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 m^2 in area, and consists of nepheline, albite, pyroxenes (mainly aegirine-augite), amphiboles (mainly hastingsite), 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 pegmatitic) and hydrothermal fluids were alkaline (mainly sodium), with significant, but varying, amounts of F and CO_2.

Batievaite-(Y), ($Ca_2Y_2[(H_2O)_2\square]Ti(Si_2O_7)_2(OH)_2(H_2O)_2$), and hainite-(Y), ($(Ca_3Y)Na(NaCa)Ti(Si_2O_7)_2(OF)F_2$), 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: $2Na^{+}+2Ca^{2+}+O^{2-}+3F^{-} \leftrightarrow Y^{3+}+\square+2(OH)^{-} +4H_2O$. It could be suggested from structural properties of batievaite-(Y) (cation deficiency, vacancies, substitution of cations by H_2O 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) (euhedral 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 CO_2 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 CO_2 content in the mineral-forming solutions and affects the $(La/Nd)_n$ in *REE* minerals (> 4 for CO_2-rich solution, <4 for H_2O-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 CO_2-rich and F-poor fluid, while the hainite-(Y) from CO_2-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).

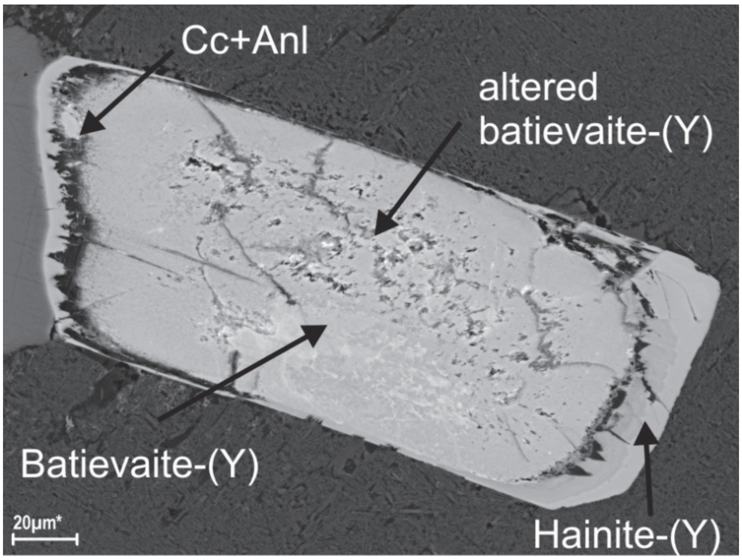

Fig. 1. *Relationship between batievaite-(Y) and hainite-(Y) in the Sakharjok nepheline syenite pegmatite. SEM, BSE image. Cc – calcite, Anl – analcime*

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