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Non-invasive assessment of the formation of tourmaline nodules by X-ray microtomography and computer modeling

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Abstract

Tourmaline nodules occurring in the Capo Bianco (Elba Island, Italy) aplitic rocks are here investigated by X-ray microtomography 3D imaging. This non-invasive technique provides 3D images of the tourmaline nodules, revealing an irregular morphology consisting of branches that extend radially from the cores. The nodules present scale-invariant features that can be described by a box-counting fractal dimension. The value of the fractal dimension is proportional to the size of the nodules and tends asymptotically to a value of 2.5, in agreement with the results obtained from the simulation of virtual nodules, by means of a diffusion-limited aggregation model based on a Monte Carlo Metropolis algorithm, in which the growth probability at the tips of the nodule is an inverse function of the diffusion coefficient. The results support the hypothesis that tourmaline formed by a disequilibrium magmatic process, in which diffusion represents the rate-limiting step, inducing the formation of nodules with irregular shapes. This study shows the potential of X-ray microtomography, in combination with numerical modeling, as a probe for accessing the 3D microstructural information of complex mineral morphologies with a non-invasive approach. The combination of numerical and experimental, non-invasive, 3D techniques represents a fundamental step forward in bridging the gap between the observation of microstructures and the interpretation of the associated processes.

Keywords: Disequilibrium, fractal, tomography, tourmaline, diffusion-limited aggregation