ISSN 1028-334X, Doklady Earth Sciences, 2019, Vol. 488, Part 2, pp. 1200–1202. © Pleiades Publishing, Ltd., 2019.
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GEOCHEMISTRY

# Nikmelnikovite, $Ca_{12}Fe^{2+}Fe^{3+}_3Al_3(SiO_4)_6(OH)_{20}$: A New Mineral from the Kovdor Massif (Kola Peninsula, Russia)

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Received July 11, 2019

**Abstract**—Nikmelnikovite, $Ca_{12}Fe^{2+}Fe^{3+}_3Al_3(SiO_4)_6(OH)_{20}$, a new mineral from the Kovdor massif (Kola Peninsula, Russia), is described. It is the first trigonal representative of the garnet supergroup. The mineral is named in honor of Academician Nikolai Nikolaevich Melnikov (1938–2018), an outstanding Soviet and Russia mining engineer, long-time (1981–2015) director of the Mining Institute of the Kola Science Center, Russian Academy of Sciences.

**DOI:** 10.1134/S1028334X19100143

In 2018, the International Mineralogical Association approved a new mineral, nikmelnikovite (nikmelnikovite, IMA-2018-043) $Ca_{12}Fe^{2+}Fe^{3+}_3Al_3(SiO_4)_6(OH)_{20}$, named in honor of Academician Nikolai Nikolaevich Melnikov (1938–2018), an outstanding Soviet and Russia mining engineer and science organizer, director of the Mining Institute, Kola Science Center, Russian Academy of Sciences (1981–2015). Nikmelnikovite was discovered on the Kovdor phlogopite deposit, the largest in the world, located within the alkaline–ultramafic massif in Murmansk Region, Russia (67°33′ N, 30°31′ E).

The Kovdor massif of peridotite, foidolite–melilitolite, foscorite–carbonatite, and related metasomatic rocks (fenite, diopsidite, phlogopitite, and skarnoids) is the polyphase complex intruded into Archean granite–gneiss of the Belomorian Block ~400 m. y. ago [1]. Nikmelnikovite was found in skarnlike rocks of the Kovdor phlogopite deposit, the major minerals of which are represented by diopside, phlogopite, forsterite, hydroxylapatite, vesuvianite, monticellite, tremolite, and magnesiohastingsite; and the minor elements, by magnetite, pargasite, andradite, glagolevite, kirschteinite, wollastonite, and dolomite. These rocks contain and isometric giant-granular segregation (~80 cm in diameter) composed of calcite, magnesiohastingsite, pectolite, andradite, manaevite-(Ce) (new mineral of the vesuvianite group), glagolevite, natrolite–gonnardite, scolecite, thomsonite-Ca, tobermorite, magnetite, and sphalerite [2], where nikmelnikovite was found.

Nikmelnikovite overgrows octahedral faces of large (up to 6 cm in diameter) crystals of andradite impregnated in calcite as semitransparent brownish red crusts (with a thickness of up to 1 mm). On the calcite side, these crusts are inlaid by small (up to 0.1 mm in diameter) rhombohedral crystals of nikmelnikovite (Fig. 1) and spherical globules (up to 5 μm in diameter). The

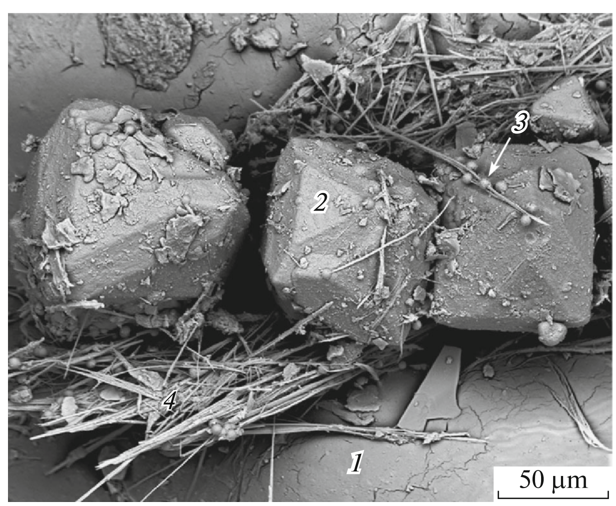


**Fig. 1.** SEM image of (*1*) the crust, (*2*) sectorial crystals, and (*3*) globules of nikmelnikovite overgrowing (*4*) an andradite crystal together with tobermorite.

† Deceased.

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**Table 1.** Chemical composition of nikmelnikovite (wt %)

| Component | Mean | Min | Max |
|---|---|---|---|
| $H_2O$ | 12.08 | | |
| MgO | 0.38 | 0.32 | 0.46 |
| $Al_2O_3$ | 12.08 | 11.40 | 12.44 |
| $SiO_2$ | 22.10 | 21.57 | 23.57 |
| CaO | 39.71 | 38.31 | 40.36 |
| MnO | 0.52 | 0.44 | 0.55 |
| FeO | 3.19* | | |
| $Fe_2O_3$ | 9.48* | 11.82** | 16.38** |
| Total | 99.54 | | |

* The value of the $Fe^{3+}/Fe^{2+}$ ratio was accepted as 2.12/0.88 on the basis of the data of X-ray structural analysis; ** total Fe content.

crystals have rhombohedral $\{10\bar{1}1\}$ and pinacoid {0001} faces and have a sectorial structure resulting from alternation of the areas with the different concentrations of Al and $Fe^{3+}$.

The crusts and crystals of nikmelnikovite are fragile, with a conchoid fracture. Cleavage and jointing are not observed. Merohedral twins by (110) are typical. The hardness by the Mohs scale is 5.5. The density determined by the method of equilibration in a Clerici liquid is 3.00(3) g/cm$^3$; the density calculated by the empirical formula and by the data of powder X-ray structural analysis is 3.08 g/cm$^3$. Macroscopically, nikmelnikovite is reddish brown, with a glassy to greasy luster. The crusts covered by crystals and globules are matte. The mineral is uniaxial, with $N_o = 1.682(5)$ and $N_e = 1.675(5)$ (at 589 nm). The color of the mineral in transmitting light is light reddish brown, without pleochroism. The convergence by Gladstone–Dale is excellent (0.002).

The chemical composition of nikmelnikovite (Table 1) was analyzed on a Cameca MS-46 wavelength-dispersive microanalyzer (Geological Institute, Kola Science Center, Russian Academy of Sciences) with the following parameters: voltage 20 kV, beam current 22 nA, beam diameter 5 μm; the standards were pyrope (Mg and Al), diopside (Si and Ca), $MnCO_3$ (Mn), and hematite (Fe). The concentration of $H_2O$ was determined by the method of Penfield from the sample of 24.92 mg.

The mean chemical composition of nikmelnikovite (0.38 MgO, 12.08 $Al_2O_3$, 22.10 $SiO_2$, 39.71 CaO, 0.52 MnO, 3.19 FeO, 9.48 $Fe_2O_3$, 12.08 $H_2O$, total 99.54 wt %) corresponds to the following empirical formula calculated for 68 charges (based on the structural data):

$$Ca_{11.81}(Fe^{2+}_{0.74}Mn_{0.12}Mg_{0.16})_{\Sigma1.02}(Al_{3.95}Fe^{3+}_{1.98})_{\Sigma5.93}[Si_{6.14}O_{24}](OH)_{20} \cdot 1.18H_2O.$$

**Table 2.** Standard X-ray pattern of nikmelnikovite *

| $D_{meas}$, Å | $D_{calc}$, Å | *hkl* | $I_{meas}$ | $I_{calc}$ |
|---|---|---|---|---|
| **8.57** | **8.60** | **110** | **65** | **100** |
| 6.06 | 6.09 | 021 | 0.8 | 1 |
| 4.967 | 4.968 | 300 | 16 | 22 |
| 4.297 | 4.302 | 220 | 17 | 19 |
| 3.849 | 3.849 | 131 | 8 | 5 |
| 3.505 | 3.513 | 401 | 0.4 | 1 |
| 3.250 | 3.252 | 140 | 16 | 23 |
| **3.042** | **3.044** | **042** | **58** | **35** |
| 2.873 | 2.872 | 303 | 6 | 5 |
| **2.720** | **2.720** | **223** | **100** | **91** |
| 2.594 | 2.595 | 511 | 11 | 12 |
| 2.483 | 2.484 | 600 | 27 | 18 |
| 2.388 | 2.391 | 214 | 16 | 22 |
| **2.223** | **2.225** | **134** | **28** | **26** |
| 2.154 | 2.154 | 404 | 1 | 1 |
| 2.087 | 2.087 | 351 | 1 | 2 |
| 2.035 | 2.032 | 205 | 0.5 | 1 |
| **1.9747** | **1.9745** | **532** | **30** | **31** |
| 1.9259 | 1.9263 | 244 | 5 | 4 |
| 1.8778 | 1.8775 | 630 | 2 | 2 |
| 1.8348 | 1.8375 | 045 | 0.6 | 1 |
| 1.7945 | 1.7942 | 271 | 2 | 1 |
| 1.7572 | 1.7567 | 802 | 10 | 15 |
| 1.7220 | 1.7209 | 811 | 2 | 2 |
| **1.6871** | **1.6875** | **461** | **31** | **27** |
| 1.6568 | 1.6567 | 363 | 5 | 4 |
| **1.6264** | **1.6264** | **642** | **32** | **25** |
| 1.5489 | 1.5481 | 416 | 3 | 5 |
| 1.5231 | 1.5221 | 084 | 7 | 6 |
| 1.4981 | 1.4984 | 903 | 2 | 3 |
| 1.4570 | 1.4574 | 217 | 0.3 | 1 |
| 1.4345 | 1.4350 | 464 | 0.5 | 1 |
| 1.4151 | 1.4150 | 743 | 1 | 2 |
| 1.3612 | 1.3606 | 482 | 6 | 3 |

* The seven most intense lines are indicated in bold.

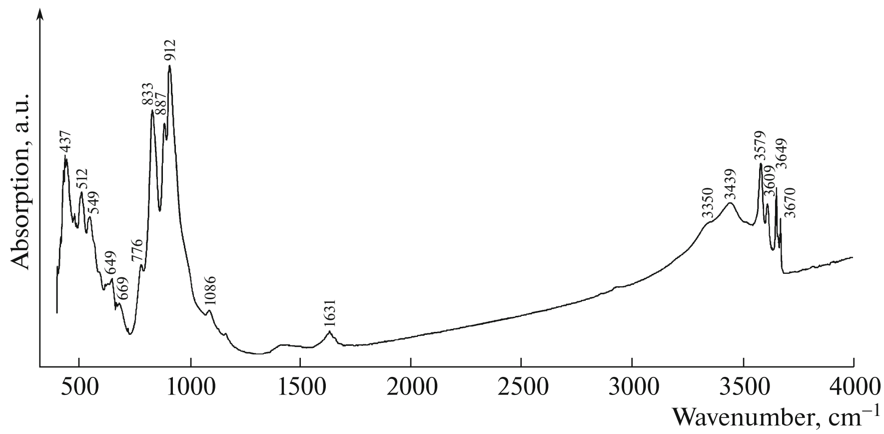


**Fig. 2.** IR spectrum of nikmelnikovite.

With account for the results of X-ray structural analysis, an ideal formula of the mineral may be written as $Ca_{12}Fe^{2+}Al_4Fe_2^{3+}[SiO_4]_6(OH)_{20}$.

The IR spectrum of nikmelnikovite (Fig. 2) was obtained at room temperature with a resolution of 2 $cm^{-1}$ on a Nicolet 6700 FTIR spectrophotometer (Institute of Chemistry and Technology of Rare Elements and Mineral Raw Materials, Kola Science Center, Russian Academy of Sciences) using KBr as the standard. The spectrum contains 16 clear absorption bands. Most of them are similar to those of andradite [3–5]: an intense triplet at 833–912 $cm^{-1}$ corresponds to asymmetrical stretching vibrations of Si–O bonds; the bands at 512–776 $cm^{-1}$ result from symmetrical and asymmetrical bending vibrations of Si–O bonds; and the band at 437 $cm^{-1}$ most likely corresponds to the vibrations of (Al,Fe)–O in $(Al,Fe)O_6$ octahedra. In contrast to anhydrous garnets, the IR spectrum of nikmelnikovite contains intense well-resolved absorption bands of stretching vibrations of O–H bonds in the area of 3300–3700 $cm^{-1}$, as well as an intense maximum of absorption at 1631 $cm^{-1}$ corresponding to bending vibrations of H–O–H bonds in water molecules.

According to the data of the structural analysis, nikmelnikovite is trigonal, $R\overline{3}$, $a$ = 17.2072(6), $c$ = 10.5684(4) Å, $V$ = 2710.1(2) $Å^3$, $Z$ = 3. The powder X-ray diffraction pattern was obtained on a Bruker Phazer D2 diffractometer with $CuK_\alpha$ radiation, an accelerating voltage of 40 kV, and a cathode current of 15 mA (Table 2). According to the data of powder X-ray diffraction, the cell parameters of the minerals are the following: $a$ = 17.2079(8) Å, $c$ = 10.5617(9) Å, $V$ = 2708.5(3) $Å^3$, $Z$ = 3.

The crystallochemical patterns of nikmelnikovite and its close association with manaevite-(Ce), a highly hydrous representative of the vesuvianite group, allow us to conclude that the mineral crystallized from late low-temperature hydrothermal solutions, overgrowing andradite epitaxially and using the coexisting magnetite and calcite as extra sources for Fe and Ca.

Nikmelnikovite is the first trigonal representative of the garnet supergroup [6].

## FUNDING

This study was performed within the scientific tasks of the Federal Research Center Kola Science Center, Russian Academy of Sciences (project nos. 0226-2019-0051 and 0186–2019–0011) and was supported by the Presidium of the Russian Academy of Sciences (program no. I-48) and by the Council for Grants of the President of the Russian Federation for Support of Leading Scientific Schools (project no. NSh-3079.2018.5).

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*Translated by A. Bobrov*