Seeking evidence of life in sulphides from the Boltysh impact structure

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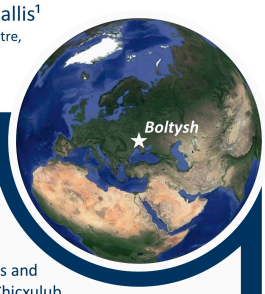


Boltysh, was there life? Did it eat tasty sulphur? Isotopes will tell.

Introduction

Impact cratering provides a heat source on otherwise cold planetary surfaces, and thereby creates habitable environments for micro-organisms [1-5]

Finding direct evidence for microbial colonization within impact structures has proven to be challenging and contentious [e.g., 6–9]

Recent work on sulphides in terrestrial impact structures [e.g., 10,11] has demonstrated that sulphur isotopes were fractionated in a manner consistent with biological activity

The presence of hydrothermal alteration in the central uplift and crater fill impactites of the Boltysh impact structure, Ukraine [1,12,13] has motivated us to investigate whether the Boltysh sulphides have an isotopic signature consistent with biological fractionation

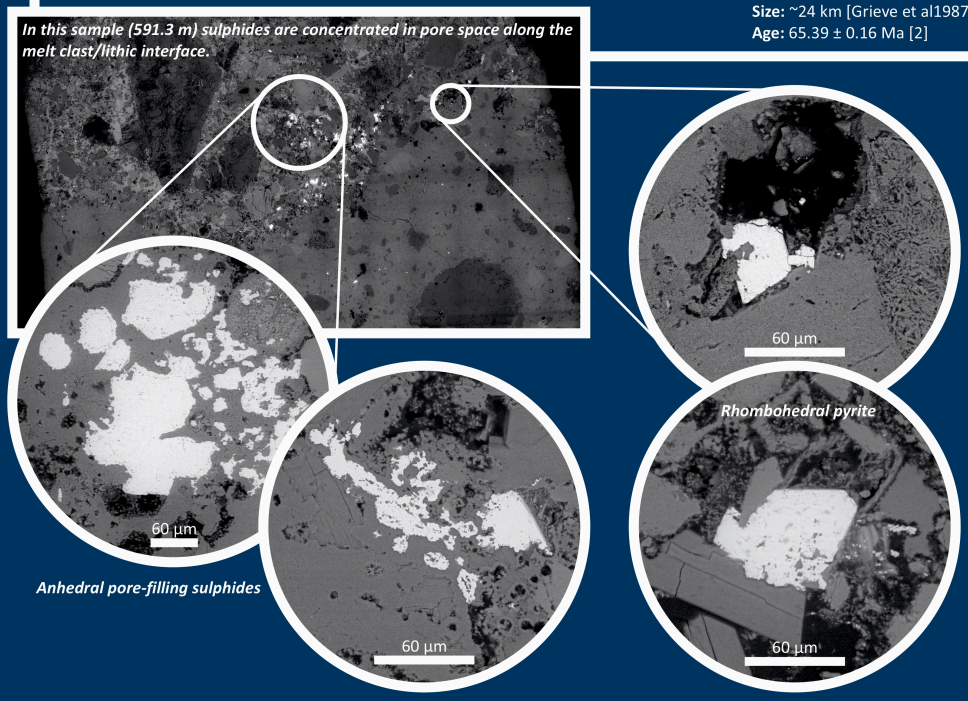
Summary

Preliminary observations of secondary sulphide minerals (i.e., pyrite) in Boltysh polymict breccias show similar morphologies and relationships to surroudnding minerals as those observed in Chicxulub which yielded negative $\delta^{34}S$ and $\Delta S_{sulphate\text{-}sulphide}$ values indicative of biological fractionation [11]

Planned EBSD and sullphur isotope measurements will provide insight into the formation mecahanisms of the Boltysh sulphides and potentially evidence of biologically mediated sulphur isotope fractionation

Boltysh Impact Structure

Location: central Ukraine (48°45' N, 32°10' E)
Size: ~24 km [Grieve et al1987]
Age: 65.39 ± 0.16 Ma [2]
Target lithology: Precambrian granites and granitic gneisses (Ukrainian Shield) [1]



Petrography

- Four samples of impact melt-bearing (suevitic) breccia from different depths (589-584 m) in core 42-11 [16].
- Sulphides are more concentrated in lithic portion than in melt clasts
- Found infilling porespace; filling fractures; replacing other minerals; and as euhedral crystals in cavities
- Most are anhedral following the shape of fractures and pores that they fill, those replacing other minerals or in cavities are euhedral rhomboid or pyritohedral.

Electron backscatter diffraction (EBSD)

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Sulphur isotope analysis

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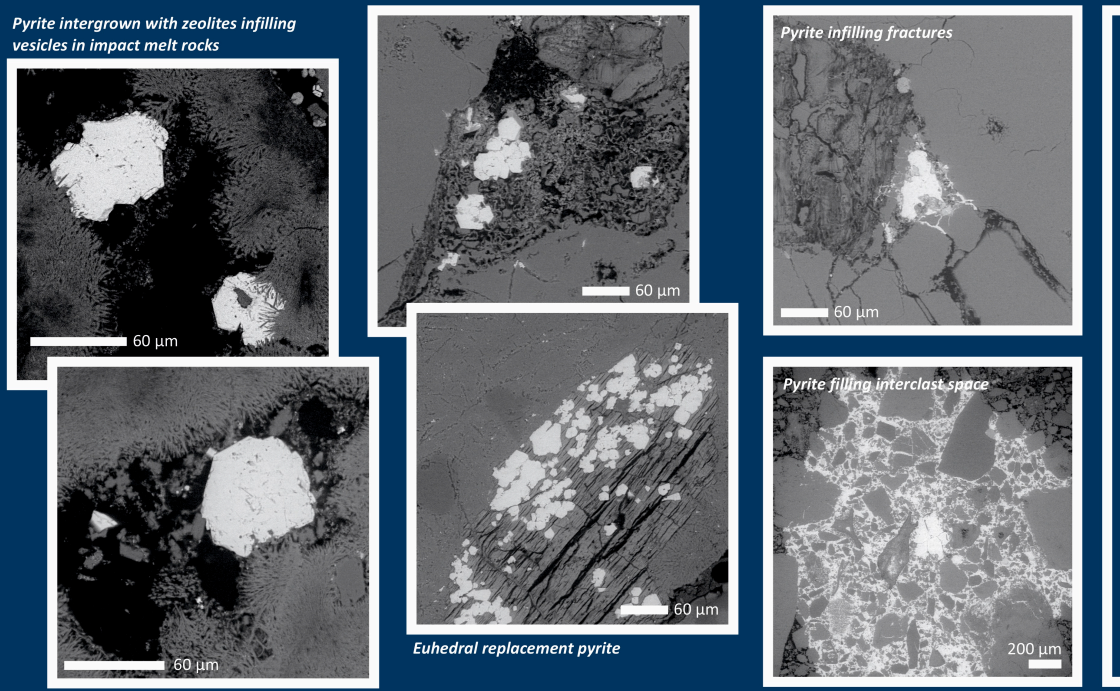

Discussion

Our initial observations of sulphide mineralization in the Boltysh impact-melt-bearing breccia match the descriptions of Gurov et al. [17], and we will expand upon this work by determining sulphur isotope ratios and investigating microstructures in more detail via EBSD.

Similar sulphide morphologies and relationships to surrounding minerals were observed at the Chicxulub impact structure [11]. Those sulphides yielded negative $\delta^{34}S$ and $\Delta S_{sulphate\text{-}sulphide}$ values indicative of biological fractionation.

Upcoming sulphur isotope measurements on the Boltysh samples described here will provide another data point for our understanding of sulphide minerals in post-impact hydrothermal systems, and their possibilities for preserving signs of past life.

References:[1] Osinski G.R., et al. (2013) *Icarus*, *224*, 347-363. [2] Farmer J.D. (2000) *GSA Today*, *10*, 1-9. [3] Cockell C.S. and Lee P. (2002) *Biological Reviews of the Cambridge Philosophical Society*, *77*, 279-310. [4] Cockell C.S. (2006) *Philosophical Transactions of the Royal Society B: Biological Sciences*, *361*, 1845-1855. [5] Osinski G.R., et al. (2020) *Astrobiology*. [6] Versh E., et al. (2006) *Planetary and Space Science*, *54*, 1567-1574. [7] Sapers H.M., et al. (2014) *Geology*, *42*, 471-474. [8] McLoughlin N. and Grosch E.G. (2014) *Geology*, *42*, e346-e346. [9] Sapers H.M., et al. (2014) *Geology*, *42*, e348-e348. [10] Simpson S.L., et al. (2017) Earth & Planetary Science Letters, 460, 192-200. [11] Kring D.A., et al. (2021) Astrobiology, 21, 103-114. [12] Williams F. (2014) PhD Thesis, The Open University. [13] Gurov E.P., et al. In Cockell CS,Koeberl C,Gilmour I, eds. Biological Processes Associated with Impact Events. Berlin: Springer-Verlag, 2006; 335-358. [14] Grieve R.A.F., et al. (1987) Contributions to Mineralogy and Petrology, 96, 56-62. [15]]Pickersgill, A.E., et la. (2021) Science Advances, 7, eabe6530.[16] Jolley D., et al. (2010) Geology, 38, 835-838. [17] Gurov E.P., et al. (2015) Meteoritics and Planetary Science, 50, 1139-1155. **Acknowledgements:** We gratefully acknowledge funding from the Leverhulme Trust though RPG-2018-061.

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