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Temperature shocks at the origin of regolith on asteroids

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Abstract

Space-based [12] (Fig. 1) and remote sensing observations [4] reveal that regolith – a layer of loose unconsolidated material – is present on all asteroids, including very small, sub km-sized near-Earth asteroids (NEAs) such as (25143) Itokawa [7] (See Fig. 2).

Classically, regolith is believed to be produced by impacts of small particles hitting asteroid surfaces. Such explanation works for bodies whose gravity field is strong enough for substantial reaccretion of impact debris, but it fails to account for the ubiquitous presence of regolith also on small asteroids with weaker gravity.

Several works [6, 5, 10] have proposed that the thermal fatigue due to a huge number of day/night temperature cycles is a process responsible for the formation of regolith on the Moon, Mercury, and on the NEA (433) Eros by fracturing boulders and rocks on their surfaces. However, this process lacks a demonstration.

We calculate typical temperature cycles for NEAs and we perform laboratory experiments of thermal cycling of meteorites – taken as analogue of asteroid surface material – to study under which conditions rock cracking on NEAs occurs.

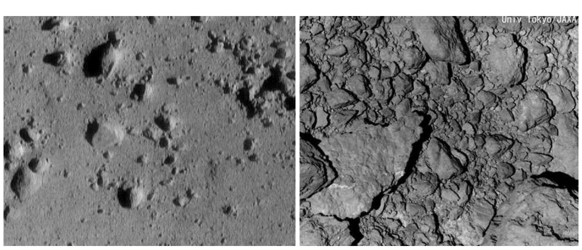

Figure 1: Regolith on NEAs from direct imaging. **Left panel**: the 30 km-size asteroid (433) Eros – the second largest NEA observed by the NASA NEAR Shoemaker mission [12]. **Right panel**: the 0.35 km-size Itokawa, visited by the JAXA Hayabusa spacecraft [7].

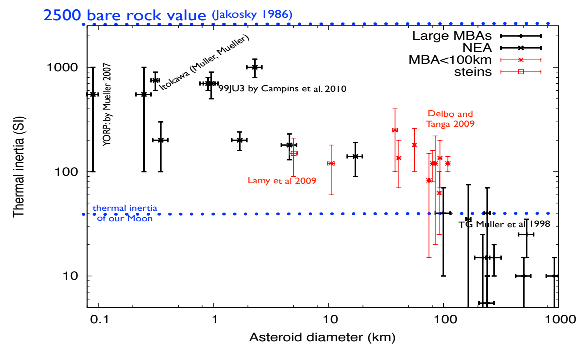

Figure 2: Thermal inertia values (Γ) vs. sizes of asteroids. The value of Γ is ∼inversely proportional to the porosity of the material [13, 1]. A regolith-covered surface has a porosity larger than a bare, solid surface of the same material. Consequently, the presence of regolith decreases the value of the asteroid thermal inertia: the finer the regolith, the higher the porosity, the lower the thermal inertia. Values of the thermal inertia determined for all asteroids so far are more than a factor 2 below the value for a typical bare rock [3, 4]. This is consistent with the dominant presence of fine particles on asteroid surfaces.

1. Temperature shocks on NEAs

In order to show that the day/night temperature variations on NEAs are capable of breaking rocks, we calculated temperature time gradients (dT/dt) by means of a Thermo-Physical Model (TPM) [2, 3] and compared the value of dT/dt with the threshold (2 K/min) for rock fragmentation solely due to temperature shocks [9]. Fig. 3 shows the results: $dT/dt > 2$ K/min for almost all NEAs, which implies rock fracture.

Moreover, the number of temperature shocks for NEAs over their dynamical lifetime (1-10 My [8] is between 0.5 and 30 $\times 10^9$ (rotation periods of NEAs are between 3 and 10 h [11]). Thus, we expect temperature shocks to be very effective in producing regolith. However, this process was never demonstrated with laboratory experiments in the context of NEAs temperatures.

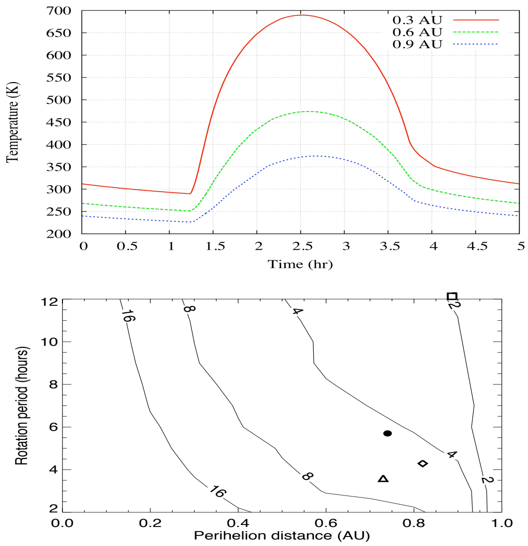

Figure 3: Top: Examples of day/night temperature curves on NEAs. $\Gamma = 200\ J\ m^{-2}\ s^{-0.5}\ K^{-1}$. Bottom: contour plot of the MAX value of the temperature time gradient dT/dt as a function of the rotation period and the perihelion distance. Symbols: • (433) Eros, ◇ (101955) 1999 RQ_{36}, △ (175706) 1996 FG_3, □ (25143) Itokawa

2. Laboratory demonstration

We performed laboratory experiments of temperature cycles on meteorites. Samples of the Murchinson meteorite (CM) were exposed to 410 temperature cycles between 243 and 410 K with a period of about 2.2 hours in a climatic chamber. This temperature range is typical for the large majority of NEAs, including Eros (Fig. 3).

The samples were analyzed by means of X-ray tomography before and after the heating cycles. Tomographies show that cracks in the bulk of the meteorite have grown after the treatment and some debris detached (see Fig. 4). A more thorough analysis of the tomographies is on-going.

3. Summary and Conclusions

The value of the temperature time gradient dT/dt is > 2 K/min (threshold value for rock fragmentation) for perihelion distances less than 0.9 AU and rotation periods < 10h. This is the case for the large majority of NEAs (Fig. 3).

Our laboratory experiment of thermal cycling of asteroid analogue materials shows that cracks are developed in the CM chondrite.

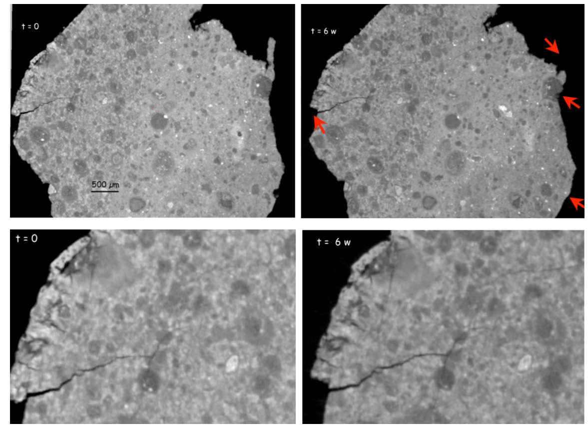

Figure 4: Tomographic sections of the Murchinson meteorite sample before and after 6 weeks. Top: note the fracture in some areas (indicated by the arrows). Bottom: the cracks in the bulk of the meteorite become wider and longer as time passes.

Our preliminary results indicate that thermal fatigue cracking is a process capable of regolith formation on NEAs.

Acknowledgements

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References

[1] Consolmagno et al., 2010. DPS meeting #42, #48.03

[2] Delbo, M. 2004. PhD thesis. FU-Berlin.

[3] Delbo, M., Dell'Oro, A., Harris, A.W., Mottola, S., Mueller, M. 2007. Icarus 190, 236-249.

[4] Delbo, M., Tanga, P. 2009. Planetary and Space Science 57, 259-265.

[5] Dombard, A.J., Barnouin, O.S., Prockter, L.M., Thomas, P.C. 2010. Icarus 210, 713-721.

[6] Duennebier, F., Sutton, G.H. 1974. JGR 79, 4351-4363.

[7] Fujiwara, A., et al. 2006. Science 312, 1330-1334.

[8] Gladman, B., Michel, P., Froeschlé, C. 2000. Icarus 146, 176-189.

[9] Hall, K. 1999. Geomorphology 31, 47–63.

[10] Molaro, J. L., and Byrne, S. 2011. 42nd LPSC pp. 1494

[11] Pravec, P., et al. 2008. Icarus 197, 497-504.

[12] Veverka, J., et al. 2001. Science 292, 484-488.

[13] Zimbelman, J.R. 1986. Icarus 68, 366-369.