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Thermal cracking as a source of regolith on asteroids

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Abstract

Regolith, a layer of loose material that includes dust, pebbles, and broken rocks, covers all asteroids studied so far. Regolith generation on asteroids has traditionally been attributed to the fall back of impact ejecta and by the break-up of boulders by micrometeoroid impact [1]. We recently showed that an alternative mechanism, thermal fatigue, can break up rocks on asteroid and contribute to regolith production [2]. Driven by the diurnal thermal cycling, thermal fatigue is found to be the dominant process of regolith generation on small (kilometer-sized and smaller) asteroids.

1. Introduction

Remote and *in-situ* observations have revealed that surfaces of asteroids are covered by loose unconsolidated material called regolith (see Fig. 1. This is also the case of the Moon).

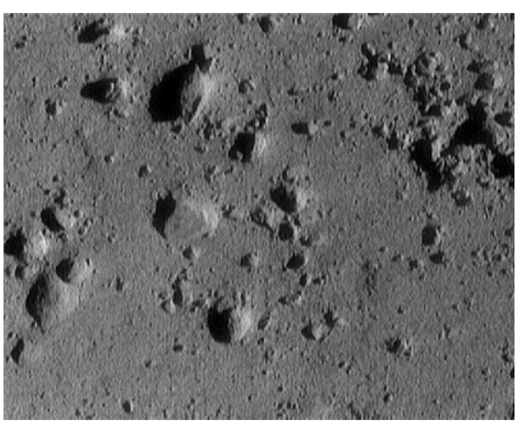

Figure 1: Regolith on the asteroid (433) Eros. Image credit: NEAR-Schoemaker space mission, NASA

Such a material is present on asteroids of all sizes, from the largest one, i.e. (1) Ceres (900 km of diameter), to objects as small as a few hundreds meters, e.g. (25143) Itokawa (350 m of spherical equivalent diameter).

It is fundamental to understand how regolith forms as this knowledge is crucial for the interpretation of observational data provided by on going and future space missions (e.g. Rosetta, ESA; Dawn, NASA; OSIRS-REx, NASA; Hayabusa II, JAXA). Furthermore, nearly all physical properties of asteroids are obtained from remote observations of the regolith.

Classically, regolith is believed to be produced by the impact of meteoroids on asteroid surfaces. During such events ejecta is generated, many of which fall back due to asteroid's gravity. Over its history, an asteroid undergoes many such impact events that can contribute to the accumulation of small fragments constituting a layer of regolith. However, the ejecta velocities produced by these impact events are typically in the order of several tens of cm/s [3]. These ejecta velocities exceed the gravitational escape velocity from km-sized and smaller asteroids. Therefore, impact debris cannot be the main source of regolith on small asteroids.

Rock breakdown by temperature cycling is an alternative process to produce regolith on planetary bodies [2]. Its effectiveness has been debated for over a century, but recent studies [4-6] have proven its effectiveness for temperature cycles occurring on Mars, Earth, and asteroids.

Here we present the recent results of our study [2] which permits us to conclude that thermal fatigue is the dominant process of regolith generation on small (kilometer-sized and smaller) asteroids.

2. Experiments

We performed laboratory experiments on specimens of about 1 cm in size of two types of chondrite meteorites (Murchison a CM2 carbonaceous chondrite and Sahara 97210 a LL/L3.2 ordinary silicate chondrite). These are the best analogs of C-type and S-type asteroids.

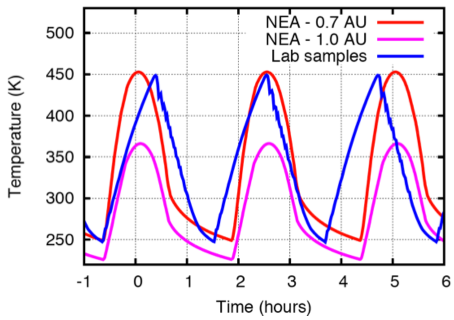

Figure 2: Temperature cycles. NEAs are near-Earth asteroids at 0.7 and 1.0 AU from the Sun.

After 400 temperature cycles (Fig. 2), we found that most cracks in both meteorites widened and become longer. In addition, fragments of Murchison broke away because thermal cycling from the surface (see Fig 3).

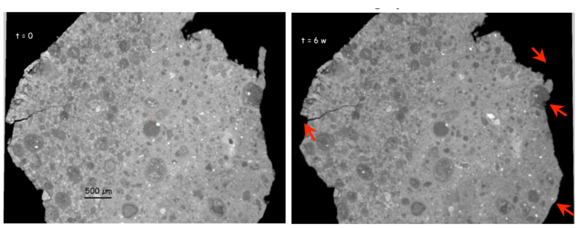

Figure 3: The arrows indicate the fragments of Murchison that broke off after temperature cycling.

3. Model

We developed a thermomechanical and crack growth model allowing us to study the crack growth rate in rocks subjected to the temperature cycles typical of asteroids from early stages until break up [2].

Model predictions agree well with the crack growth measured in our experiments. When the model is applied to the temperature cycles of asteroids, it predicts rock break up in times between 10,000 and 100,000 years. This is one to two orders of magnitude more quickly than the time required for micrometeoroids to break rocks of similar size [2].

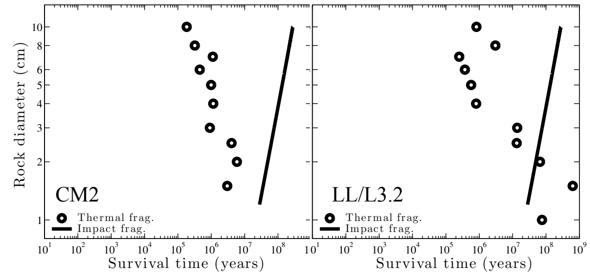

Figure 4 : Time required to break rocks on asteroids. Symbols show the time required to thermally fragment 90% of rocks by thermal fatigue at 2.5 AU from the Sun. The thick vertical lines show the times at which 90% of these same rocks are broken by micrometeoroid impacts. Left : carbonaceous chondrite ; right ordinary chondrite.

4. Summary and Conclusions

Thermal fatigue is found to be the dominant process of regolith generation on small (kilometer-sized and smaller) asteroids.

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References

[1] Horz, F. & Cintala, M. Impact experiments related to the evolution of planetary regoliths. Meteorit. Planet. Sci. 32, 179–209 (1997).

[2] Delbo, M. et al. Nature http://dx.doi.org/10.1038/nature13153 (2014).

[3] Housen, K. R. & Holsapple, K. A. Ejecta from impact craters. Icarus 211, 856–875 (2011).

[4] Viles, H. A. et al. Geophys. Res. Lett.37, L18201 (2010).

[5] Molaro, J. & Byrne, S. J. Geophys. Res. 117, E10011 (2012).

[6] Eppes,M.C.,McFadden,L.D.,Wegmann,K.W.& Scuderi, L. A. Geomorphology 123, 97–108 (2010).