Investigation of meteorite porosity by computed microtomography

G.J. Flynn[1], M. Rivers[2], and S.R. Sutton[2]
[1]*SUNY-Plattsburgh, Plattsburgh, NY 12901 USA*
[2]*Consortium for Advanced Radiation Sources, The University of Chicago, Chicago, IL 60637 USA*

Introduction

Meteorites are believed to be fragments from main-belt asteroids; thus, the physical properties of meteorites should provide constraints on the physical properties of the asteroids. Porosity is an important property of asteroids, providing a way to dissipate shock so that it requires more energy for an impactor to produce a crater or disrupt a porous target than a nonporous target. Most modeling of asteroid cratering and disruption has assumed that asteroids are non-porous. However, the NEAR spacecraft measured a bulk density of 1.3 ± 0.2 gm/cc for the main belt asteroid Mathilde (well below the density of the minerals of which Mathilde is composed based on reflection spectroscopy), indicating this asteroid has significant porosity.

To better understand the degree of porosity in meteorites, Flynn *et al*. [1] and Consolmagno and Britt [2] have measured the porosities of more than 55 ordinary chondrite meteorites and five carbonaceous chondrite meteorites, comparing the volume of a sample measured using a He-pycnometer with the volume determined by displacement of a “fluid” (as described in [2]). All “fresh” samples (meteorites collected immediately after falling to Earth) show significant porosity, averaging 8 to 10% for the ordinary chondrites and closer to 20% for the carbonaceous chondrites [1]. Meteorites subjected to terrestrial weathering have lower porosities, suggesting that weathering products fill the voids [2]. These results indicate that the asteroids that are parent bodies of the carbonaceous and ordinary chondrite meteorites are porous or contain porous regions.

Other investigators have examined thin sections of meteorites in a effort to locate the porosity. They have identified gaps between large crystals or chondrules and the surrounding matrix as well as cracks across the thin sections. These gaps could be particularly significant because continuous porosity is more likely to alter shock propagation through the meteorite and its parent body. However, both gaps and cracks in thin sections could have been be induced during the cutting and polishing required to produce thin sections for the optical examination.

Methods and Materials

X-ray computed microtomography (CMT) provides three-dimensional images of the x-ray absorption coefficient distribution within a specimen. The x-ray absorption coefficient depends on both the atomic number (Z) and the density of the material in each volume element of the sample. *In situ* examination of meteorites by CMT allows detailed study of the porosity in meteorites identifying the type of porosity in each meteorite, determining if the porosity is continuous or localized, and excluding porosity induced by thin-section preparation.

Using the GSECARS (sector 13) CMT instrument, we performed CMT on centimeter-size fragments of five carbonaceous chondrite meteorites (Murchison, Murray, Allende, Axtel, and Kainsaz), 11 ordinary chondrites (Acfer 132, Bjurbole, Saratov, Gao, Hammadah al Hamra 071, Juanchang, Zag, Gao, Kaufman, Mt. Tazerzait, and Nadia), and four “whole stones,”which are complete meteorites having fusion crust on all surfaces (Holbrook, Juancheng, Mbale, and Gao).

Results

We observed three distinctly different types of porosity in these meteorites: cracks, gaps, and vugs. Cracks were the most common void spaces identified, occurring in more than half of the meteorites we examined. Figure 1 shows several cracks in a plane through a Murchison fragment.

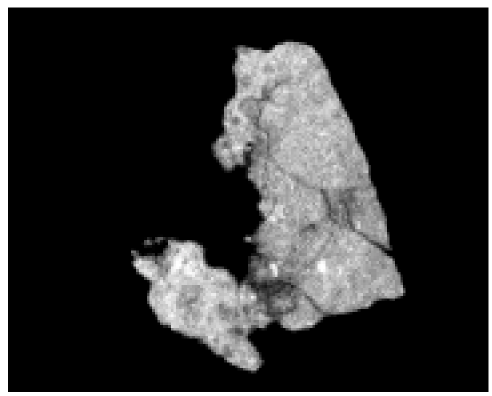

Figure 1: CMT image of a “slice” through a Murchison fragment showing cracks (dark regions) through the sample.

Low-density regions, or gaps, occurred between the chondrules and the matrix in two extremely friable meteorites, Saratov and Bjurbole. The vugs and gaps are unambiguously preterrestrial. However, one whole stone of the Holbrook meteorite shows several cracks, each of which cuts the fusion crust. Since the fusion crust is a glassy material that forms due to frictional heating on atmospheric entry, fusion crust would be expected to cover or seal cracks that existed prior to atmospheric entry. Cracks that cut the fusion crust may be terrestrial artifacts, produced by thermal effects during entry, impact with the ground, or subsequent handling. Higher resolution CMT imaging of this Holbrook sample may allow us to see if there are features suggesting the crack pre-existed formation of the fusion crust, but was widened, breaking the crust, by terrestrial events.

Discussion

CMT examination provided *in situ* images of the voids in meteorites, identifying cracks, gaps, and vugs in the samples. The CMT analysis of the Holbrook whole stone raises concern that some of the cracks seen in thin section may be of terrestrial origin, rather than reflecting a property of the parent asteroid.

The first results of this project also demonstrate the instrument capability and scientific value of CMT as a noninvasive, nondestructive screening tool for rock cores to be returned from Mars (in 2008, according to current NASA plans) and other solar system bodies, such as comets and asteroids [3].

Acknowledgments

This work was supported by NASA Cosmochemistry Grant NAG-5-4843 (G.J.F.). Use of the Advanced Photon Source was supported by the U.S. Department of Energy, Basic Energy Sciences, Office of Science, under Contract No. W-31-109-Eng-38.

References

[1] G.J. Flynn *et al*., *Icarus* **142**, 97–105 (1999).
[2] G.J. Consolmagno and D. T. Britt, *Meteoritics and Planetary Science* **33**, 1231–1241 (1998).
[3] G.J. Flynn *et al*., *Lunar & Planetary Science* **XXXI**, in press.