Genetic relationship between batievaite-(Y) and hainite-(Y) from Sakharjok nepheline syenite pegmatite, Keivy alkaline province, NW Russia

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The Keivy alkaline province, Kola Peninsula, NW Russia, consists of vast alkali granite massifs and several dike-like nepheline syenite bodies. The studied pegmatite body occurs within the contact zone between Sakharjok nepheline syenite and essexite, outcrops up to 30 m² in area, and consists of nepheline, albite, pyroxenes (mainly aegirine-augite), amphiboles (mainly hastingite), biotite and analcime. Common accessory minerals observed in the pegmatite are the apatite supergroup minerals, batievaite-(Y), calcite, fluorite, hainite-(Y), meliphanite, thomsonite-Ca, zircon (Lyalina et al. 2015; 2016).

REE and actinides distribution in host nepheline syenite (Zozulya et al. 2015), REE and F variations in the britholite group minerals from pegmatite (Zozulya et al. 2017) indicate that the late-magmatic (including pegmatic) and hydrothermal fluids were alkaline (mainly sodium), with significant, but varying, amounts of F and CO₂.

Batievaite-(Y), [(Ca₂Y₂[(H₂O)₂□](Si₂O₇)₂(OH)₂(H₂O)₂], and hainite-(Y), ((Ca₃Y)Na(NaCa)Ti(Si₂O₇)₂(OF)F₂), belong to rinkite group of seidozerite-supergroup minerals, their crystal structures based upon the same HOH block (Lyalina et al. 2016). Batievaite-(Y) can be considered as the Na-deficient yttrium analogue of hainite-(Y). Crystalo-chemical link between hainite-(Y) and batievaite-(Y) could be expressed by following isomorphic scheme: 2Na⁺+2Ca⁺+O₂⁻+3F⁻ ↔ Y³⁺+□+2(OH)⁻+4H₂O. It could be suggested from structural properties of batievaite-(Y) (cation deficiency, vacancies, substitution of cations by H₂O molecules), that mineral is related to transformational mineral species (Khomyakov 1992), formed by solid state transformation with inheritance of the main structural elements of the primary full-cation phase such as hainite-(Y) and removal of alkali cations from the structure during low-temperature hydrothermal alteration.

Typically, batievaite-(Y) and hainite-(Y) form intergrowths. Grains of batievaite-(Y) (euohedral or tabular crystals with length 0.25–0.3 mm) are surrounded by hainite-(Y) rims of 0.01–0.15 mm thickness (Fig. 1). The hainite-(Y) rim is separated from the batievaite-(Y) core by aggregates of analcime and calcite. The resorption of batievaite-(Y) and patches of altered batievaite-(Y) are observed therewith. The paragenesis of analcime and calcite crystallized after batievaite-(Y) and before hainite-(Y) indicates the CO₂ saturation of pegmatitic fluid due to temperature drop down to 250-100°C. During this stage the Ca activity in fluid decreases provided the relative rise of Na activity that is favorable to crystallization of hainite-(Y).

The study of REE composition in batievaite-(Y) and hainite-(Y) confirms the assumptions driven from textural data. An informative geochemical indicators of fluid composition in postmagmatic REE-bearing mineral formation are (La/Nd)ₙ and Y/Dy ratios. It was shown (Smith et al. 2000) that the fractionation of La and Nd depends on the CO₂ content in the mineral-forming solutions and affects the (La/Nd)ₙ in REE minerals (>4 for CO₂-rich solution, <4 for H₂O-rich solution). It is known, that Y-fluoride complexes
are more stable than Dy-fluoride complexes (Gramaccioli et al. 1999), thus the variations of Y/Dy ratios in minerals may indicate the change of F content in fluid.

In case of Sakharjok, the average values of (La/Nd)n are successively decreasing in the range batievaite-(Y) – altered batievaite-(Y) – hainite-(Y): 5.6, 5.0 and 1.7, respectively. Batievaite-(Y) has a Y/Dy average value of 24.3; altered batievaite-(Y) – 20.3; hainite-(Y) – 20.6. The lowest Y/Dy ratio observed in hainite-(Y) apparently indicates that the mineral crystallized from F-rich fluid, comparing to composition of crystallization media for batievaite-(Y).

On the whole, it is deduced from textural information and composition of minerals that batievaite-(Y) crystallized from CO2-rich and F-poor fluid, while the hainite-(Y) from CO2-poor and F-rich fluid. The content of a significant amount of water in the structure of batievaite-(Y) can explain later postcrystallization transformation (hydration).

**Fig. 1. Relationship between batievaite-(Y) and hainite-(Y) in the Sakharjok nepheline syenite pegmatite. SEM, BSE image. Cc – calcite, Anl – analcime**

**Acknowledgments:** The study was supported by the Russian Foundation for Basic Research grant 16-05-00427 and Russian government grant 0231-2015-0009.

**References:**


