.08 |
| Cr               | 95    | 73    | 368   | Er   | 0.4  | 0.6  | 0.26 |
| Co               | 15    | 15    | 36    | Tm   | –    | –    | 0.04 |
| Ni               | 49    | 89    | 227   | Yb   | 0.3  | 0.3  | 0.27 |
| Cu               | 13    | 17    | 35    | (La/Yb)$_n$ | 12.6 | 13.4 | 3.4 |
| Rb               | 2     | 2     | 128   | Eu/Eu* | 4    | 2.6  | 3   |

*Note. Oxides in %, trace elements in g/t.*

In the initial rocks (Fig.4), the REE content is very low, which is typical for gabbro-anorthosites [24, 26]. In phylolithites, the rare-earth elements are uniformly reduced, while the ratio (La/Yb)$_n$ also decreases due to the more intensive removal of LREE (plagioclase substitution) (Table 1). The positive europium anomaly (Eu/Eu* = 3) remains high, which correlates with the high barium concentration in the phylolithites. Rocks with a positive Eu/Eu* anomaly are enriched with barium, which indicates the participation of reduced fluids [27].

Using the VEGA TESCAN electron microscope (IEM RAS), the mineral composition of the phylolithite was determined: anorthite, albite, oligoclase, microcline, K-Na-feldspar, diopside, muscovite-fengite, biotite, Ba-aluminoseladonite, garnet – grossular-almandine-pyrope, chlorite – corundophyllite, amphibole – magnesian ferrochermakite, REE carbonate, Fe-Mn-Mg-Ca-carbonate, pyrite (Fig.5), their chemical composition is characterized (Tables 2, 3).

![Fig. 4. Chondrite-normalized REE distributions in the phylolith and initial rocks](image-url)
The textures of the initial rocks are very diverse, but they are always large-giant-grained differences. The primary minerals are clinopyroxene-diopside, hypersthene, and plagioclase. The presence of anorthite, albite, and K-spar, which are not typical for the initial gabbro-anorthosites [32], indicates the high-temperature nature of the transformations antecedent to the formation of micas. Areas of phylolitization develop by plagioclase, and depending on the intensity of the transformation process, its crystals are almost completely replaced by a mica aggregate – muscovite-phengite with small inclusions of Ba-aluminoseladonite (up to 20-30 microns). Ba-aluminoseladonite contains 6.6-10.5 % by weight of BaO. Manganese is the only chromophore that accumulates in the rock during metasomatosis, namely manganese (Table 2), the content of which is 0.09-0.64 % by weight of MnO, provides a purple-violet color of pseudomorphs of mica (muscovite-phengite) by plagioclase. Samples of muscovite-phengite preparations were studied using the following methods: X-ray phase, IR spectroscopy, and electron paramagnetic resonance. The results of the study clearly showed that the violet chromophore of the muscovite-phengite color is trivalent manganese. In the literature, a similar conclusion about the presence of Mn$^{3+}$ in mica was made in 1977 after studying the nature of the color of pinkish muscovite from Precambrian metamorphic rocks of New Mexico [34].

The composition of garnet (grossular-almandine-pyrope) with 34-60 % Pir is very unusual (Table 3). Its idiomorphic secretions suggest that it is a secondary metasomatic
garnet. The maximum pressure values (11-13 kbar) were calculated from such high – magnesian garnets-this is the metamorphism of the granulite facies [32]. Dark-colored silicates do not change much during this process, although the appearance of chlorite-corundophyllite is associated with the replacement of amphibole (magnesio-ferro-chromite). Judging by the gross chemical composition of the phyllolite samples, they are significantly enriched in K₂O (4 % by weight) relative to 0.1-0.2 % in the initial gabbro-anorthosite, i.e., the rocks were subjected to K-metasomatosis. The initial gabbro-anorthosites are abnormally depleted of rubidium (2 g/t), so its high concentration (128 g/t) in the phyllolite also indicates the process of metasomatic substitution.

Table 2

| Oxides | 2 | 3 | 6 | 12 | 22 | 46 | 13 | 15 | 18 | 21 | 23 | 25 | 26 | 27 | 37 | 44 | 1 | 16 | 19 |
|--------|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| SiO₂   | 52.98 | 55.23 | 55.65 | 46.68 | 45.86 | 47.99 | 48.83 | 45.95 | 47.05 | 46.22 | 46.14 | 46.63 | 45.17 | 44.76 | 36.85 | 37.94 | 38.19 |
| TiO₂   | 0.64 | 0.73 | 0.69 | 0.16 | 0.07 | 0.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 | 3.83 | 4.29 |
| Al₂O₃  | 20.02 | 18.52 | 19.58 | 28.22 | 30.94 | 29.78 | 29.77 | 31.29 | 30.28 | 31.50 | 34.04 | 33.87 | 31.85 | 30.82 | 15.20 | 15.36 | 15.68 |
| FeO    | 0.04 | 0.25 | 0.16 | 0.81 | 0.98 | 0.76 | 0.38 | 0.34 | 1.03 | 1.35 | 1.22 | 1.62 | 10.65 | 10.61 | 11.17 |
| MnO    | 0.14 | 0.10 | 0.00 | 0.43 | 0.47 | 0.00 | 0.09 | 0.21 | 0.23 | 0.32 | 0.32 | 0.17 | 0.26 | 0.64 | 0.04 | 0.20 |
| MgO    | 0.00 | 0.09 | 0.14 | 2.86 | 1.31 | 2.25 | 1.37 | 1.72 | 2.28 | 1.01 | 0.83 | 1.13 | 0.58 | 0.89 | 14.15 | 15.52 | 15.65 |
| CaO    | 0.87 | 0.28 | 0.00 | 0.45 | 0.13 | 0.07 | 0.54 | 0.00 | 0.22 | 0.29 | 0.32 | 0.08 | 0.00 | 0.04 | 0.12 | 0.10 |
| Na₂O   | 0.44 | 0.33 | 0.30 | 0.15 | 0.11 | 0.07 | 1.20 | 0.00 | 0.18 | 0.61 | 0.27 | 0.37 | 0.13 | 0.21 | 0.09 | 0.50 | 0.26 |
| K₂O    | 11.83 | 13.01 | 12.17 | 11.27 | 11.42 | 11.44 | 9.70 | 10.65 | 11.52 | 10.53 | 11.18 | 10.48 | 10.71 | 10.38 | 10.15 | 10.18 | 10.36 |
| BaO    | 10.50 | 6.57 | 8.33 | 0.19 | 0.19 | 0.00 | 0.07 | 0.37 | 0.45 | 0.03 | 0.16 | 1.52 | 0.75 | 0.31 | 0.00 | 0.00 | 0.32 |
| Total  | 97.46 | 95.11 | 97.02 | 92.03 | 91.31 | 92.84 | 92.44 | 90.27 | 90.57 | 90.85 | 94.00 | 95.60 | 90.67 | 89.67 | 91.50 | 94.10 | 96.22 |

Note. Analyses 2, 3, 22 correspond to the composition of micas of the Ba-aluminosodalite series; analyses 6, 13, 15, 18, 21, 23, 25, 26, 27, 37 belong to the series of muscovite-fengite; 1, 16, 19 – phlogopite-eastonite.

Table 3

| Oxides | 1 | 8 | 9 | 12 | 14 | 16 | 22 | 46 | 34 | 36 | 45 | 46 | 3a | 8a |
|--------|---|---|---|----|----|----|----|----|----|----|----|----|----|----|
| SiO₂   | 37.59 | 38.78 | 38.85 | 39.22 | 39.42 | 39.28 | 39.21 | 39.71 | 39.69 | 39.36 | 39.03 | 39.12 | 39.26 | 39.26 |
| TiO₂   | 0.00 | 0.00 | 0.17 | 0.14 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.06 | 0.05 |
| Al₂O₃  | 22.39 | 21.97 | 22.07 | 22.23 | 22.34 | 22.24 | 22.21 | 22.49 | 22.45 | 22.41 | 22.11 | 22.17 | 22.27 | 22.24 | 21.89 | 22.09 |
| FeO    | 16.89 | 23.75 | 21.19 | 18.99 | 18.83 | 19.27 | 18.93 | 14.53 | 14.71 | 15.78 | 19.83 | 18.53 | 17.84 | 25.24 | 22.24 |
| MnO    | 0.05 | 0.49 | 0.27 | 0.18 | 0.34 | 0.22 | 0.30 | 0.50 | 0.13 | 0.19 | 0.83 | 0.45 | 0.01 | 0.35 | 3.69 | 5.06 |
| CaO    | 6.75 | 6.03 | 5.80 | 6.57 | 7.21 | 6.44 | 6.50 | 6.66 | 6.52 | 6.20 | 5.39 | 5.46 | 5.58 | 5.81 | 7.61 | 9.10 |
| MgO    | 14.35 | 8.98 | 11.61 | 12.61 | 11.85 | 12.51 | 12.57 | 16.10 | 16.37 | 15.84 | 12.82 | 14.16 | 15.32 | 14.26 | 2.91 | 2.44 |
| Total  | 100.00 | 100.00 | 99.96 | 99.98 | 99.98 | 99.99 | 99.72 | 99.99 | 100.03 | 99.98 | 100.01 | 99.93 | 99.98 | 99.95 | 100.05 | 100.00 |

Note. The first 14 analyses correspond to the composition of the garnet of the grossular-almandine-pyrope series; 3a, 8a belong to the spessartin-grossular-almandine series.
The manifestation of phylolithites is located within the Poryegubskiy lamproite field, whose rocks are characterized by ultra-high concentrations of K₂O and are, according to some data, 1750 million years old [21], according to the other – 1200 million years old [7]. However, both of these age boundaries can be associated not only with post-plate magmatism in the Baltic Shield [28], but also with the stages of Riphean or Pre-Riphean rift formation [17]. Moreover, in the Baltic region, early rift structures are known, the basal deposits of which are older than 1650 million years [19]. There is also one of the areas (pockets) of the distribution of Devonian lamprophyre dikes (see Fig.2). The K-Ar value of the age of the 1320 million-year-old phylolithite mica indicates the time of the metasomatic development of the gabbro-anorthosites, which probably coincides with the main stage of the northwestern strike formation of the White Sea rift system [25].

The Onega-Kandalaksha graben is the largest structure in the White Sea rift system, formed, according to modern data, due to horizontal sliding along the system of shallow discharges falling to the northeast (Fig.6). According to some data, within the Onega-Kandalaksha graben, the current depth of the foundation sinking and the thickness of the Riphean deposits reaches 8 km [11, 25]. Accordingly, the uplift of the rift shoulder was very significant, which contributed to the decompression.
fluids formation. The main fault controlling the development of this graben is the discharge along its western side. According to geophysical data and modern morphostructure, this discharge can be clearly traced from the mouth of the Onega River to the Sredniye Ludy archipelago [11, 15, 25]. The recumbent wing of this discharge experiences uplift, which is expressed in the appearance of highly metamorphosed rocks and positive gravitational anomalies on the surface. In the area of the Sredniye Ludy archipelago, the observed fault experiences an alternating inversion of its fall, and in the segment of the Sredniye Ludy – Kandalaksha archipelago, it falls to the southwest. According to the geological data (the Sredniye Ludy archipelago and the islands in the Porya Bay, where the granulite complex rocks are exposed), it is obvious that the Onega-Kandalaksha Riphean graben closes in the area of the archipelago and does not continue further to the northwest, as is often shown on small-scale maps [5]. Therefore, the area of the Srednyye Ludy Archipelago and Cape Kataranskiy on the mainland of the south-west of the Kola Peninsula can be considered as a zone of dynamic influence of the Riphean graben closure area. Naturally, the question arises about the time of the fault formation to the northwest of the Sredniye Ludy archipelago. It is probably of Devonian age, updated at the present stage. Previously, this segment of the rift was called the Kolvitskiy Trough [25]. Within the limits of this trough, according to seismic survey data, shallow-lying deposits are distinguished, which can also be considered as Paleozoic [8]. But a more important argument for the Devonian age of the Kolvitsky Trough is the dike fields associated with its northern and southern closures. These are the Kandalaksha area (more than 200 Devonian dikes) and the Lake Dolgoe – Kasyan Island area (more than 100 dikes) (see Fig.2). Thus, the Sredniye Ludy archipelago is the junction of the Riphean and probably Devonian grabens. It is the areas of rift deflections closure and the places where the inversion of structural-forming faults occurs (the so-called accommodation zones) that are characterized by the presence of areas of increased fracturing, pseudotachylites, dikes and metasomatites of various compositions, as well as increased concentrations of hydrocarbon emanations [9, 25]. A characteristic feature of the framing of the Onega-Kandalaksha rift is conglomerate-like rocks of non-sedimentary genesis. They were first described in the Kandalaksha region, where rounded boulders and pebbles of granulites in sandy-carbonate cement form a plast-like intrusive body (the Telyachii Island) [33]. In the southern part of the Sredniye Ludy archipelago, a vein-like body was observed, composed of rounded fragments of gabbro-anorthosites. The role of cement here is played by hornblende, which probably crystallized directly from the fluid (Fig.7, a). At a deeper level, among the eclogite-like rocks, vein-like bodies of hornblendites are distinguished, which were also formed under the influence of fluids penetrating through cracks into the rocks of the granulite complex (Fig.7, b).

![Image](https://example.com/image1.png)

**Fig.7. Rift formations in the rocks of the crystalline basement**

Fluidizes in the rocks of the granulite complex (a-b): a – injection conglomerate-breccias, the fragments are represented by anorthosite, the space between them is filled with coarse-grained hornblende (arch. Sredniye Ludy); b – injection veins represented by hornblende among eclogite-like rocks (Kataranskiy Cape area, Pedumka Bay). Injection conglomerates in the recumbent wing of the main discharge of the Onega graben (near the village of Pokrovskoye) (c-d): a crack-fault among granite-gneisses (c), falls under the Riphean graben (d), it contains lenses of injection-conglomerates
Numerous rock outcrops associated with the formation of the Onega-Kandalaksha graben are known on its southwestern flank near the island of Kiy – the village of Pokrovskoye (see Fig.6). These are injection conglomerates confined to the basement rocks: amphibolites and granite-gneisses [4, 18]. Conglomerates form lenses and low-power layers confined to tectonic zones falling towards the Riphean graben (Fig.7, c, d). The semi-rolled fragments of the host rocks are unevenly distributed in the draining aphanite mass of gray-green or almost black color with a shell-like fracture and a greasy gloss on the fracture. In the cuts, it can be seen that the cement mass consists of a fine-grained sandy material. The clastic fraction of cement consists of grains of quartz, plagioclase, microcline, pyroxene, amphibole, garnet, biotite and ore mineral. Cement is represented by calcite and to a lesser extent by glass, which occurs in the form of lenses or shells around the grains. Within the limits of carbonate cement, micro-loads of analcime were diagnosed, for which the formation temperature is higher than 450 °C [31]. The glass has a main-ultrabasic composition, and in some analyses the K₂O content reaches 5 % by weight. By the fact of the glass presence, conglomerate-breccias are close to pseudotachylites [22]. At the same time, their large thickness, the main-ultrabasic composition of the glass, and the presence of high-temperature neoplasms allow to consider them as a special type of rocks – fluidizates formed during the flow of incandescent suspension masses inside the earth’s crust [16]. At the same time, the age of the newly formed zircon grains is 1200 million years, which corresponds to one of the phases of the formation of the White Sea rift system [25].

**Conclusion.** Rocks of unusual violet color are formed by gabbro-anorthosite due to metasomatic replacement of plagioclase by muscovite-phengite fine-grained aggregate. The increased content of manganese in metasomatic rocks determined their unusual purple color, and high concentrations of K₂O are typical for formations that are synchronous to the formation of the Onega-Kandalaksha graben. To the south of the phylolithites distribution there is a graben, and on land there is an annular structure typical of the closure of rift deflections and shifts (see Fig.2, cut). This type of structure is formed at the end of faults experiencing shear deformations, and it is within their limits that stress discharge occurs, which is expressed in the formation of local thrusts and crushing zones of different orders. Phylolithites are also found on the islands of the Sredniye Ludy archipelago. These islands are considered as a kind of reference structure of accommodation in rift zones, where the main displacement changes its polarity, and there are increased tectonic stresses (see Fig.2). At first glance, it seems paradoxical that alkaline dikes (lamprophyres and lamproites) are confined to these areas (i.e., compression zones). However, the study of alkaline dikes in the Kandalaksha Bay showed that these are extremely fluid-saturated formations, which are formed in the form of dikes and explosion tubes, only in those places where the fluid cannot freely reach the surface [29]. In areas where the rifts are wide open, there are no alkaline dikes, and pseudoconglomerates or injection conglomerates can form in the degassing areas [18, 25]. Therefore, the formation of phylolithites formed by gabbro-anorthosites under the influence of alkaline fluids is also associated with the development of this rift system in the Middle Riphean time.

*The authors express special gratitude to the Candidate of Geological and Mineralogical Sciences P.V.Lyutoev for determining the nature of the color of the phylolithite.*

**REFERENCES**

1. Arzamastsev A.A., Fedotov Zh.A., Arzamastseva L.V. Dike magmatism of the north-eastern part of the Baltic Shield. St. Petersburg: Nauka; 2009, p. 383 (in Russian).
2. Vasileva T.I., Przhialyovskii E.S. Evolution of stress fields in the Poryuguba dike field (Kandalaksha gulf, White Sea). Geotectonics. 2006. Vol. 40. N 1, p. 53-63. DOI: 10.1134/S0016852106010055
3. Vinogradov L.A., Bogdanova M.N., Efimov M.M. Granulite belt of the Kola Peninsula. Leningrad: Nauka, 1980, p. 208 (in Russian).
4. Voinov A.S., Polekhovskii Yu.S. Some questions of geology and metamorphism of the Belomorides of the Kiyostrovskii Archipelago. Vestnik Leningradskogo gosudarstvennogo universiteta. 1971. N 4, p. 48-56 (in Russian).
5. State Geological Map of the Russian Federation. Scale 1: 1,000,000 (new series). List Q – (35) – 37-Kirovsk. Explanatory note. St. Petersburg: Vserossiiskii nauchno-issledovatelskii geologicheskii institute imeni A.P.Karpinskogo, 2004, p. 268 (in Russian).

6. Efimov M.M., Krylova M.D., Vasileva S.I., Marchak V.P. Decorative purple pseudomorphism by plagioclase. *Zapiski Vseso-
uznogo mineralogicheskogo obschestva*. 1986. Vol. 115. N 6, p. 720-721 (in Russian).

7. Zhuravlev V.A. Lamproites of the White Sea mobile-metamorphic belt. Tezisy dokladov mezhdunarodnoi konferentsii “Belomorskie podvizhnoi poyas. Geologiya, geodinamika, geokronologiya”. Petrozavodsk: Karel'skii nauchnyi tsentr RAN, 1997, p. 37 (in Russian).

8. Zhuravlev V.A. Structure of the Earth's crust of the White Sea region. *Razvedka i okhrana nedr*. 2007. N 9, p. 22-26 (in Russian).

9. Leonov M.G., Morozov Yu.A., Stefanov Yu.P., Bakeev R.A. Zones of concentrated deformation (flower structures): field observations and modeling data. *Geodynamics & Tectonophysics*. 2018. Vol. 9. N 3, p. 693-670. DOI: 10.5800/GT-2018-9-3-0368 (in Russian).

10. Ivanov S.N., Rusin A.I. Continental rift metamorphism. *Geotektonika*. 1997. N 1, p. 6-19 (in Russian).

11. Kazanin G.S., Zhuravlev V.A., Pavlov S.P. Structure of the sedimentary cover and perspectives of the oil and gas potential of the White Sea. *Burenie i nefть*. 2006. N 2, p. 26-28 (in Russian).

12. Kazmin V.G., Byakov A.F. Continental rifts: structural control of magmatism and continental cleavage. *Geotektonika*. 1997. N 1, p. 20-31 (in Russian).

13. Kaulina T.V., Bogdanova M.N. The main stages in the development of the northwestern White Sea region: U-Pb isotopic data. *Lithosphere*. 2000. N 12, p. 85-97.

14. Kosygin Yu.A., Maslov L.A. The main types of brittle and non-brittle geological dislocations and their interaction. Tektionicheskie protsessy. Doklady sovetskikh geologov na XXVIII sessii Mezhdunarodnogo geologicheskogo kongressa. Moscow: Nauka, 1989, p. 193-201 (in Russian).

15. Makarov V.I., Shchukin Yu.K., Yudakin F.N. The position of Solovets islands in neotectonic structure of the White Sea area, their nature and recent geodynamics. *Lithosphere (Russia)*. 2007. N 3, p. 86-94 (in Russian).

16. MakhlavievL.V., Golubeval I. Magmatogenic fluidized (pseudofluidized) systems and their role in rock formation and associated migene. *Problemgeologii i mineralologii*. 2006, p. 143-159 (in Russian).

17. Moralev V.M., Samsonov M.D. A Tectonic Interpretation of Petrochemical Signatures of Proterozoic and Paleozoic Alkaline Rocks from the Porjugabi Dike Swarm, Kandalaksha Bay, White Sea. *Geotectonics*. 2004. N 2, p. 30-41 (in Russian).

18. Baluev A.S., Moralev V.M., Przhizhalgovskii E.S. et al. On Probable Endogenic Origin of Conglomerate-Like Rocks from the Southeastern Coast of the White Sea. *Litologiya i poleznye iskopaemye*. 2003. N 4, p. 412-424.

19. Bogdanov Yu.B., Levcchenkov O.I., Komarov A.N. et al. About a new type of the Lower Riphean cut on the Baltic Shield. *Doklady Akademii nauk*. 1999. Vol. 366. N 1, p. 76-78 (in Russian).

20. Sheshenko E.N., Nikolaev A.I., Bayanova T.B. et al. Paleoproterozoic Kolivskiy anorthosite rock mass: new data on the age (U–Pb, ID-TIMS) and geochemical features of zircon. *Doklady Akademii nauk*. 2018. Vol. 479. N 2, p. 187-191. DOI: 10.7868/S0869565218080169 (in Russian).

21. Nikitina L.P., Levskii L.K., Lokhov K.I. et al. Proterozoic alkaline-ultrabasic magmatism of the eastern part of the Baltic Shield. *Petroleigvra*. 1999. Vol. 7. N 3, p. 252-275 (in Russian).

22. Morozov Y.A., Matveev M.A., Smulskaya A.I., Kulakovskii A.L. Two genetic types of pseudotachylites. *Doklady Earth Sciences*. 2018. Vol. 491. N 2, p. 129-133. DOI: 10.1134/S1028334X19020144 (in Russian).

23. Sklyarov E.V., Muzakabov A.M., Mešnikov A.I. Complexes of metamorphic cores of the Cordillera type. Novosibirsk: Nauchno-izdatelstvii tsentr Obedinenego instituta geologii, geofiziki i mineralogii SO RAN, 1997, p. 182 (in Russian).

24. Skabiev S.G. Geochemistry of rare earth elements in rock-forming metamorphic minerals. St. Petersburg: Nauka. 2005, p. 147 (in Russian).

25. Baluev A.S., Zhuravlev V.A., Terekhov E.N., Przhizhalgovskii E.S. Tectonics of the White Sea and adjacent territories (Explanatory note to the tectonic map). Moscow: GEOS, 2012, p. 104 (in Russian).

26. Terekhov E.N., Levitski V.I. Granulites of the Lapland belt: rare earth elements and problems of petrogenesis. *Izvestiya vuzov. Geologiya i razvedka*. 1993. N 5, p. 3-17 (in Russian).

27. Terekhov E.N. To the Problem of the Origin of Acid Rocks, Characterized by Positive Eu Anomaly as Indicators of Extension Processes (Eastern Baltic Shield). *Doklady Akademii nauk*. 2004. Vol. 397. N 5, p. 675-679 (in Russian).

28. Terekhov E.N., Baluev A.S. Post-folding magmatism (1.85-1.7 Ga) in the eastern part of the Baltic shield: correlation of its structural position and evolution of surrounding complexes. *Stratigraphy and Geological Correlation*. 2011. Vol. 19. N 6, p. 600-617. DOI: 10.1134/S0869593811060074 (in Russian).

29. Terekhov E.N., Baluev A.S., Przhizhalgovskii E.S. Structural setting and geochemistry of Devonian dikes in the Kola Peninsula. *Geotectonics*. 2012. Vol. 46. N 1, p. DOI: 10.1134/S0016852121010074.

30. Terekhov E.N., Konilov A.N., Makeev A.B. Muscovite-plengite metasomatites (phylolithites) from the zone of dynamic influence of the Kandalaksha graben of Riphean age. Materialy XIV Mezhdunarodnoi konferentsii “Novyeidei v naukah o Zemle”, 2-5 aprelya 2019, Moscow, Russia. Rossiiskii gosudarstvennyi geologorazvedochnyi universitet, 2019. Vol. 2. p. 396-399 (in Russian).

31. Turoshin V.F. Upper limit of analcime stability. Ocherki fiziko-khimicheskoi petrologii. Iss. IV. Moscow: Nauka. 1974, p. 23-28 (in Russian).

32. Fonarev V.I. Metamorphic Evolution of the Kolivtsa Anorthosite Massif (Lapland-Kolivtsa Granulite Belt, Baltic Shield). *Doklady Earth Sciences*. 2004. Vol. 395. N 3, p. 364-368.

33. Shurkin K.A. About the “conglomerates” of the Kandalaksha Islands and Turya Cape. Trudy Laboratorii geologii Dokombriya. 1960. Iss. 9, p. 398-411 (in Russian).

34. Gresem R.L., Stensrud H.L. More data on red muscovite. *American Mineralogist*. 1977. Vol. 62, p. 1245-1251.
35. Platt J.P., Soto J.I., Comas M.C. Decompression and high-temperature–low-pressure metamorphism in the exhumed floor of an extensional basin, Alboran Sea, western Mediterranean. Geology. 1996. Vol. 24. Iss. 5, p. 447-450. DOI: 10.1130/0091-7613(1996)024<0447:DAHTLP>2.3.CO;2

36. Wernike B., Axen G. On the role of isostasy in the evolution of normal fault systems. Geology. 1988. Vol. 16. Iss. 9, p. 848-851. DOI: 10.1130/0091-7613(1988)016<0848:OTROII>2.3.CO;2

Authors: Evgenii N. Terekhov, Doctor of Geological and Mineralogical Sciences, Chief Researcher, terekhoff.zhenya@yandex.ru, https://orcid.org/0000-0002-0489-4545 (Geological Institute of the Russian Academy of Sciences, Moscow, Russia), Aleksandr B. Makeev, Doctor of Geological and Mineralogical Sciences, Chief Researcher, abmakeev@mail.ru, https://orcid.org/0000-0001-8815-0959 (Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, Moscow, Russia), Aleksandr S. Baluev, Doctor of Geological and Mineralogical Sciences, Leading Researcher, abaluev@yandex.ru, https://orcid.org/0000-0003-3597-4430 (Geological Institute of the Russian Academy of Sciences, Moscow, Russia), Aleksandr N. Konilov, Senior Researcher, chalma@bk.ru, https://orcid.org/0000-0002-9750-3573 (Geological Institute of the Russian Academy of Sciences, Moscow, Russia), Konstantin V. Van, Senior Researcher, https://orcid.org/0000-0002-8053-332 (Institute of Experimental Mineralogy of the Russian Academy of Sciences, Chernogolovka, Russia).

The authors declare no conflict of interests.

The paper was received on 28 January, 2021.
The paper was accepted for publication on 29 March, 2021.