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Unusual alteration textures in allanite – a clue to metamictization processes

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Allanite represents the primary host for LREE in weakly peraluminous granites of I- and S-type affinity as well as in pegmatites, some skarns and to a lesser extent also in Ca-rich metamorphic rocks. In some of these occurrences, allanite is metamict and/or altered. Allanite alteration has been studied by a number of authors. Of them, only one has briefly mentioned (but not explained) the existence of a special type of alteration textures, „worm-like" (Poitrasson 2002). I have found this alteration feature in allanites from a number of different rocks. The „worm-like" features occur predominately in rocks that have suffered late-magmatic or post-magmatic hydrothermal alteration (Sulovsky 2003), as well as in pegmatites and skarns.

This texture consists of curvilinear, circular or elliptical zones about 0,3 – 0,7 μm wide, arranged in a onion-shell pattern, resembling the perlitic texture observed in some rhyolite glasses. It occurs in allanites with all kinds of original zoning – oscillatory, sectorial as well as patchy. The fissures mostly run across the sector or growth zone boundaries. Most allanites with this alteration pattern have it this texture across the whole grain, what apparently indicates this pattern developed after its growth finished. In some grains the perlitic texture develops only in some growth zones or sectors with specific composition, probably originally richer in radiogenic elements. The electron microanalysis totals are much lower than reported in other types of allanite alteration.. The perlitic fissures are sometimes brighter than the matrix, being filled with material of higher Z (Th and REE enriched). Perlitic texture occurs often together with other types of alteration, in detail described by Poitrasson (2002). Anyway, the role of larger cracks is much lesser than in allanites without the perlitic alteration textures. The larger cracks, often running across the whole grain, are usually filled with thorium silicate, occasionally with cerianite. Thorium silicate in some occasions fills also the perlitic fissures.

We can expect that a process analogous to perlitic texture formation in volcanic glass may have lead to the formation of this alteration texture in allanites as well. In rhyolitic glass, such texture develops by hydration on fracture surfaces that are exposed to to meteoric water. As the outer rind hydrates, it expands and separates along a crack from the nonhydrated substrate. Inward repetition of this process creates a sequence of concentric perlitic cracks. If such a process occurred in allanite, this mineral must first have had a glass structure. Actually, earlier studies on metamictization have assumed that metamictization transforms crystalline structure to glass structure. The similarity between the metamict state and glass state has been recently questioned in several studies on zircon (e.g. Zhang et al. 2000), titanite and zirconolite. Most of the methods used to study metamict state do not allow to draw unequivocal conclusions about the questioned glass state in metamict minerals, as they e.g. compare quenched glasses melted from metamict and non-metamict minerals, or thermally treated metamict minerals with untreated.

In all cases the perlitic texture occurs in allanites from U- and Th-rich host rocks, which have undergone chemical alteration, caused by hydrothermal fluids containing F^- and CO_2^{2-} ions. This condition has anyway been fulfilled in other rocks studied, but without the occurrence of perlitic texture in allanite. The clue can probably be sought in the timing of metamictization and alteration. Poitrasson (2002) in his study on allanite from Corsican granites assumed that the time interval between the crystallization of allanite and the hydrothermal alteration stage was too short for accumulation of radiation damage sufficient to cause metamictization. It is generally difficult to exactly date the alteration period, as it may be multiphase and the system cannot be considered as closed, precluding thus the use of most isotopic methods. I have therefore tested the possibility to use the occurrence of perlitic texture in allanite for a rough estimation of the minimum interval between rock formation and alteration. Based on average Th and U contents in allanite grains with perlitic texture, the time necessary for metamictization to occur can be calculated from the formula of Murakami (1991), relating the number of alpha disintegrations per miligram of mineral with the length of actinide decay and recent content in the mineral:

The whole-grain U and Th concentrations determined by EMPA (from a grid of defocused 30-μm spots covering the whole cross-section of allanites) allow one to calculate the α-decay dose:

$$D\alpha = 8N_1[\exp(\lambda_1 t) - 1] + 7N2[\exp(\lambda_2 t) - 1] + 6N3[\exp(\lambda_3 t) - 1]$$

where $D\alpha$ is the accumulated dose in α-decay events/mg; N_1, N_2, and N_3 are the present numbers of ^{238}U, ^{235}U, and ^{232}Th atoms/mg, λ_1, λ_2, and λ_3 are the decay constants for ^{238}U, ^{235}U, and ^{232}Th, and $t$is the time between allanite crystallization and hydrothermal alteration. The minimum time span calculated upon the assumption that the limit alpha particle dose for metamictisation was achieved in allanites with perlitic texture was calculated for several different samples with known dating of rock crystallization and exhumation. In all cases, the calculated time exceeded the known alpha damage accumulation time. The limit alpha dose used in the calculation was, like in all previous studies, the same as the well-defined saturatin dose for zircon and thorite (1.10^{16} alpha events per mg).

For average Th content in allanites from the Trebic durbachite massif equal to about 1.1 wt.% and U = 0.27%, the time span between the time of granite emplacement (340 Ma) and hydrothermal alteration that overprinted the metamictization would be 58 Ma. Pebbles of durbachites occur in the youngest formation of the Drahany Culm basin, so called Luleč conglomerates; they also contain allanites with perlitic alteration texture. The age of this formation is 325 Ma (Gradstein & Ogg 1996), i.e. the maximum time that elapsed between the emplacement of Třebíč massif and formation of the pebbles must have been 15 Ma. The explanation for this big discrepancy might be in the fact that the limit alpha dose triggering amorphisation in allanite is much lower than in zircon. According to measurements on allanites from Třebíč massif and Luleč conglomerates around $2.6.10^{14}$ events per mg, i.e. at least 40 times lower than in zircon.

There of course is a possibility that these calculations are biased due to mobility of thorium and uranium during and after alteration. The evidence for Th mobility in studied allanites with perlitic structure can be seen in all allanite grains as well as in their close environs as fracture fillings, precipitates of thorium phases at the outer rim of allanite grains and in thin veinlets of Th phases radiating from these grains into surrounding rock/forming minerals.

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