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Multi-analytical approach for non-destructive analyses of a diamond from Udachanya and its trapped inclusions: the first report of (Fe,Ni)1+xS mackinawite sulphide in diamonds

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The study of diamonds and the mineral inclusions trapped in them is of great interest for Earth science, since they can provide insight about deep mantle conditions and its evolution. The conventional techniques commonly used are destructive and thus do not allow the employment of different methods used simultaneously to obtain integrated and complementary results. Significant information about the growth conditions of diamonds and their inclusions still trapped within them can be preferably obtained by in situ investigation. In this study, we propose a multi-analytical approach, using a set of non-destructive techniques with conventional sources, to investigate one diamond from Udachnaya kimberlite (Siberia, Russia). The combined use of micro-X-ray Tomography, micro-X-ray Fluorescence, X-Ray Powder Diffraction and micro-Raman spectroscopy, allowed us to determine the spatial distribution of the inclusions, their chemical and mineralogical composition and, finally, the paragenetic suite, totally preserving the diamond host. The sample was also studied by means of X-ray Diffraction Topography to characterize the structural defects and to obtain genetic information about the growth history of the diamond. The combination of the different data provided a sort of «mapping» of a diamond. The X-Ray Topographic images show that the sample investigated exhibits plastic deformation. Actually, one set of {111} slip lamellae, corresponding to polysynthetic twinning, affect the whole sample. The tomographic images reveal that the primary inclusions, not observable optically, show a poly-faceted shape corresponding to an assemblage of tiny crystals. The chemical data display that the trapped minerals are mono-sulphides of Fe, Ni. The diagrams obtained by the X-Ray diffraction reveal that the inclusions mainly consist of an assemblage of tiny crystals of pentlandite and pyrrothite. Nevertheless, a thorough analysis of the diffraction data suggests the presence of another mono-sulphide of Fe,Ni: mackinawite. Raman spectra taken on these inclusions confirm, for the first time, the presence of this metastable phase as inclusion in diamond. The genetic implications of these results are discussed.