DISTRIBUTION OF STRENGTH AND POROSITY IN SMALL ASTEROIDS.
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Introduction: The internal structure of small, several meter sized, stony asteroids is to large extent unknown. Some of these small bodies may be coherent monolithic blocks, while others can be loose, structurally or compositionally inhomogeneous rubble piles as for example asteroid 2007 TC_3 – parent body of the Almahata Sitta meteorites [1].

In order to obtain more insight into internal structure of such small asteroids, physical properties as bulk and grain density and porosity of Bjurböle (L/LL4) and Chelyabinsk (LL5) meteorite showers were studied. Bjurböle and Chelyabinsk were chosen for several reasons:

1. Both meteorite showers are compositionally homogeneous. Thus, any density variations in recovered meteorites can be attributed to their internal structure (e. g. porosity).
2. Both showers consist of hundreds of recovered individual meteorites, thus probing large volume of their parent asteroid.
3. Size range of the individual meteorites of both showers spans over several orders of magnitudes from grams to tens (Bjurböle) or hundreds (Chelyabinsk) of kilograms.
4. There is a difference in average porosity between the two showers. While Bjurböle represent highly porous chondrite (20%), the porosity of Chelyabinsk is rather average for chondrites (6%).

Physical properties measurements: Bulk and grain density and porosity was measured on 21 Chelyabinsk meteorites (light-colored lithology, [2]) ranging in mass from 5.15 g to 502 kg, and on 10 Bjurböle meteorites ranging in mass from 17.27 g to 13.5 kg. The bulk volume vas measured utilizing a combination of glass-beads and 3D laser scanning techniques (Fig. 1). Grain volume was measured utilizing gas pycnometry.

Results: Both meteorite showers show similar grain density value (3.53 g/cm^3 for Bjurböle vs. 3.51 g/cm^3 for Chelyabinsk) which is in agreement with overall similar LL-chondrite composition. The relative homogeneity of meteorite showers grain densities was also observed in other meteorite showers [3]. Bjurböle has, however, lower average bulk density values (2.81 g/cm^3) compared to Chelyabinsk (3.32 g/cm^3) resulting in higher porosity (20% for Bjurböle versus 6% for Chelyabinsk).

Surprisingly, there is no trend in bulk density and porosity as a function of meteorite mass (Fig. 2) in both showers.

Discussion: The interpretation of this observation is based on distribution of the strength and the porosity within the parent meteoroid body. The meteorite fragments surviving meteoroid atmospheric entry must be made of material above certain strength threshold. Naturally, the stronger fragments contain less porosity. Thus, the surviving fragments are also the least porous parts of the meteoroid.

In contrast, any weaker, more porous zones within the meteoroid are most likely subject of disintegration during atmospheric entry and thus are not preserved. This is the reason why we do not observe less dense (and more porous) meteorites even among the largest masses.

Further, the fact that we observe surviving meteorites of identical density and porosity among masses spanning over 5 orders of magnitudes (from grams to hundreds of kilograms) within single meteorite shower indicates that the distribution of strength and porosity is highly inhomogeneous within the parent meteoroid. Small, several meter sized, stony asteroids can be thus composed of heterogeneous zones with high variation (on centimeter scale) in strength and porosity. These zones are producing numerous small meteorites. In contrast, other parts of the same body may be relatively homogeneous with consistent density and porosity values over meter distances. These zones are producing large intact meteorites.

Conclusions: Based on evidence from Bjurböle and Chelyabinsk meteorite showers we conclude that some small, meter-sized, stony asteroids may have highly heterogeneous distribution of their strength and porosity with both weak zones and large coherent areas. This highly varying pattern is reflected in size range and physical properties of recovered meteorites. It also represents an undesired uncertainty in assessment of asteroid impact hazard or in asteroid atmospheric entry modeling.

References:

[1] Kohout T. et al. (2011) *Icarus, 212,* 78-85. [2] Kohout T. et al. (2014) *Icarus, 228,* 697-700. [3] Consolmagno G. et al. (2006) *MAPS, 41,* 331-342.

 

Fig. 1. 3D laser scanning of the 502 kg Chelyabinsk meteorite (left) and resulting 3D model (right).

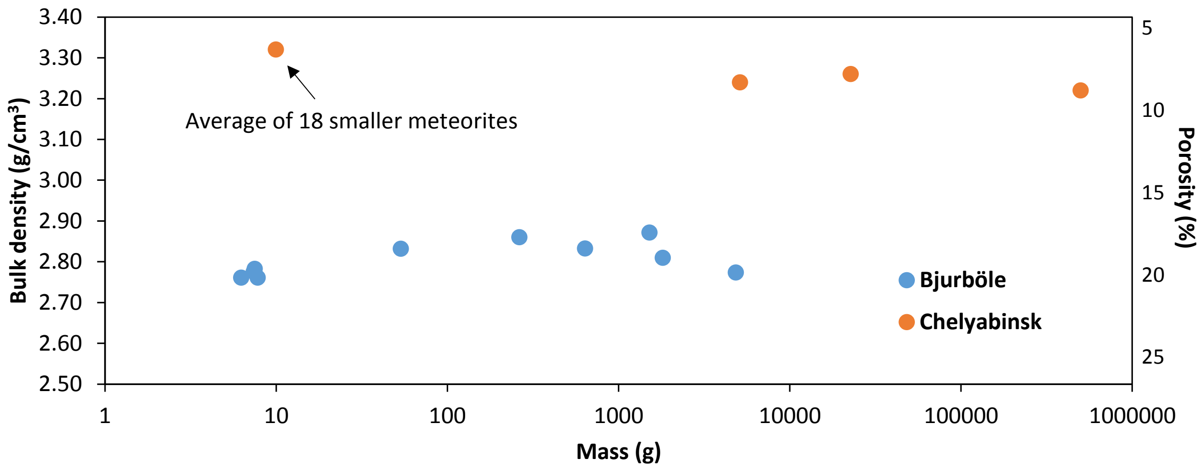

Fig. 2. Bulk density and porosity as a function of meteorite mass.