Tackling 3D chemical imaging in zircons: growth zoning, trace element mapping and inclusion mineralogy by non-invasive multimodal x-ray nanotomography

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Zircon is by far the most widely used mineral in geochronology and dating rocks. However, little efforts have been made to non-invasively visualize and quantify internal textures within zircons, their growth and zoning patterns and chemical distribution of trace elements in 3D. We present a novel multimodal approach of using a synchrotron radiation nanobeam to non-destructively quantify the internal morphology, trace element content, and crystal structure of <100 μm zircons at high resolution (~ 100 nm) in 3D. To demonstrate the utility of this approach, we have analyzed 1.882-1.891 Ga old zircons from the Central Finland Granitoid Complex. We have used scanning x-ray absorption and fluorescence tomography at the newly established nanoprobe beamline ID16B of the European Synchrotron to reveal the sector and oscillatory zoning patterns of the zircons as well as differences in zoning pattern between trace elements. Additionally, x-ray diffraction helped to identify inclusions within a zircon (hematite in this case), and to measure lattice parameters the zircon matrix itself. Finally, full-field x-ray nanotomography was used to extrapolate the information gained with scanning methods from individual cross-sectional data to the entire 3D volume of the zircon crystal. Compared with conventional methods for analyzing zoning and chemical composition in minerals, such as cathodoluminescence (CL) microscopy, backscatter electron imaging (BSE), and ion or laser ablation mass spectrometry, the combined fluorescence/absorption approach has the advantage of coupling high resolution with chemical sensitivity. By combining these features with the 3D view provided by nanotomography, the internal textural and chemical characteristics of submillimeter-sized zircons are revealed in unprecedented detail. Moreover, the technique is equally applicable to other minerals besides zircon, and non-destructive, allowing the same samples to be used for further studies, most importantly isotope dating.