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Non-invasive characterization of mafic/ultramafic, and Ca, Mg-carbonate rocks using spectral X-ray tomography: first data on detection, identification and quantification

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Dissolution-precipitation reactions during carbon mineralization are typically studied using destructive chemical and mineralogical analysis. Although X-ray computed tomography (XCT) is widely used for the non-invasive study of dynamic geological processes, phase identification in mafic/ultramafic rocks using this technique is challenging, as these rocks typically contain minerals with similar linear attenuation coefficients. A similar challenge arises when distinguishing minerals in the Ca-Mg carbonate solid solution series. We used recently developed laboratory-based spectral X-ray micro-computed tomography (sp-CT) to characterize mafic/ultramafic and carbonate rocks.

By detecting the energy of individual transmitted photons, the employed system, a Tescan UniTOM XL Spectral, enables reconstructing the linear attenuation coefficients within the range from 20 kV to 160 kV. While phases containing heavy elements (e.g., W, Au, Pb) can be directly identified by their characteristic absorption edges (K-edges) within this energy range [1], common silicate- and carbonate-forming minerals consist of lighter elements whose K-edges fall below the operational X-ray energy range of the system, limiting direct identification. We demonstrate that a data-processing workflow inspired by dual-energy CT can be used to distinguish these light-element-bearing phases.

Using this method, we successfully distinguished olivine, pyroxene, amphibole, orthoclase, and plagioclase in a mafic rock non-invasively [2]. Additionally, we distinguished calcite, magnesian calcite, dolomite, and magnesite and developed a calibration strategy to identify and quantify them [3]. Furthermore, coupling time-lapse sp-CT with hydrothermal batch experiment, we demonstrated that this approach can also be used to monitor mineral replacement reactions, such as the transformation of calcite to dolomite.

These examples highlight the versatility of sp-CT in non-invasive phase identification, even without characteristic absorption edges. Our method opens up new perspectives on the non-invasive visualization of mineralogical changes in mafic and ultramafic rocks and the tracking of replacement and dissolution-precipitation reactions involving carbonate phases.

References

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