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Mineral quantification at the nanoscale by combining synchrotron radiation x-ray tomography, fluorescence and diffraction

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Novel 3D imaging methods such as x-ray microtomography (µCT) are becoming increasingly popular tools in the geosciences to understand three dimensional (3D) aspects of geological processes. Microtomography not only provides relatively easy visualization of the rock or grain structure, but can also reveal features that would be time consuming or impossible to quantify with traditional thin-sectioning methods. The technique can be utilized with two very different types of x-ray source: 1) so-called 'desktop' µCT scanners, which are based on an x-ray tube and best suited for analysis of relatively large samples with micrometer resolution [1], and 2) synchrotron radiation sources, where the significantly higher flux enables a wider choice of beam modes and resolutions [2].

A key advantage provided by a synchrotron source is the possibility to perform multimodal experiments, correlating the micro- or nanotomography scan with chemical or crystallographic information. At the European synchrotron radiation facility (ESRF), recently developed nanoprobe beamline ID16B [3] allows phase-contrast nanotomography to be complemented by x-ray diffraction and fluorescence scanning with a beam size of approximately 50 nm.

In this work, the capabilities of the beamline for geoscientific research are illustrated by two examples. In the first, growth zoning in individual zircon grains is quantified in 3D with nanotomography, and subsequently correlated with diffraction analysis of inclusion mineralogy and spatial variations in the uranium, thorium and lead content, all key elements for the use of zircon as a geochronometer (Fig. 1). As a second example, nanotomography is used to hunt the spatial distribution of refractory gold grains locked inside arsenopyrite crystals, followed by x-ray fluorescence analysis of trace element distribution within the arsenopyrite.

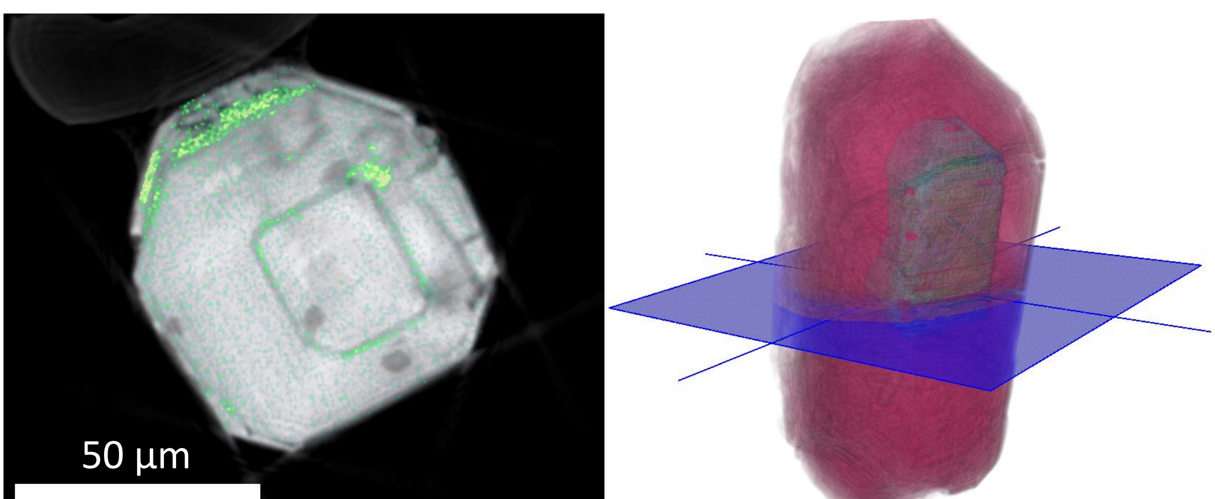

Figure 1: Left: X-ray nanotomography cross section of zircon grain, showing the smaller core of the crystal and a zoned outer shell. Green color indicates uranium concentration as observed with x-ray fluorescence tomography. Right: 3D-rendering of the grain, with the uranium-rich interface between core and shell within the grain rendered in green. Blue plane indicates position of the left image.

References:

[1] Sayab M et al. (2015) Geology 43(1): 55-58

[2] Fusseis F et al. (2014) J Struct Geol 65: 1-16

[3] Martínez-Criado G et al. (2016) J Synchrotron Rad 23: 344-352