Quantitative electron diffraction analyses of natural and synthetic imogolites

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Imogolite, a hydrous aluminum silicate, is an inorganic macromolecule with a tubular structure. Imogolite is formed naturally as a weathering product from volcanic pumice or ash, and synthesized by hydrothermal reactions at relatively low temperatures. The structure of natural imogolite proposed is an orthosilicate, consisting of a tubular gibbsite sheet and SiO_4 tetrahedra attached to the inner side of the gibbsite sheet [1]. However, the detail and its structural variation is still not well known. Electron diffraction (ED) is the best method to investigate the structure of such a macromolecule. Furthermore, Imaging plates (IPs) make quantitative analyses of ED possible and recent energy-filtered transmission electron microscopy (EF-TEM) also improves the quality of the diffraction patterns. In this study, the structures of natural and synthetic imogolites have been investigated mainly by ED using an EF-TEM and IPs.

The natural specimen was collected from Kurayoshi, Tottori-pref., Japan. The synthetic specimen was prepared by the process previously described [2]. TEM was performed using a JEOL JEM-3100 FEF operated at 300 kV and JEM-2010 operated at 100-200 kV. Diffraction patterns were recorded on Fuji imaging plates with 25 µm pixel size.

Imogolite is regarded as a one-dimensional crystal with a periodicity along the tube (the c-axis) of 0.84 nm. Intensity distribution on the reciprocal lattice planes at $l = 0$ and $l = 2$ in the diffraction patterns from natural imogolite bundles can be well explained by the calculated amplitude using the proposed structure model with n = 11 plus/minus 1 [1]. On the other hand, intensity distribution on the same planes was considerably different for the synthetic specimen and cannot be explained by the structure model. As high-resolution images definitely show a tubular structure, a new structure model is necessary for the synthetic imogolite. A part of this work was supported by “Nanotechnology Support Project” of MEXT, Japan.

References

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Combined low temperature thermochronology in slowly-cooled terranes: Challenges and strategies

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Combining results of apatite fission track (AFT) and (U-Th)/He (AHe) thermochronometry potentially leads to new insights into upper crustal t-T paths and surface processes. Several studies have shown the effectiveness of this approach in relatively rapidly cooled terranes, but the few results that have been reported from slowly cooled terranes suggest that the dual approach in such environments may not be straightforward. We evaluate the results of combined AFT-AHe studies in Precambrian shields of West Australia, North America and Fennoscandia. We find problems mainly arise in applying the AHe system and may include: ‘excess’ AHe ages compared to coexisting AFT ages, inability to reproduce AHe ages, effects of variable grain size, chemical variations within grains, the presence of U and Th-rich micro-inclusions and the possible consequences of prolonged residence in the He partial retention zone. In the Shield environment, Phanerozoic stratigraphic or structural information is commonly scarce or missing so we find it essential to use coexisting AFT data to aid in sample selection for AHe analysis and as a first-order check on the reliability of results. In some cases, more consistent AHe results arise from mafic to ultramafic rock types with much lower overall U and Th content in the host environment. Tighter constraints on t-T paths can also be made where AFT data modelling provide some boundary conditions and when a suite of deep borehole samples, possessing a ‘linked’ thermal history at different crustal levels, are available.

AFT results from the southern Canadian Shield, including a 3.44 km deep borehole in the Sudbury intrusion, reveal a spatial distribution related to burial under foreland sediments during late Ordovician to Silurian and late Permian to early Triassic time, following the Taconic and Alleghanian Orogenies respectively to the east. Our AHe results show that parts of south eastern Ontario had cooled to temperatures <~40°C by late Jurassic time, whereas samples deep in the Sudbury borehole also record a ‘weak’ late Cretaceous heating event not recorded by AHe data from near-surface samples. Similar patterns related to burial beneath now missing sedimentary sequences are also inferred for both the West Australia and Fennoscandia shield examples. The combined results provide complementary insights into the lowest part of the thermal history, which would not have been recognised using either method alone.