Laboratory collisional disruption experiments of D-type asteroids analogue targets

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Background

D-type asteroids are found outside the asteroid belt, in the Hilda group and the Trojans. The Mars moons Phobos and Deimos also have reflectance spectra close to those of D-type asteroids[*1]. Tagish Lake is a unique meteorite, which exhibits a reflectance spectrum similar to the spectra of the D-type asteroids. Tagish lake has a different chemical composition and oxygen isotope ratio from those of CM and CI chondrites, and it does not belong to any existing chemical groups[*2].

Collisional disruption threshold and re-accumulation conditions of the fragments have been studied for chondrites and chondrite analogue targets. The disruption threshold Q* of 3 ordinary chondrites (OCs) and 1 carbonaceous chondrite (CV) is approximately 1400 J/kg, which is nearly 2 times that of terrestrial rocks[*3]. Experiments using targets simulating internal structure of parent bodies of ordinary chondrites showed that fragments from catastrophic destruction of parent bodies of ordinary chondrites more easily re-accumulate regardless of the size of the chondrules than those without chondrules[*4]. The purpose of this study is to investigate the collisional disruption threshold of D-type asteroids and the re-accumulation conditions of the fragments by conducting collisional disruption experiments using a Phobos simulant (UTPS-TB)[*5].

Experiments

The density of the sample was 1.43 ±0.04 g/cm^3. If the composition of the simulant is the same as that of the Tagish Lake meteorite, the porosity of the simulant is 46%. Tensile strength and compressive strength were measured at a loading rate of 0.001 mm/s for a cylinder with a diameter of 20 mm and a height of 6 -21 mm. The results were 0.222 ±0.087 MPa and 1.11 ±0.31 MPa, respectively.

Laboratory collisional disruption experiments were conducted by using a horizontal two-stage light gas gun at Institute of Space and Astronautical Science, JAXA, with a 1/8 inch nylon spherical projectile at a velocity of 4.1-5.3 km/s. The target was prepared by cutting the sample into cubes about 5 cm in length. Three high-speed cameras were installed around the target to obtain images for analyzing the fragment velocity. One of the cameras observed the target from the top. The others observed from the side.

Results

Fragments were grouped into three. The largest fragment, several smaller fragments, and fine fragments. An empirical relationship between the largest fragment mass fraction, m_1/M_t, where m_1 is the mass of the largest fragment and M_t is the mass of the pre-impacted target, respectively, and the specific energy Q was given as: $m_1/M_t = 10^{3.05\pm1.44} \cdot Q^{-1.11\pm0.48}$. The disruption threshold Q*, that is the specific energy necessary for $m_1/M_t = 0.5$, is obtained Q*=1000 J/kg. This is comparable to OC and CV [*3] and smaller than the value of gypsum [*6,7] and larger than the value of glass[*8].

We measured the velocity of the fragments from the corners of the impacted surface of the targets in the center-of-mass system from the high speed images. The fragment velocity at catastrophic disruption, i.e., $m_1/M_t = 0.5$, is almost the same as that of gypsum (porosity 50%)[*4] and is about 4 -5 times faster than that of an ordinary chondrite analogue target (porosity 35%)[*4]. The result suggests that the re-accumulation of bodies composed of UTPS-TB is less likely to occur than those composed of the ordinary chondrite analogues, but occur in the similar degree with those composed of gypsum.

References

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