LABORATORY SIMULATION EXPERIMENTS AND THE PONDS ON ASTEROID 433 EROS

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Introduction. Photographs of the surface of 433 Eros from the Near Earth Asteroid Rendezvous (NEAR) mission have been interpreted in terms of regolith processes. “Ponded deposits”, regions of relatively flat and smooth terrain, were noted in the bottoms of craters [1]. Ponds are sharply delineated, are found preferentially at low latitudes and in the bottoms of craters >1 km in diameter, and have slightly bluer color than surrounding terrain. These properties suggest they formed as fluid deposits, but the presence of craters and steep walled gullies in them indicates that they later became more cohesive. Based upon the latitudinal distribution of ponds >30 m, Robinson *et al.* [2] suggested that electrostatic levitation of fine grains with following accretion might play a role in pond formation. Another possible formation mechanism is seismic-shaking mobilization, as suggested by Cheng *et al* [3].

We suggest that surface out-gassing and evaporation/sublimation of water (or ice) from newly formed craters might play a significant role in fluidization and grain size sorting on asteroids. We have performed experiments in the laboratory to show that it is possible to separate chondrules and metal grains to produce chondrite-like mixes, via gas fluidization of unconsolidated deposits [4]. We have assessed the influence of gravity on this process [5] and, in this abstract, we assess the influence of low atmospheric pressure on de-volatilization and fluidization of regolith.

Experimental setup. The Andromeda environmental chamber was used as a test bed [6]. The facility, while not currently offering full space-vacuum, does allow use of large samples (up to half a meter in diameter and depth), thus reducing the influence of container walls. JSC Mars-1 soil simulant (a volcanic ash from Hawaii) was used as a regolith analog in our first series of experiments, because it is dominated by fine-grained material but exhibits a range of grain sizes, as would be expected for asteroidal regolith. The composition of the grains was not important, although the presence of absorbed water in the soil might deviate significantly from asteroidal conditions. For our first experiments, a cylindrical 0.5 m diameter sample container, with 10 cm depth of soil simulant was used. Volatile sources, either blocks of ice or containers of water, were placed on or under the soil surface in the buckets. The Andromeda chamber was then pumped to ~0.1 mbar at various rates. Pressure in the chamber and temperature in the soil were measured throughout the experiment. The efects of devolatilization were monitored by video cameras, installed 30 cm above the soil surface.

We report here on five experiments:

A. 20 g blocks of ice, in glass containers, buried within the soil simulant at high pressure ~300 mbar;

B. 20 g samples of water, in containers with small orifices in their tops buried in the soil simulant at various depths;

C. 20 g ice blocks, on the surface buried at various depths in the soil profile;

D. 1 g ice blocks, on the surface buried at various depths in the soil profile;

E. Soil simulant with no volatile sources added.

Results and discussion. From our experiments, we made the following general observations:

1. De-volatilization, with obvious production of surface deformation, occurred only when for experiments with fast pumping rates. Altering pumping rate could control the degree of surface deformation.
2. De-volatilization events occurred with equal ease with water and ice sources.
3. The soil simulant with no volatile sources also exhibited surface deformation (see below) at fast pumping rates. Thermo-gravimetric analysis indcated that the soil contained up to 11% absorbed water. However, the effect of simulant de-volatilization was distinct from the effect of source de-volatilization.

When de-volatilization occurred, typically at about 200 mbar at ~2.7 l s^{-1}, we noted a distinct sequence of events. First, there was a sudden onset of “boiling” of the soil, with generation of a plume of fine-grained dust. While this rapid boiling could occur continuously, we chose to reduce pumping rate slightly in order to reduce the amount of dust generation, which posed a danger for the pump system. Boiling would continue, but with decreasing intensity as a function of time. Boiling apparently ceased after about 30 minutes of continuous pumping. For all experiments, low degrees of “boiling” were noted “throughout the soil sample”. When volatile sources were present, more energetic boiling was noted on the surface over their locations, often appearing like geysers of soil. These also decreased in intensity as a function of time, and ceased observable activity at about the same time as the soil.

After de-volatilization events, we removed the soil from the chamber and observed that a thick (~1-5 mm thick) layer of fine-grained material had formed across the surface of the sample. The boundary between the top layer and the bottom soil layer was generally distinct. The layer tended to be thickest in pre-existing depressions in the soil. Sieve analysis shows the pronounced difference in grain size between this top layer and the initial soil profile (Fig. 1). The presence of two peaks in the grain sizes in the data for the top layer probably reflects difficulty in sampling, with portions of the underlying soil contaminating the top layer sample. Spectroscopic measurement indicates significantly greater reflectance for the surface layer compared with the bottom layer.

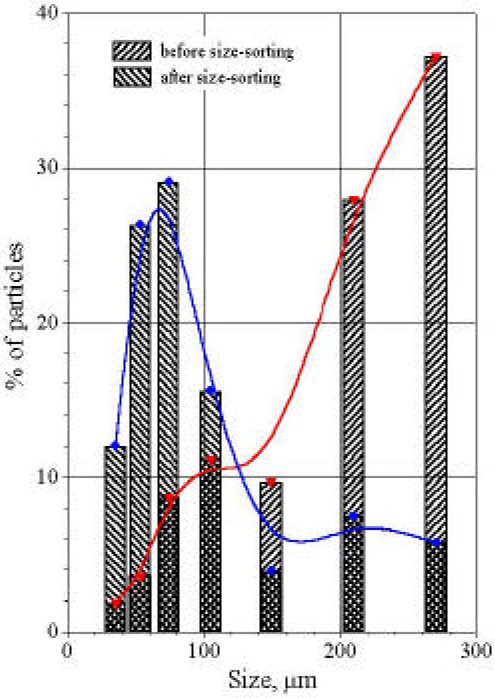

Figure 1. Observed size distribution of samples before and after de-volatilization. Lines are best fits of polynomial equation (b-spline).

Discussion. Our experiments are relevant to the formation of fine-grained deposits on an asteroid, if a volatile source is (or was) present. The most likely source of volatiles on Eros is ice or hydrated minerals, possibly reflected in the low density of Eros ~2.5 g cm^{-3}. The distinction between comets and asteroids has become increasingly blurred with further exploration of asteroids [7].

Our experiments indicate that sudden release of volatiles, either from rapid heating of the body or by sudden release of pressure (perhaps by impact) can result in "boiling" of the unconsolidated regolith. If the de-volatilization continues and gradually diminishes in intensity, as seen in our experiments, the result is fluidization separation on the basis of grain size and density [8].

Conclusions. We will continue with other fluidization experiments, using other regolith simulants to reduce effects from volatilization from the soil itself. However, we stress that our experiments show that a simple physical process, using loss of volatiles from the interior of an asteroid body can produce fine-grained, fluid-like deposits from thick unconsolidated regoliths.

Such deposits might concentrate in local depressions, especially in places of weakest local gravity, and, then consolidate, and become capable of preserving subsequent features, such as seismic cracks, or impact craters on the surface of Eros. The limited occurrence of ponds on the surface of Eros might reflect accentuated fluidization in portions of weakest surface gravity on a non-spherical body, or it might reflect localized channels into the interior, perhaps from faulting from impacts. Other asteroids might or might not have ponds, depending on the abundance of volatiles, the presence of faults/channels, and the degree of heating experienced by the bodies.

Other proposed mechanisms for pond formation have possible weaknesses. Electrostatic levitation, for example, should occur at all times, being used to explain "lunar horizon glow". No observations from NEAR suggest that there is significant horizon glow on Eros. Seismic shaking, on the basis of laboratory analogs, might be expected to result in concentrations of boulders on the surface, rather than deposits of fines. Being driven by "seismic kinetic sieving", large particles can be brought to the surface by falling of fines through gaps between them. Also, we would expect pond deposits to occur on virtually all-small bodies in the solar system with this model, although one can argue that we do not yet have adequate imaging of other asteroids to verify or refute this idea.

References: [1] Cheng A.F. *et al.* (2001) *Science, 292,* 488-491. [2] Robinson M.S. *et al.* (2001*) Nature, 413,* 396-400. [3] Cheng A.F. et al (2001) *Meteoritics & Planet. Sci.,* (submitted). [4] Kunii D., Levensiepel O. (1991) *Fluidization Engineering.* [5] Benoit P.H. (2001) *Lunar & Planet. Sci. XXXIII.* [6] Sears D.W.G. *et al.* (2001) *North American luminescence dating Workshop, I.* [7] Sears D.W.G. *et al.* (1999) *Meteorit. Planet. Sci., 34,* 497-525. [8] Huang S. *et al.* (1996) *JGR, 101,* 29,373-29,385; Akridge D.G. *et al.* (1998) *Icarus, 132,* 185-195.