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3D investigation of inclusions in diamonds using X-ray micro-tomography

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The study of mineral inclusions in diamonds is providing invaluable insights into the geochemistry, geodynamics and geophysics of the Earth's mantle. Over the last two decades, the identification of different inclusion assemblages allowed to recognize diamonds deriving from the deep upper mantle, the transition zone and even the lower mantle. In such research field the in-situ investigation of inclusions using non-destructive techniques is often essential but still remains a challenging task. In particular, conventional 2D imaging techniques (e.g. SEM) are limited to the investigation of surfaces and the lack of access to the third dimension represents a major limitation when trying to extract quantitative information. Another critical aspect is related to sample preparation (cutting, polishing) which is typically very invasive. Nowadays, X-ray computed micro-tomography (X-μCT) allows to overcome such limitations, enabling the internal microstructure of totally undisturbed samples to be visualized in a three-dimensional (3D) manner at the sub-micrometric scale. The final output of a micro-tomography experiment is a greyvalue 3D map of the variations of the X-ray attenuation coefficient (μ) within the studied object. The high X-ray absorption contrast between diamond (almost transparent to X-rays) and the typical inclusion-forming minerals (olivines, garnets, pyroxenes, oxides and sulphides) makes X-μCT a straightforward method for the 3D visualization of inclusions and for the study of their spatial relationships with the diamond host.
In this work we applied microfocus X-μCT to investigate silicate inclusions still trapped in diamonds, in order to obtain in-situ information on their exact position, crystal size, shape and X-ray absorption coefficient (which is related to their composition). We selected diamond samples from different deposits containing mainly olivine and garnet inclusions. The investigated samples derived from the Udachnaya pipe (Siberia, Russia), the Jericho Kimberlite (Slave Craton, Canada) and São Luiz–Juina (Brazil). The information obtained by tomographic experiments were combined with X-ray single-crystal diffraction data (see Nestola et al 2011) in order to identify the inclusion parageneses (peridotitic, eclogitic or websteritic) and to finally determine the origin of the studied diamonds.
Our results showed that, by combining X-μCT with X-ray diffraction data, it is possible to exactly determine the 3D position of each inclusion together with their crystal size, even though they cannot be detected by using an optical microscope. In addition, such method could have strong crystallographic implications for inclusions still trapped in diamonds as it enables the application of a reliable numerical absorption correction to the 3D intensity data collections.

REF.
Nestola, F., Nimis, P., Ziberna, L., Longo, M., Marzoli, A., Harris, J.W., Manghnani, M.H., Fedortchouk, Y. (2011): First crystal-structure determination of olivine in diamond: composition and implications for provenance in the Earth's mantle. Earth Planet. Sci. Lett., 305, 249-255.