FLUIDIZATION AS A POTENTIAL MECHANISM FOR FORMATION OF POLAR SURFACE FEATURES ON ASTEROID ITOKOWA.

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Introduction: The Hayabusa mission, the first near-Earth asteroid sample return mission, was designed to demonstrate several key technologies for future sample return missions: ion engines, autonomous navigation, and the use of a projectile and an ejecta catching horn as a sample collecting mechanism [1]. Hayabusa was launched in May 2003 and arrived at asteroid Itokowa (1998 SF36) in September 2005 [2]. A two month reconnaissance period was followed by two sample collection attempts on November 20th and 26th, 2005. The mission is due to return its samples to Earth in July 2007.

The importance of asteroid sample return missions has been stressed in several recent studies [e.g. 3, 4]. Ground-based astronomical data for asteroids are difficult to reconcile with laboratory data for meteorites, giving rise to the often quoted “S asteroid paradox” [5, 6]. Contextual information and new materials can be acquired during sample return missions that can yield important new understandings of surface processes on asteroids and our early solar system [7]. However, the most important contribution of the Hayabusa mission is that it points the way to the new era of solar system exploration: the era of sample return.

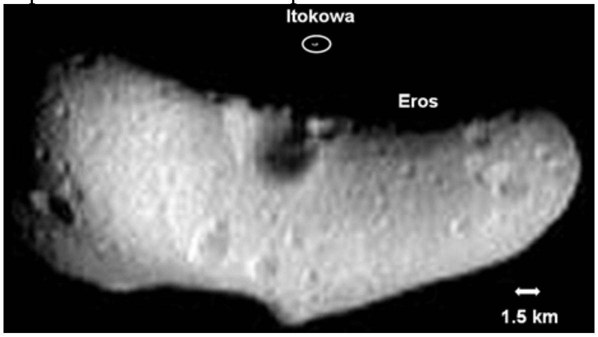

Fig. 1. **Itokowa and Eros size comparison. Itokowa and Eros are on the same scale. The large crater on Eros will fit approximately 11 Itokowas in it. (Pictures courtesy of JAXA and NASA.)**

Asteroid Itokowa: The Hayabusa mission target was Itokowa whose size and shape, determined by radar observations, are 0.548 x 0.312 x 0.276 km ± 10% [8]. The rotation period is just over 12 hours and it is classified as a S or Q-type asteroid [9].

Itokowa’s size. Itokowa is very small in comparison to asteroid 433 Eros, which is 34 x 11 x 11 km [10]. Eros is ~60 times larger in the longest axis. Both Itokowa and Eros are potato-shaped. The large crater seen on the middle of Eros in Fig. 1 (Shoemaker) is approximately 6 km in diameter [10] which means that almost 11 Itokowas can fit inside.

Very few craters are observed on Itokowa, while Eros is peppered with them. This is presumably due to the much smaller size of Itokowa. Conversely, large expanses of boulders are present on both asteroids, meaning that some regions of Eros are indistinguishable from Itokowa (Fig. 2).

However, the most notable features of the surface of Itokowa are regions of smooth texture suggesting a fine grained material is present such as a thick layer of regolith. These are particularly prevalent in the north and south pole localities (Fig. 2). These are also regions of gravitational highs [2], where one would expect dust to accumulate.

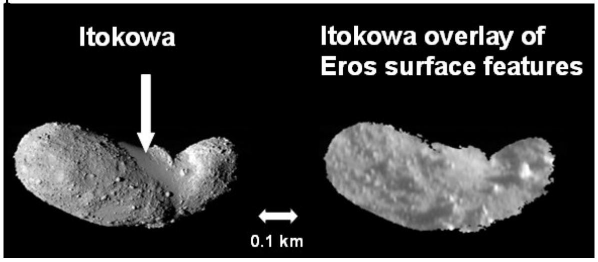

Fig. 2. Itokowa (left) with arrow pointing to smooth appearing region of the south pole. Itokowa outline (right) overlayed on top of a heavily bouldered section of Eros on the same scale (but somewhat reduced resolution) of Itokowa’s largest diameter. (Pictures courtesy of ISAS/JAXA and NASA/JHUAPL.)

Fluidization: There are many potential explanations for these polar regions of fine grained material, one being that they were caused by fluidization. Fluidization is the suspension of solid particles in a gas to produce a fluid-like state [11]. The movement of the particles is governed by the Ergun equation which compensates the downward pull of gravity with upward aerodynamic drag. Previous work in a simulation chamber at the University of Arkansas (Fig. 3) and on NASA’s KC-135 aircraft have shown that particle separation and fine grained regions, like “ponds” on Eros, can be created by gas passing up through regolith [12, 13, 14]. For most sizes and densities of particles, small diameter particles move to the top of the fluidized bed and the larger particles fall to the bottom of the bed. In the gravity field of a small asteroid, the gas velocity needed to sustain fluidization is only 0.1 to 1.0 mm/s [15]. The fluidized particles would tend to settle in gravitational high points of the asteroid such as seen on Itokowa and Eros (where the dust settles in the bowls of craters giving the appearance of ponds).

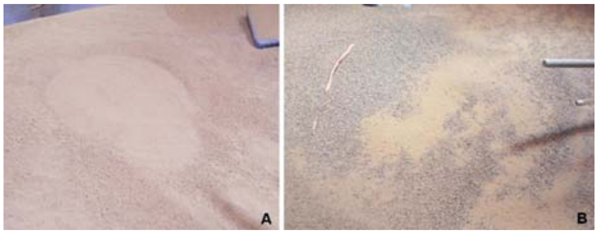

Fig. 3. In A, fluidization by gas flow has created a fine grained "pond" region. In B, fluidization has caused particle separation according to size. The lighter regions are finer grained particles. This type of process may have occurred on Itokowa in the polar regions.

Source of volatiles for fluidization. At this point the source of the volatiles is unclear. Based on the measured density for Itokowa of 2.3 ± 0.3 g/cm^3 [2] and a mean density for the silicates of 3.0 g/cm^3, the interior of Itokowa could have a porosity of ~25% or a water content of ~35% or lie on a mixing line between these values (Fig. 4). At its distance from the Sun, Itokowa's postulated water would not be present as ice but would be chemically bound, but this does not affect these calculations. Water released during impact would fluidize the fine grains and cause them to float to the gravitational high spots, namely the polar regions on Itokowa. There is no indication in Itokowa's ground-based reflectance spectrum of water of hydration [16], where absorption in the 0.7 µm region would suggest a Fe^{+3} absorption feature which is sometimes indicative of water of hydration [17]. At this time, a detailed spectrum including the 3.0 µm region has not been released but will be more indicative if water of hydration is present on Itokowa.

Other suggestions for the "ponds" on Eros that might be extended to the flat regions on Itokowa are that they are fine grained deposits of material mobilized by electrostatic effects [18] or mechanical vibrations accompanying impacts [19]. Hayabusa did not observe any glow discharges that were characteristic of electrostatic effects on the Moon.

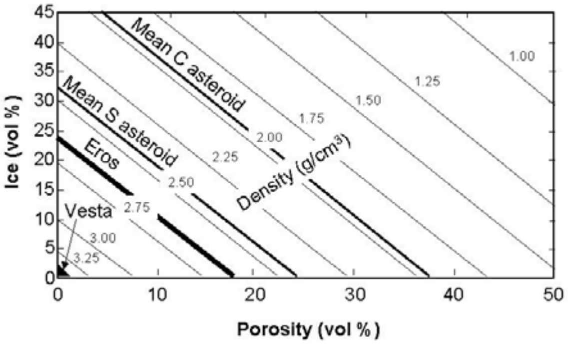

Fig. 4. Porosity of asteroid versus content of water-ice. Itokowa's density falls below that of the typical S-type asteroid.

Conclusions: The Hayabusa Mission is the first asteroid sample return mission and was designed to demonstrate important technologies that will contribute to the development of future sample return missions. Itokowa is a very small asteroid that may not look anything like asteroids we have studied previously. However, a closer look at Eros reveals many terrains that look similar to Itokowa. The smoother looking polar regions may reveal sites on Itokowa that have been influenced by fluidization processes through the outgassing of volatiles in the interior of the asteroid.

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