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Multi-scale and multi-modal imaging study of mantle xenoliths and petrological implications

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Abstract

The accurate textural characterization of mantle xenoliths is one of the fundamental steps to understanding the main processes occurring in the upper mantle, such as sub-solidus recrystallization, magmatic crystallization, and metasomatism. Texture, composition, and mineralogy reflect the temperature, pressure, stress conditions, melting, and/or contamination events undergone before and during the entrapment in the host magma. For these reasons, characterizing the three-dimensional (3D) texture of silicate, oxide, sulfide, and glass phases has great importance in the study of mantle xenoliths. We performed a multi-scale and multi-modal 3D textural analysis based on X-ray computed microtomography (μ-CT) data of three mantle xenoliths from different geodynamic settings (i.e., mobile belt zone, pericraton, oceanic hotspot). The samples were selected to represent different, variably complex internal structures composed of grains of different phases, fractures, voids, and fluid inclusions of different sizes. We used an approach structured in increasing steps of spatial and contrast resolution, starting with in-house X-ray μ-CT imaging (spatial resolution from 30 μm down to 6.25 μm) and moving to high-resolution synchrotron X-ray μ-CT at the micrometer scale.

We performed a 3D characterization of mantle xenoliths, comparing the results with the analysis of conventional 2D images (thin sections) obtained by optical microscopy and simulating the random sectioning of several thin sections to estimate the probability of correct modal classification. The 3D models allow the extraction of textural information that cannot be quantified solely from thin sections: spinel layering, distribution of silicic glass, and related vesicles. Moreover, high-density volumes identified as sulfides were detected in two xenoliths, showing no relation with the spinel layering in one case and a preferential concentration along fractures in the other. Given the variety of textures and mineral assemblages of mantle xenoliths worldwide, the results are used to suggest experimental and analytical protocols for the characterization of these materials.

Keywords: 3D microcomputed tomography, X-ray synchrotron-based μ-CT, mantle xenoliths, petrology