Lessons Learned From OSIRIS-REx at Bennu: Implications for the Regolith and Cohesion Properties for the Surface of Apophis. K. J. Walsh[1], [1]Southwest Research Institute, 1050 Walnut St. Suite 300, Boulder, CO 80303.

Introduction: Three small rubble pile asteroids have been visited, contacted and sampled by spacecraft. This collection of efforts has provided a wealth of knowledge about each objects' global geology and their response to spacecraft interaction.

Small rubble pile asteroids, with diameters well below ~5km, have shown diversity in their surface geology. Specifically, the presence of, or lack thereof, ponded deposits of fine grains is starkly different among these three bodies. Itokawa, an S-type body with an elongated shape and slow spin rate has significant ponding [1]. Meanwhile, Bennu and Ryugu, B- or C-type asteroids respectively, with top shapes and more rapid rotation rates do not have significant ponding [2,3].

What connections, if any, can be drawn between the sub-surface of these asteroids determined by spacecraft interaction and their basic physical properties and observed surface geology? Specifically, the cratering experiment at Ryugu and sampling at Bennu explored the near-subsurface of each asteroid providing constraints on strength and packing efficiencies below their surfaces.

OSIRIS-REx sampling of Bennu: The OSIRIS-REx spacecraft interaction with Bennu provided a valuable test of its near-subsurface properties. The spacecraft was equipped with a Touch-and-Go Sample Acquisition Mechanism (TAGSAM), which is an annular container attached to an extendable arm. On 20 October 2020 the sampling operation successfully pressed TAGSAM into the surface of the asteroid at 10 cm/s, released high pressure gas and after a few seconds of contact initiated a backaway manuever to leave Bennu.

The interaction with the surface prior to gas release was bracketed with two images of the surface with ~mm/pixel resolution and the forces imparted on the spacecraft were recorded with a Inertial Measurement Unit. This data was combined to estimate the penetration profile of TAGSAM into the near-subsurface of Bennu, characterizing peak accelerations during the extent of the interaction prior to gas release. Then granular mechanics penetration force laws and numerical modeling can be used to constrain the packing fraction of material in the upper few 10's cm of Bennu [4,5].

Lessons Learned: A general lack of strength was similarly determined by the measured forces and the size of the crater that formed from gas release [6], but this property had been postulated in various studies at both Bennu and Ryugu (see [7] for example). Inferences from crater morphology, terraces and mass movement all similarly suggested low strength [8,9,10].

A low packing fraction at the near-subsurface (approzimately one half that for the bulk asteroid) was inferred both from the measured forces and also the characteristics of the crater formed from the release of gas into the surface [6]. Stratification of regolith, with increasing density and packing fraction with depth, on low gravity bodies has been hypothesized as a natural outcome of particle settling with final states depending on the gravity level and particle properties [11]. Naturally, the surface of a small asteroid are subjected to numerous additional forces (e.g. spinup by YORP and millions of years of impacts) over their lifetimes to exacerbate or hinder stratification of their regolith. So, understanding the key mechanisms responsible for this finding of low packing fraction near-subsurface at Bennu requires the context provided by its global geology and the physical properties of its constituent materials.

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References:

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