BOULDERS AND BEYOND:

A Multiscale Analysis of Asteroid (101955) Bennu

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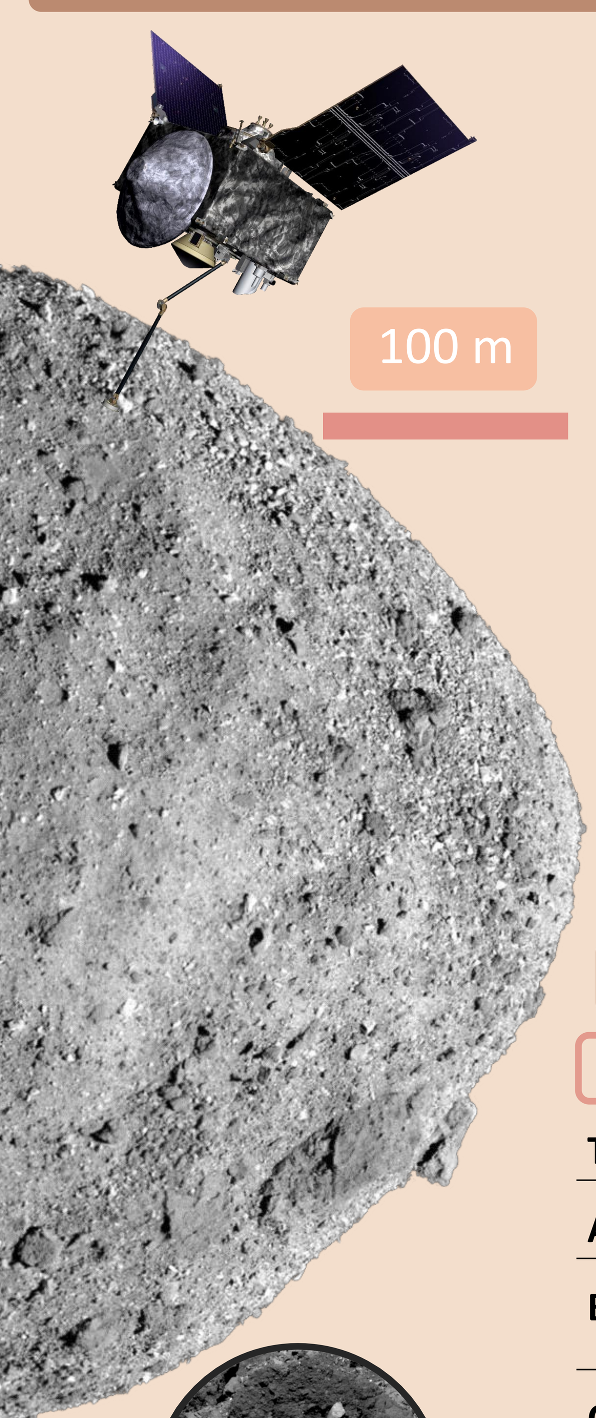
Research Question:
How can we better understand the diversity and characteristics of boulders on Bennu by examining boulder features at various spatial scales?

Larger Scale: Boulder Diversity Analysis

Background



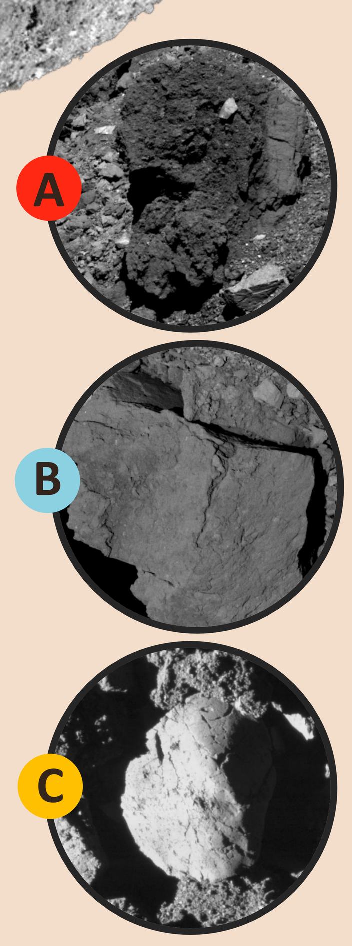
NASA's first asteroid sample return mission is **OSIRIS-REx** (Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer), set to return a sample from near-Earth asteroid (101955) **Bennu**[1].

Bennu is a **carbonaceous rubble-pile** asteroid, meaning it likely originated from the main asteroid belt and contains **rocks** and **chemicals** preserved from the **birth** of the **solar system**[2,3].

Aim

To map out **key characteristics** of boulders, including shape, size, aspect, surface texture, and more**,** in order to create a **working classification system** for boulders on Bennu and **characterize their diversity,** thus providing insight into Bennu's **surface processes.**

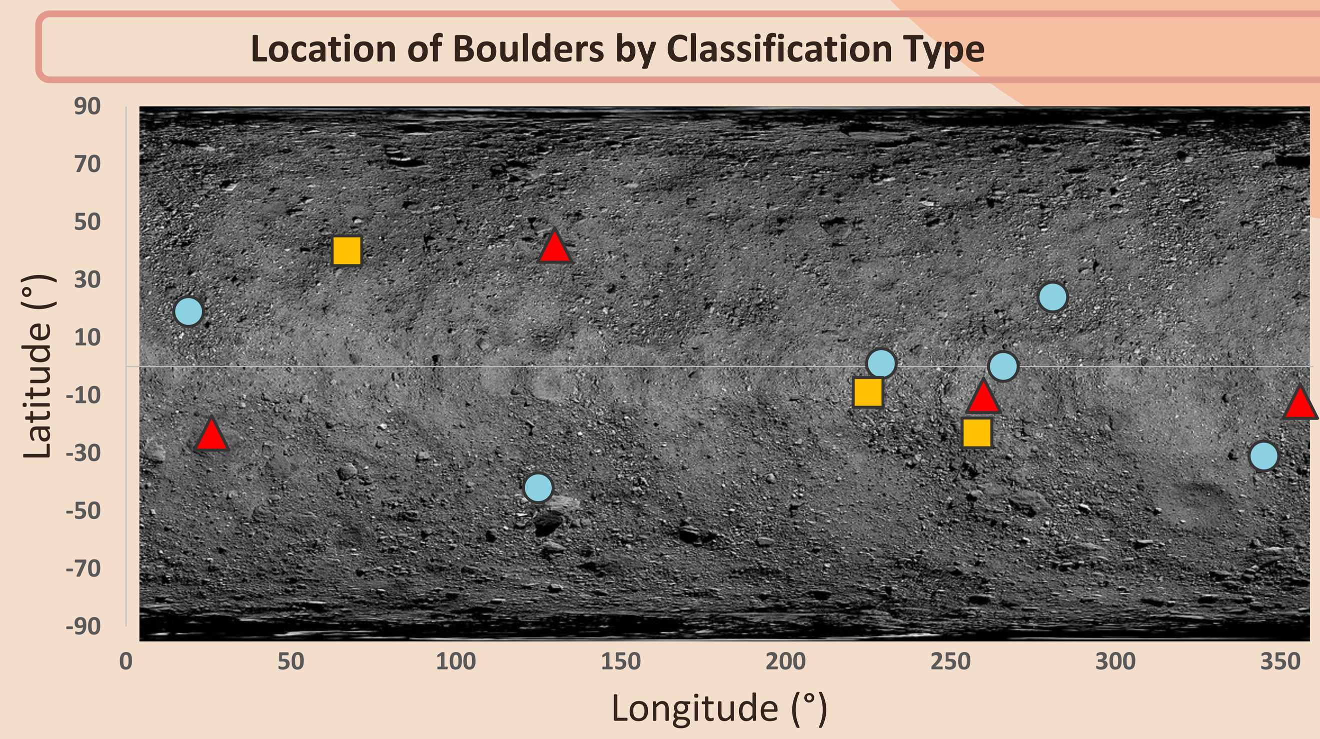
Methodology and Data



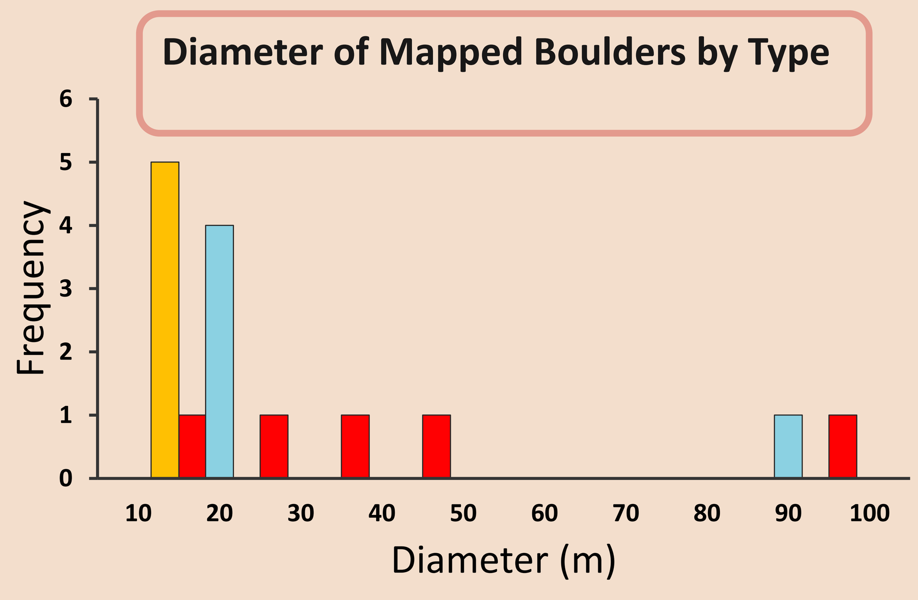
Boulder Classification System

Type	Characteristics
A ▲	dark toned, rounded aspect, clastic, rugged, hummocky boulders
B ●	intermediate tone, relatively round, scattered clasts, swaths of smooth and rough terrain, undulatory texture
C ■	bright toned, angular aspect, smooth with little to no clasts, linear fractures

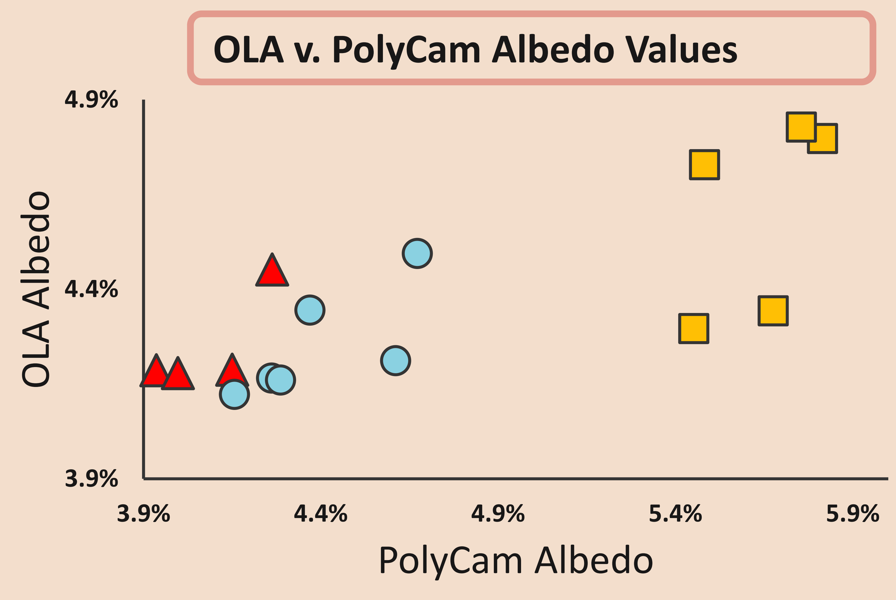
Location of Boulders by Classification Type



Diameter of Mapped Boulders by Type



OLA v. PolyCam Albedo Values

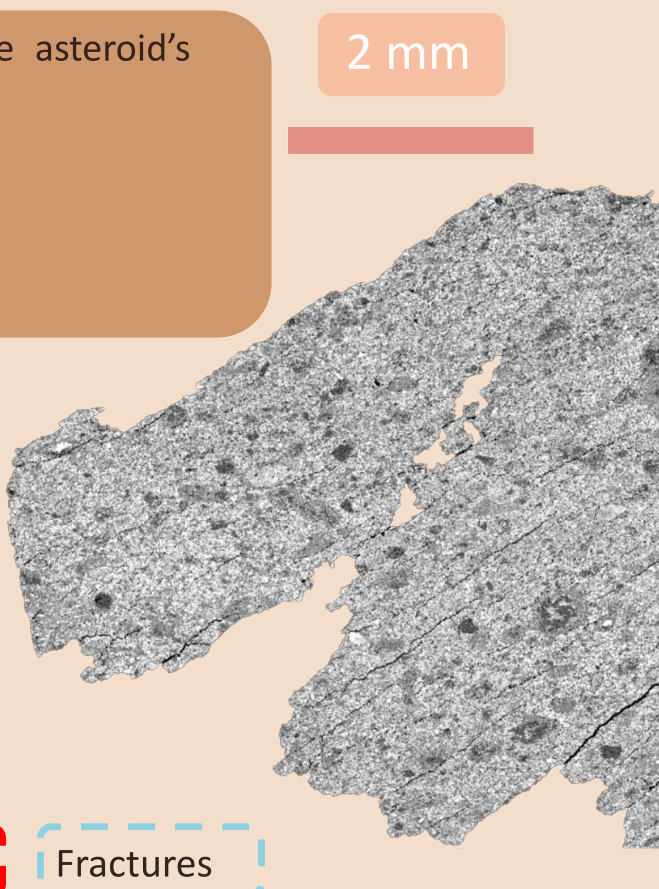


Smaller Scale: Carbonaceous Chondrite Analysis

Background

Spectral and remotely sensed data of Bennu has revealed that the asteroid's properties are most closely analogous to **CM chondrites**[4], because of:

- presence of **magnetite**
- ample evidence for **hydration** features
- very **low reflectance**, typical of dark and volatile-bearing material



Aim

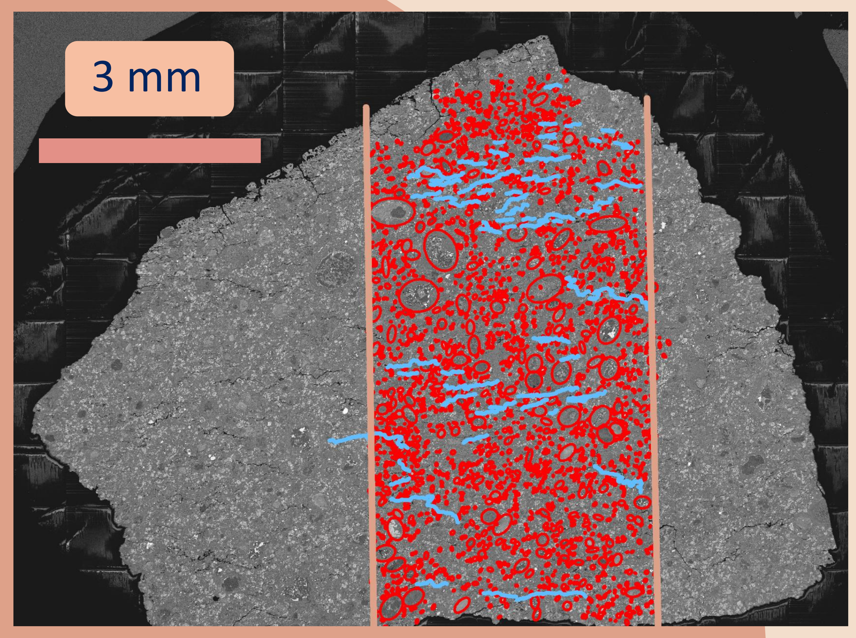
To conduct **micro-geospatial mapping** of backscattered electron images of CM meteorite thin sections **uncover potential similarities** between the **fabrics** of the **meteorites** and the **boulders** on Bennu's surface.

Methodology and Data

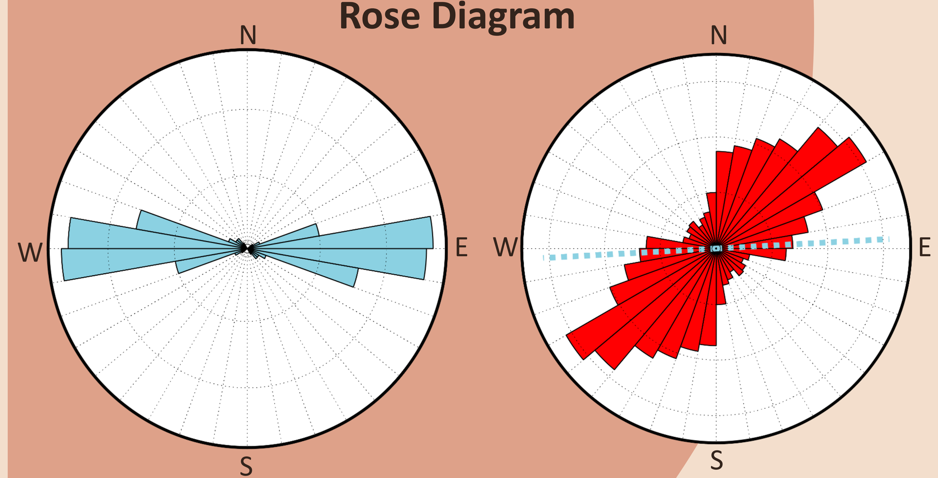
Particles | Fractures

MET00431

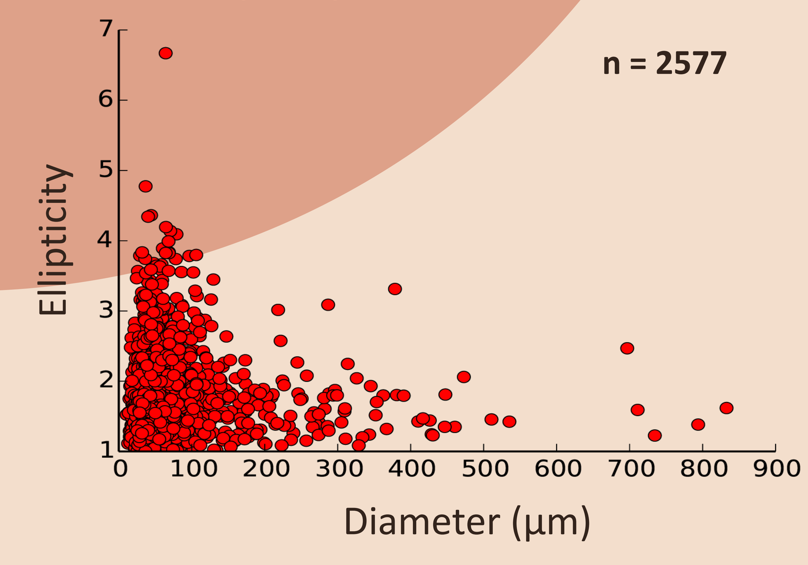
Thin Section Map



Rose Diagram

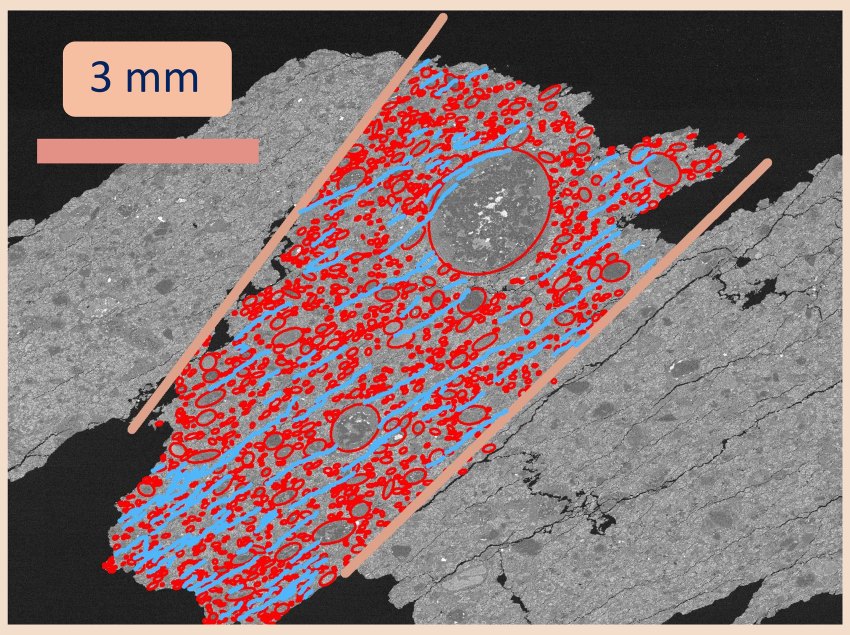


Ellipticity v. Particle Diameter

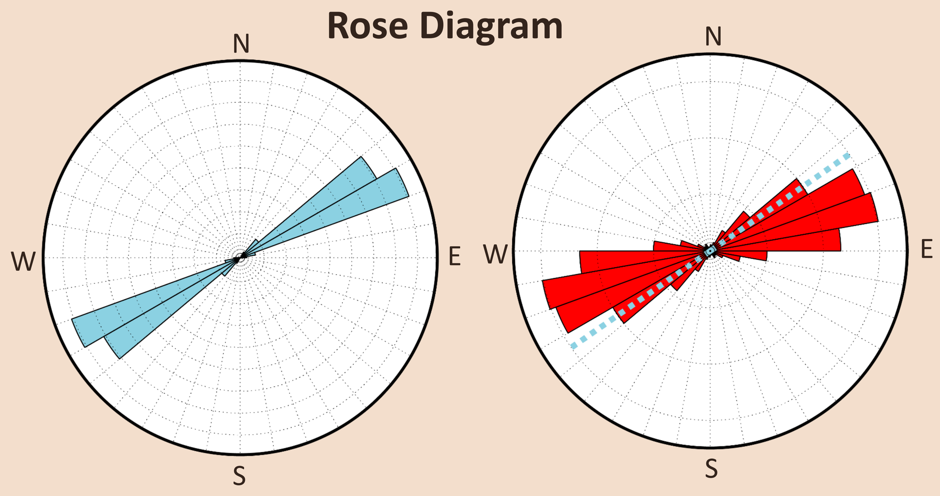


MET00434

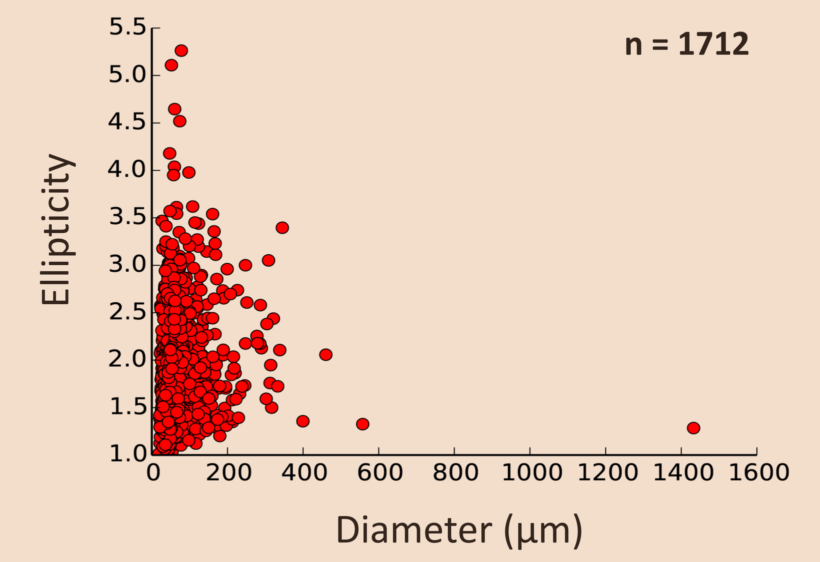
Thin Section Map



Rose Diagram



Ellipticity v. Particle Diameter



Discussion

Part 1

- Since the location of boulders bears little to no correlation to boulder type, we hypothesize that these **boulder characteristics** are due to **parent body processes**, rather than surface processes on Bennu.
- **Type A** and **B** have closely **linked** featured, to the point where there are "**transitional**" boulders with overlapping characteristics, which indicates that the oldest boulders start as Type A and eventually transition to Type B through weathering and deformation.
- **Type C** appears to be a **separate** group, possibly from a separate impactor.
- **Next step**: continue mapping boulders to increase sample size.

Part 2

- In both **MET 00434** and **MET 00435, particles** exhibited deformation along a **preferential orientation**, indicating that the layering observed on Bennu's boulders can be explained by **fabric-scale deformation** as the rock was undergoing **aqueous alteration** on the parent body, as opposed to in-situ weathering processes. This data is substantial due to the range of **ellipticities**.
- **MET 00431** does not exhibit this same correlation, but since it's from the same sample, this could be due to the sample preparation technique not considering the **plane of deformation**.
- **Next step**: confirm findings by analyzing the returned regolith samples in 2023.

Conclusion

By examining boulder features at various spatial scales, we were able to identify several **boulder morphology groups** and interpret their diversity to be caused by **parent-body processes**, back before Bennu was ejected from the main asteroid belt due to a cataclysmic collision. Additionally, the mapping of thin sections from CM chondrites implies that the morphologies can be traced to the **fabric** of the boulder, where even aqueous features were altered, once again pointing to a parent-body process.

Selected References:
[1] Lauretta, D.S. et al., 2017, Space Sci Rev 212, 925-984; [2] Jawin, E. 2020, *JGR Planets* 125, 64-75; [3] Walsch, K. 2008, *Nature 454*, 188-291. Images of Bennu from NASA/Goddard/University of Arizona. This material is based upon work supported by NSF grant OCE-1560088 through the NHRE Program.