

Distribution of fractures on boulders on (101955) Bennu and their implication for asteroid surface evolutionary processes.

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Observations of the near-Earth asteroid (101955) Bennu by NASA's Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer (OSIRIS-REx) space mission revealed a body covered with boulders ranging in size from some tens of meters down to several centimeters (Lauretta et al. 2019). Some of the boulders are fractured, some present arrangements consistent with them having broken down in place (Lauretta et al. 2019, Walsh et al. 2019, Molaro et al. 2020), several show evidence of exfoliation, which has been attributed, by the study of Molaro et al., to stresses generated by diurnal temperature cycles. These stresses can lead to boulders damage by the propagation of fractures, a phenomenon that is known as thermal fatigue. Additional evidence for this process comes from images of asteroid surfaces (e.g. Dombard et al. 2010), laboratory experiments (Delbo et al. 2014, Libourel et al. 2021, Hazeli et al. 2018) and theoretical modelling (Molaro et al. 2017).

The study of the morphology of boulder fractures, broken boulder arrangements, and the orientation and spatial density of fractured boulders (Eppes et al., 2019) may clarify the processes that act on the surface of a planet or small body. Moreover, when a weathering process creates fractures, their spatial density and the distribution of the fractured to non-fractured boulder ratio may shed light on relative surface unit ages.

Here we report on the identification and mapping of fractures on Bennu's boulders using the mosaics of images of the surfaces of Bennet et al. (2020). We globally covered the surface between -50 and 50 degrees of latitude, mapping fractures on boulders of different type and size. We will show that the global distribution of fractures is consistent with their propagation caused by diurnal temperature variations. We will also describe our attempt to model the fracture propagation in order to assess the time it took to form the observed ones. In combination with other OSIRIS-REx science results (e.g. Jawin et al. 2020), this modelling allowed us to estimate the rate of the thermal fracturing process. We argue that this process is general on those carbonaceous asteroids similar to Bennu and an important phenomenon for sculpting the surfaces of these bodies.

REFERENCES:

Dombard, A. J., Boulders and ponds on the Asteroid 433 Eros. *Icarus*. 210, 713-721 (2010).
Hazeli, K., et al. The origins of Asteroidal rock disaggregation: Interplay of thermal fatigue and microstructure. *Icarus* 304, 172-182 (2017).

Eppes, M.-C., Willis, A., Molaro, J., Abernathy, S. & Zhou, B. Cracks in Martian boulders exhibit preferred orientations that point to solar-induced thermal stress. *Nature Communications* 6, 6712–11 (2015).

Jawin, E. R. et al. Global Patterns of Recent Mass Movement on Asteroid (101955) Bennu. *Journal of Geophysical Research: Planets* 125, 501–21 (2020).

Lauretta, D. S. et al. The unexpected surface of asteroid (101955) Bennu. *Nature* 568, 55–60 (2019).

Libourel, G. Et al. Network of thermal cracks in meteorites due to temperature variations: new experimental evidence and implications for asteroid surfaces. *Monthly Notices of the Royal Astronomical Society* 500, 1905–1920 (2021).

Molaro, J. L. et al. In situ evidence of thermally induced rock breakdown widespread on Bennu’ s surface. *Nature Communications* 11, 2913–11 (2020).

Molaro, J. L., Byrne, S., Le, J. L. Thermally induced stresses in boulders on airless body surfaces, and implications for rock breakdown. *Icarus* 294, 247–261 (2017).

Walsh, K. J. et al. Craters, boulders and regolith of (101955) Bennu indicative of an old and dynamic surface. *Nature Geoscience* 12, 242–246 (2019).

Keywords: Asteroids, Evolutionary processes, Remote sensing observations