POROSITY DETERMINATIONS IN INTERPLANETARY DUST PARTICLES AND PRIMITIVE METEORITES; Jason M. Dahl[1], Michael E. Zolensky[2], Clyde A. Sapp[3], and P.J. Burkett[4]; [1]Bemidji State University, Bemidji, MN 56601; [2]NASA Johnson Space Center, Houston, TX 77058; [3]Lockheed ESCO, 2400 NASA Rd.1, Houston, TX 77058; [4]Naval Research Laboratory, Stennis Space Center, MS 39529.

Abstract: We describe results of porosity determinations of IDPs, and find that most values are less than 15%. These results are comparable to those for chondritic meteorites.

Introduction: The study of Interplanetary Dust Particles (IDPs) and their various properties has come to be of great interest within the scientific community in recent years. By exploring the nature of IDPs, we hope to learn a great deal about the original state of the solar nebula, as well as the subsequent processes that have shaped it. IDPs constitute an extremely important source pool of extraterrestrial material for study, especially since they provide such a broad sampling of material, having accreted at such a wide range of distances from the sun, as well as being less biased (with respect to source) than conventional meteorite samples [1]. Consequently, IDPs represent, in many cases, the only samples we have of most of this material. One particular area of interest is the process of aqueous alteration of materials, which has played a large role in the development of some asteroids. Many IDPs show evidence of aqueous alteration, and by understanding the conditions under which it occurs, we may be better able to model the geologic histories of the IDP parent bodies and the wider solar system community [2]. Integral to the study of aqueous alteration is the concept of porosity. There are already a number of time proven methods for determining porosity in a bulk sample, and actual physical liquid/gas flow measurements work quite well in samples large enough to test in this manner. However, these methods are not applicable to IDPs and other extremely small samples. Thus, up to this point there has been no reliable method for accurately determining porosity in these particles, and expected porosity values have been largely estimated. It has been suggested that in the high porosity anhydrous family of IDPs, porosities are much higher than those seen in meteorites, which typically exhibit porosities of 20% or less [3]. We hope to be able to test this hypothesis. By utilizing scanning electron microscope (SEM) images and computer image processing, we have developed a method by which sample porosity may be determined both efficiently and accurately for nanogram-sized samples

Philosophy and Method: If a sample is fairly homogeneous at some scale, i.e. the individual grains and pore spaces are fairly small compared to the total volume of the particle, then if we pass a plane through the sample at some arbitrary point, it should intersect a volume of pore and grain space representative of the entire sample. We determined porosities by measurement of relative pore space in particle cross-sections. The IDPs we have been working with were collected in the stratosphere [4]. The samples were mounted on epoxy blocks and impregnated with EMBED-812 low viscosity epoxy, after which thin sections were sliced away with an ultramicrotome. The remaining "polished" portions of the samples were then available for our examination. First, a scanning electron microscope (SEM) was used to collect back scattered electron (BSE) images of each particle at 13 kV.. Next, these images were digitized by "grabbing" each image using a CCD camera, multi-component video rack, a Gould IP8500 Image Processor, and the Library of Image Processing Software (LIPS) (Gould Electronics, Image and Graphics Division) program set installed on a VAX/VMS operating system. The images were then imported to a Macintosh IIcx workstation for use with NIH Image, a computer-based image processing program. Each image was inverted (after import, images were in negative form, i.e. with black and white reversed) using the program's Invert command, so as to reproduce the original hard copy images on the screen. The NIH Image environment supports 255 level black and white images. However, for area percentage calculations, straight black/white (0/255) images are required. To produce these conditions, the software's Threshold utility was used. Threshold converts the 255 gray level image to 0/255 format by determining a threshold level, above which all pixels become black (255), and below which all pixels become white (0). This threshold level is user adjustable, and we found that for accurate porosity determinations, it had to be manually selected for each image. The best method we discovered for determining the correct threshold level utilizes histograms. When a histogram is computed for an entire image using the Compute Histogram command, in each case it shows a bi-modal distribution of pixel levels, with peaks corresponding to particle and background/void. The threshold level will fall in the saddle between histogram maxima. To increase the accuracy of threshold placement, a second histogram of the image background is computed, and the threshold can be set just below the levels occupied by the background. A particle boundary is then selected and the threshold level is set. The image is binarized using the Make Binary command, and

Compute Percent Black and White, is used to compute porosity, where porosity corresponds to the percentage of black pixels within the selected area.

Results and Discussion: First, a word on particle boundary selection. In each image, particle boundary was selected so as to minimize edge effects. If a particle boundary is very irregular, it can become difficult to determine where the particle ends and the background begins. By excluding epoxy "inlets" from our calculations, this problem can be avoided. Overall, this method of threshold level selection seems to yield accurate porosity measurements. A fine-grained rock sample with consistent, independently well-determined porosity (Brea Sandstone, 23% porosity) was obtained from Core Laboratories, Inc. (Houston, TX) and used as a standard to test our method. Measurement yielded porosities with relative measurement errors of 15% or less on the best images of the standard. In short, we are confident that, so long as one is careful to work with good, clear images of each sample, this method works well for accurate porosity determinations in nanogram-sized particles.

The results of our initial studies with 33 different chondritic IDPs are somewhat surprising. When compared to porosity in carbonaceous and ordinary chondrite meteorites, IDPs do not seem to show the significantly higher porosities that had been expected. In fact, these results appear to overlap with meteorite porosities, as measured by bulk analysis methods (C = 1-26 %, H = 2-18, L = 3-20, LL = 7-16) [5-10], to a high degree. However, until further investigation our measured porosities should be considered lower estimates, since some IDPs should have broken along large pore walls during stratospheric capture, yielding smaller apparent measured porosities for the resultant pieces. A great deal of work remains. Relatively few IDPs have been examined, and there is a general paucity of data for C chondrites. We hope that, through continued refinement and application of this method to meteorites, the important questions concerning porosity in IDPs and meteorites may be addressed.

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