TRANSMISSION ELECTRON MICROSCOPY, X-RAY DIFFRACTION AND MICRO-RAMAN SPECTROSCOPY INVESTIGATION OF EXTRATERRESTRIAL UREILITIC CARBON. A. Barbaro[1], F. Nestola[2] and F. Brenker[1], [1]Geoscience Institute, Goethe-University Frankfurt, Altenhöferallee 1, 60438 Frankfurt, Germany (barbaro@em.uni-frankfurt.de; f.brenker@em.uni-frankfurt.de), [2] Department of Geosciences, University of Padova, Via Gradenigo 6, 35131 Padova, Italy (fabrizio.nestola@unipd.it).

Introduction: Ureilitic meteorites (achondrites) consist of ultramafic 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. To address this matter and attempt to determine the shock pressure of ureilites with higher accuracy (and possibly extending to other carbon-bearing meteorites), I will deeply investigate a series of shock carbon-bearing ureilitic meteorites by a combined approach applying Transmission Electron Microscopy (TEM), micro-X-Ray Diffraction (μ-XRD) and micro-Raman Spectroscopy (MRS).

In this contribution, I will present the project plan, funded by the Alexander Von Humboldt Foundation, aimed at developing a new approach that will allow the detailed and quantitative investigation of the defects in extra-terrestrial ureilitic diamonds and graphite by multimethodological approach in order to restrict the real shock range experienced by the samples and improve the shock classification of this meteorite group.

Samples: I will perform a sample selection of 35 ureilites for the detailed analyses: five meteorites for each U-S shock level (based on optical characterization by [9]). The first samples on which we are collecting the first preliminary results for this project will be made on 5 ureilitic samples from Frountier Mountain Antarctica (FRO 95028, FRO 01089, FRO 97013, FRO 01088 and FRO 01012). The petrographic description of these samples is reported in [6].

Methods: The selected ureilites will be studied by Optical Microscopy (OP) and Scanning Electron Microscopy (SEM) [by JEOL JSM-6490] while the carbon phases extracted from these fragments will be investigated by X-ray diffraction (XRD) [using Rigaku-Oxford Diffraction Supernova kappa-geometry goniometer], micro-Raman Spectroscopy (MRS) [by WiTEC Alpha R 300] and Transmission Electron Microscopy (TEM) [using Talos 200kV]. All these analyses will be performed at the Geoscience Institute of the Goethe University, Frankfurt (Germany) with the exception of XRD which will be performed at the Department of Geoscience, University of Padova. The preparation for TEM film lamellae samples will be made using the Focus Ion Beam at the Department of Geosciences, University of Padova.

Results: The expected 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;
- determine the temperature recorded by graphite in the selected ureilitic samples with different degrees of shock using the geo-thermometer by [10];
- define a correlation between the carbon features (stacking disorder [11] in diamond, compressed 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.

Conclusion: The combined investigation of carbon features together with the shock recorded by silicates will help us to better understand the energy released by dynamic impact process(es) that involved a differentiated body as the UPB and also will allow us to improve the shock classification of ureilitic meteorites. The result of this project will very likely add a "missing piece" in reconstructing the puzzle of the UPB and its asteroidal daughter bodies' history.

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References: [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] Cody G. D. et al. (2008) *EPSL, 272:* 446–455. [11] Murri M. et al. (2019) *Sci. Rep., 9(1):*1-8.