THE EFFECTS OF POROSITY AND PORE GEOMETRY ON ACOUSTIC VELOCITIES (AND ELASTIC MODULI) IN ORDINARY CHONDRITES: PRELIMINARY RESULTS. S. F. Jones¹ and A. R. Hildebrand¹, ¹Department of Geoscience, University of Calgary, Calgary, AB, sfjones@ucalgary.ca, ahildebr@ucalgary.ca.

Introduction: Composition, petrologic type, and terrestrial weathering have all been identified as potential factors that may result in acoustic velocity variations in meteorites [1]. Particularly large velocity variations have been observed in genometric meteorites typically composed of breccias with light coloured angular fragments in a dark coloured matrix. The light and dark regions of these meteorites are compositionally the same, thus the velocity difference has been attributed to a variation in the petrologic type between the fragments and matrix. This project tests the hypothesis that different pore geometries associated with petrologic type in meteorites and fracture distributions affect the compressional and shear wave velocities, and thus the elastic properties of the rock. Significant pore geometries have been reported in the literature for ordinary chondrites [2] and anomalously low acoustic velocities in chondrites have been attributed to the presence of micro-fractures [3]; however the relationship between pore characteristics and sonic velocity in meteorites has never been explored.

Methodology: Compressional and shear wave velocities and bulk densities were measured in 80 meteorites; 78 of these samples are from the Arizona State University Center for Meteorite Studies Collection and the other 2 from the University of Calgary. Falls as opposed to finds were used to reduce the effect of terrestrial weathering which produces secondary minerals that fill the pores thereby reducing meteorite porosity [2,4]. Acoustic velocity measurements were completed using Panametrics-NDT™ V103 and V153 1.0MHz transducers, a battery-powered pulse generator, and a Tektronix TDS 420A digital oscilloscope. Bulk densities were determined using an Archimedean method [2] employing 1 mm-diameter glass beads. Twenty-four new porosity measurements were collected using a Hecypnometer.

Discussion: Four statistically strong relationships have been previously observed in ordinary chondrites: total porosity declines with terrestrial residence time, acoustic velocity increases with bulk density and with meteorite darkness, and acoustic velocity decreases as total porosity increases [5]. Results confirm that these relationships are exhibited by H, L, and LL chondrites (Figs. 1-4), and the derived shear, bulk and Young’s moduli (elastic moduli) show analogous trends.

Effects of Pore Geometry. Preliminary analysis of pore geometry via thin section observations in a subpopulation of the samples document three pore geometries in these meteorites: fracture, equant, and interstitial. Fracture porosity includes all cracks ranging from microns to hundreds of microns in width and microns to millimeters in length. Equant porosity refers to rounded to irregular equi-dimensional voids and interstitial porosity refers to irregular shaped pores between grains. Fracture porosity occurs in ~60% of the meteorites studied in thin section to date. The presence of fracture porosity is not limited to one chemical group or petrologic type and does not correlate exclusively with low elastic moduli. This distribution of fracture porosity is consistent with it being secondary porosity introduced by impacts on the parent asteroid. The equant and interstitial porosities are interpreted as primary depositional porosities as modified by compaction and heating.

A small population of fractures can reduce acoustic velocities significantly resulting in meteorites that deviate from darkness-velocity trends. This is evident in the St-Robert meteorite, an H5 light (clasts)-dark (matrix) breccia. Total porosity in this sample was previously reported as 9.9% [6] and thin section observations document equant pore geometry in the light clasts. The dark matrix contains less pore space, and pores in the matrix are dominantly fractures. The presence of fracture porosity in the dark matrix correlates with compressional and shear wave velocities that are slower than in the light clasts, a deviation from trends previously observed in light-dark breccias [5].

Summary and Future Work: The velocity relationships observed here confirm trends documented in previous research [1,3] including the surprising apparent decreased velocities in the higher petrologic types (Fig. 5). To date, pore geometry observations demonstrate that the presence of fracture porosity can have a large effect on meteorite acoustic velocities and derived elastic properties. Future work will focus on detailed characterization of pore geometry and distribution in ordinary chondrites to better understand the relationship between pore shape and meteorite physical properties.

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Fig. 1. Fall date vs. total porosity for ordinary chondrites. Total porosity declines with terrestrial residence time. Black squares, grey triangles, and black stars represent H, L, and LL chondrites respectively.

Fig. 2. P-wave and S-wave velocities increase with bulk density in ordinary chondrites. Black squares and grey triangles represent P-wave and S-wave velocities respectively.

Fig. 3. P-wave and S-wave velocities increase with darkness in ordinary chondrites. Black squares and grey triangles represent P-wave and S-wave velocities respectively.

Fig. 4. P-wave and S-wave velocities decrease with increasing total porosity in ordinary chondrites. Black squares and grey triangles represent P-wave and S-wave velocities respectively.

Fig. 5. Although a range of P-wave velocities is observed for L chondrites of the same petrologic type/grade, a correlation of slower velocities with higher grade is indicated.