The porosity of Martian meteorite Dar al Gani 476.

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INTRODUCTION: SNC meteorites are fragments of Martian surface material available for study in laboratories on Earth. These particular meteorites provide us with a history of distinct ancient impacts upon the surface of Mars; they also supply physical samples of basaltic rock from different regions of the planet's surface [Head, Melosh and Ivanov, 2002]. Indeed, until such times as Martian rock samples collected *in situ* become available for analysis, the SNC meteorites are the only examples we have of the basic lithologies that constitute both the ancient and modern crust of Mars.

While the chemical make-up and petrology of the 33 currently known SNC meteorites have been studied extensively by many research groups in recent years, relatively little data exists concerning their structural characteristics - such as porosity. A recent survey revealed, for example, that only eight fragments, from four distinct SNC meteorites, have measured and published porosity values [Britt and Consolmagno, 2003]. Porosity is of fundamental importance since it is a measure of the volume of empty space within a meteorite [Consolmagno, Britt and Stoll, 1998]. Indeed, to fully interpret the nature, origin, shock modification and cosmic ray exposure history of a meteorite some measure of its porosity is required. Here we report on the determination of the porosity of the SNC meteorite, Dar al Gani (DaG) 476.

THE METEORITE: DaG 476 is an olivine-phyric Shergottite meteorite. The original 2015-g meteorite was discovered in the Dar al Gani region of the Libyan Sahara on May 1, 1998. When found, the meteorite had no discernable fusion crust, but was coated with a thin, dark brown desert varnish, which is indicative of a long terrestrial residency. DaG 476 is believed to be paired with DaG 489 and possibly four other meteorite fragments found in the same area; it is suggested that this meteorite forms part of an extensive strewn field. The crystallisation age of DaG 476 is estimated to be 474 ± 11 Ma [Borg *et al*., 2000], and the ejection time, based upon cosmogenic isotope studies, is estimated to have been 1.05 ± 0.10 Ma ago [Nishiizumi *et al.*, 2001].

METHODOLOGY: The present study forms part of an ongoing programme to measure the porosity of Martian meteorites. Rather than using bulk meteorite samples to determine the porosity, however, our analysis is based upon the study of small slices of rock material (so-called 'thin-sections'). Accordingly, we have obtained 53 back-scattered electron images, utilising scanning electron microscopy (SEM), of a single thin-section of DaG 476 (figure 1) and have analysed each image in turn to determine an average porosity. Serial images for the 'sample mapping' procedure were collected at a fixed magnification of 100 times, used throughout. The sample dimensions are approximately 12-mm by 4-mm.

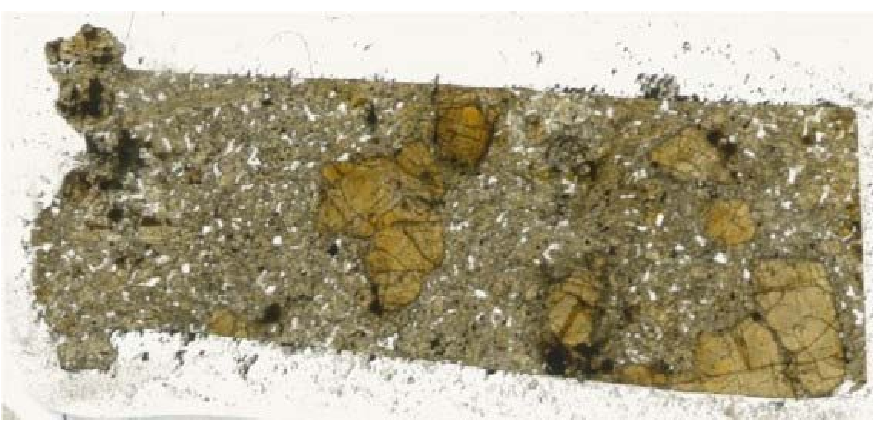

Figure 1: Low resolution image of the DaG 476 thin section used in the porosity analysis (field of view is 12 × 4 mm)

RESULTS: The porosities corresponding to the sample edges and interior have been measured and evaluated separately. For the interior we find a porosity of 1.85 ± 1.02 percent. For the edge images we find an average porosity of 2.47 ± 1.99 percent. We have also determined the average porosity of the distinctive, cleft-shaped edge of the sample (see figure 1) to be 2.38 ± 2.45 percent. These results combine to give a total average porosity of 2.33 ± 1.83 percent for the sample. Consistent with the studies by Strait and Consolmagno [2001, and 2002], we find that the average porosity tends to increase towards the 'natural' surface (to the left in figure 1) of the sample, where larger cracks are certainly more in evidence. However, it was also noted than many of the fractures are in-filled with secondary minerals (e.g., baryte), related, in part, to the chemical weathering of the meteorite during its residency in the desert environment.

DISCUSSION: Consolmagno and Strait [2002] have determined a 'model' porosity of 2.7 percent for an 18.3-g fragment of DaG 476, on the basis of its known mineralogy, and a measured bulk density 3.21 ± 0.07 g/cm^3, and this compares well with our analysis. Indeed, the close comparison between the two results suggests that the porosity of the bulk sample is completely accounted for through the micro-crack and void structures visible through SEM microscopy. The origin of the micro-cracks is still an open question, however. It is clear that the cracks are not the sole by-products of the thin-section preparation procedure, and so they presumably relate to both natural formation characteristics (cooling and vesiculation) and to shock-induced modifications imposed during the launch from the Martian surface, and during landing on the Earth.

Britt and Consolmagno [2003] quote a measured porosity of 5.7 percent for the Nakhla SNC meteorite (based upon the study of three individual fragments) and a 'model' porosity of 7.5 percent for a single fragment of the Chassigny SNC meteorite; the average 'model' porosities (based upon four fragments from two meteorites: EET 79001 and Zagami) quoted for Shergotties is 7.7 ± 4.0 percent Our preliminary results would suggest, therefore, that the porosity of DaG 476 is situated towards the lower extreme of values apparently expressed by Shergottite meteorites. Perhaps, this low value is a reflection of the altered nature of the studied sample (in-filling of fractures, due to chemical weathering). However, it is important to note that is has been demonstrated that at least some of the weathering products found in Martian meteorites were present before the fusion crust formed, during entry into Earth's atmosphere, and, thus, must have formed prior to the samples ejection from Mars [Gooding, Wentworth and Zolensky, 1987]. In future work we will report on the porosity measurements of three additional Martian meteorites: EET 79001, ALH 84001 and NWA 3171.

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