Transmission Electron Microscopy, X-Ray Diffraction and Micro Raman Spectroscopy investigation of extraterrestrial ureilitic carbon

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Introduction - Ureilites

Ureilitic meteorites (achondrites) consist of ultra-mafic rocks, mainly composed of olivine, pigeonite, minor carbon (graphite and diamond) and Fe-Ni compounds, and are believed to come from the same parent body, the Ureilitic Parent Body (UPB), which was catastrophically disrupted by impact event(s) [1]. Nowadays, the shock origin of diamonds in ureilites is the most supported and reliable process of formation [2,3,4,5,6,7].

Ureilites present different levels of shock recorded by silicates [8,9]. In particular, the shock level determination in meteorites was proposed by [8,9] and consists of an association of observations of shock features in silicates (olivine, pyroxene, and feldspar) with seven stages of shock, from S1 (very low degree of shock) to S7 (very high degree of shock) by optical microscopy. However, even if this classification method is widely used nowadays, it is more of a semi-quantitative approach and often results in significant uncertainties.

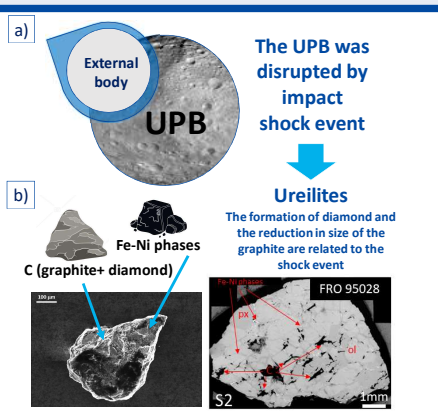
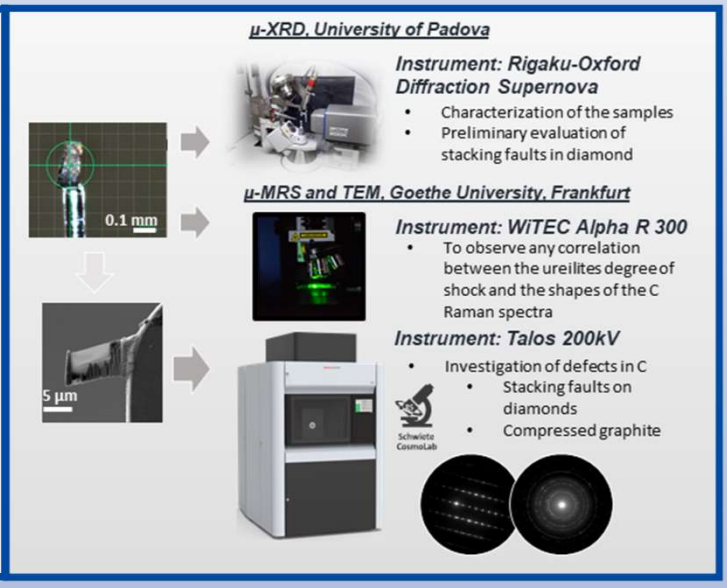


Fig.1 *Schematic illustration highlighting the connection between the disruption of the UPB (a) and the presence of diamonds and nanometric graphite on ureilites (b).*

Project's aim

This project is mostly aimed at developing a new approach that will allow the detailed and quantitative investigation of the defects in graphite and the stacking disorder on a large number of shocked extra-terrestrial ureilitic diamonds and graphite by Transmission Electron Microscopy (TEM), X-ray diffraction (μ-XRD) and micro-Raman Spectroscopy (μ-MRS), in order to restrict the real shock range experienced by the samples and improve the shock classification of this meteorite group. In principle, our results could be then applied to all carbon-bearing meteorites.

Methodological approach



Expected results

The expected μ-XRD, MRS and TEM results on carbon of the selected ureilites with a wide range of different levels of shock (from U-S1 to U-S7) will allow to:

- evaluate the presence of "compressed graphite" and of a diaphite nanostructure;
- detect and characterize the stacking disorder in extra-terrestrial ureilitic diamonds for both nanometric and micrometric;
- define a correlation between the carbon features (stacking disorder [10] in diamond, com-pressed graphite, and various nanostructures) and the degree of shock recorded by silicates in each ureilitic sample selected for this study;
- constrain the pressure range at which individual features (like lonsdaleite lamellae, twins, etc.) appear. This evaluation will help to improve the shock classification adopted so far in literature based on stacking disorder and other microstructural features.
- propose an upgraded shock classification of differentiated meteorites also based on features that will be more accurate than traditional observation by optical microscopy alone.

Literature [1] Goodrich C. A. (1992) MAPS, 27:327–352; [2] Nakamuta Y. et al. (2016). J. Mineral. Petrolog. Sci, 150906; [3] Nestola F. et al. (2020) PNAS 41:25310–25318; [4] Barbaro et al. (2021) GCA, 309:286-298. [5] Barbaro et al. (2022) Am. Min., 107 (3): 377–384. [6] Barbaro et al. (2023) EPSL, 614: 118201; [7] Christ et al. (2022) MAPS 1-18; [8] Stöffler D. et al. (1991) MAPS, 55(12): 3845-3867; [9] Stöffler D. et al. (2018) MAPS, 53(1):5-49; [10] Murri M. et al. (2019) Sci. Rep., 9(1):1-8.

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