Thermal Stresses as Driver for Boulder Cracks and their Orientation on Ryugu

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Ryugu is a Cb-type rubble-pile asteroid assumed to have formed from debris of its parent body/bodies, most likely much larger main-belt asteroids that were destroyed in a collision (Sugita et al., 2019; Wada et al., 2018). Therefore, morphologic features on Ryugu were either formed by processes that took place on Ryugu itself or prior to its formation on Ryugu’s parent body/bodies.

The surface of Ryugu is composed of boulders covering a large range of sizes (Michikami et al., 2019). The study of this regolith provides crucial information about the physical, geological and thermal evolution of the small carbonaceous body and offers insight into the processes that shape the surface. Cracks are ubiquitous within rocks on Ryugu (Sasaki et al., 2021) and form through a number of processes including thermal stresses (Delbo et al., 2022) and impacts (Sugita et al., 2019). The analysis of crack patterns, morphology and orientation is therefore especially important to determine the role of impacts and the thermal environment on Ryugu’s evolution.

We selected 200 Hayabusa-2 Optical Navigation Camera (ONC) images that were taken in a low orbit (< 1 km) and mapped ~1500 cracks on boulders. The images were taken between 20°N-20°S at a low phase angle resulting in comparatively small shadows. A crack usually consists of 1 to 3 segments, leading to ~4200 mapped crack segments, with an average segment length of 0.3 meters. We evaluated them regarding their orientation, length and morphology. Our survey confirms the identified boulder and crack types of Sasaki et al. (2020) on Ryugu and Delbo et al. (2022) on Bennu, respectively.

Our work is an expansion of the work by Sasaki et al. (2020). In agreement with them, we find that the cracks on Ryugu's rocks are aligned in a manner that suggests the boulders on the asteroid have undergone significant thermal stress and strain. The cracks show a strong north-south orientation. This meridional orientation indicates that the cracks are of thermal origin, similar to findings for boulders on Earth’s and Mars’ deserts (McFadden et. al. 2005; Eppes et al. 2015) and to boulders on Bennu (Delbo et al., 2022). This orientation also suggests that the cracks have formed faster than the transport mechanism of boulders on Ryugu, otherwise the meridional orientation would not have been preserved (Delbo et al 2022).

However, uncertainties arise from the manual detection of cracks as some of them were mapped at the resolution limit of the images. They can also be confused with shadows. Sasaki et al. (2020) circumvent this by using low phase angle images and if needed comparing with higher phase angle images. In our study this work is still in progress. Additionally, although cracks resemble two dimensional features, in reality, they are three-dimensional and continue inside the boulders, where their orientation is not known. While Delbo et al. (2022) have found a North-West/South-East orientation for cracks on Bennu, Sasaki (2020) and our work has found a North/South orientation for Ryugu. This could be explained by changes in Bennu’s spin-axis in the past that has not taken place on Ryugu (Delbo et al. 2022).

In conclusion, the study of Ryugu's surface provides a unique opportunity to better understand the evolution of small bodies in the Solar System and the processes that shape their surfaces. The analysis of cracks on Ryugu's boulders offers crucial insights into the history of the asteroid and the role that impacts and thermal events have played in its evolution. Further research on Ryugu and other asteroids will continue to advance our understanding of these fascinating bodies.

Delbo, M., et al., 2022. Nat. Geosci. 15, 453–457.
Michikami, T., et al., 2019. Icarus 331, 179–191.
Sugita, S., et al., 2019. Science, eaaw0422 364, 1–11.
Wada, K., et al., 2018. Progress in Earth and Planetary Science 5, 82.
Sasaki, S., et al., 2020. 51st Lunar and Planetary Science Conference 2020, #1822.
McFadden, L., et al. 2005. Geological Society of America Bulletin, 117 (1-2): 161–173.
Eppes, M. C., et al. 2015. Nature Communications, 6:6712.

Keywords: Ryugu, Cracks, Thermal Stresses, Asteroid, Hayabusa2

