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# Compressive strength measurements of meteorites and terrestrial rocks: Implications for physical properties of asteroidal surfaces

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Strength is one of important physical properties of planetary and asteroidal materials. It is not only a useful item for understanding the solar system evolution but also necessary information to develop a sampling system for sample return missions. However, only a few previous studies are available for strength data of extra-terrestrial samples and there had been no data for carbonaceous chondrites, which are primitive objects and possible fragments of C-type and D-type asteroids as mission target candidates in future asteroidal sample return missions of Japan. In order to characterize strength, both compressive and tensile strengths should be determined. The uniaxial compressive strength tests were conducted in this study, where two chondrites, Murchison (CM2) and La Criolla (L6), and two terrestrial volcanic rocks, pumice (Chile) and basalt (Okayama, Japan), were measured. The tensile strength tests using small grains were performed to some carbonaceous chondrites and terrestrial analogs by Tsuchiyama et al. reported in [1].

Whole rock samples were prepared as cylindrical shapes in sizes of 5 mm in diameter and 10 mm in length except for one sample of pumice that has 10 mm in diameter and 20 mm in length. The metallic disk was placed on each end of the cylinder, and their centers were compressed under room temperature using an uniaxial compression machine at ERI, University of Tokyo. The stress was monitored with keeping displacement constant (1 micron/sec). The compressive strength was determined as the point of the maximum stress just before failure of the sample. The fracture appearances indicate shear type failures.

The compressive strength was obtained to be 50 and 50 MPa for Murchison, 98 and 98 MPa for La Criolla, 1.7, 5.9 (the large size sample), 6.7, 7.0 and 11 for pumice, and 277 and 279 for basalt, respectively. Multiple measurements for Murchison, La Criolla and basalt show highly reproducible results. The data of La Criolla and basalt fit ranges within the previous reports of compressive strength of ordinary chondrites (77-380 MPa except one small value [2]) and basalts (e.g., 300 MPa for JB-1 [3]), respectively. Pumice shows variable and small compressive strength. Murchison shows 50 MPa in duplicated measurements despite its heterogeneous, fragile and high-porosity characteristics. The porosity of Murchison is about 20 %. During slow compression, micro pores might have been squashed. Murchison is composed of hard chondrules and crump matrix and other components like CAIs. Because the diameters of chondrules are as small as ˜0.2 mm and the abundance ratio of chondrule/matrix is about 0.3, strength is likely to be controlled by the matrix. The compressive strength of Murchison fits within the ranges of those of compact mudstone, welded tuff, sandstone and limestone.

The compressive strength is generally several ten times greater than those of the tensile strength. The tensile strength determined for small grains (˜100 micron) of Murchison is from 0.9 to 4.5 MPa with the average of 2.0 +/- 1.5 MPa [1]. Those of other carbonaceous chondrites show variable tensile strength from 0.6 to 18 MPa [1]. The scatters are probably due to heterogeneities in hundred micron scales of the samples and/or shape effects on the experiments.

References:
[1] Tsuchiyama et al. (2008) Abstract in this meeting.
[2] Wasson (1974) Meteorites: Classification and properties, Springer-Verlag.
[3] Iizuka and Inami (1976) Bulletin of the Geological Survey of Japan, vol. 27, 155-165 (in Japanese).