**ENSTATITE CHONDRITE PHYSICAL PROPERTIES: DENSITY, POROSITY AND MAGNETIC SUSCEPTIBILITY.** Robert J. Macke SJ[1], Daniel T. Britt[1], Guy J. Consolmagno, SJ[2], [1]Department of Physics, University of Central Florida, 4000 Central Florida Blvd, Orlando, FL 32816, macke@alum.mit.edu, [2]Vatican Observatory, V-00120 Città del Vaticano, Italy

**Introduction:** Enstatite chondrites are highly reduced meteorites marked by an abundance of enstatite, and a depletion or absence of olivine. Due to their relative rarity compared to other chondrites, they are poorly understood as a group. Based on measurements of only a few stones, Sears et al. [1] subdivided the enstatites into two groups, which they named EH and EL based on assumed iron content (EH's were assumed to have higher iron abundances than EL's). While the subdivision remains robust when criteria based on siderophile, chalcophile and other mineralogical abundances are employed, the original notion that the two differ notably in iron content has been challenged. [2]

Iron content influences meteorite grain density and magnetic susceptibility, though factors such as oxidation state of the iron also influence these properties. Consolmagno et al. [3] showed that ordinary chondrite falls group into three distinct regions (corresponding to H, L and LL chondrites, each group differing considerably in iron content) on a grain density-magnetic susceptibility plot. Some question has risen about whether enstatite chondrites may also be distinguished by these physical characteristics or by porosity, but until now it hasn't been put to the test for a significant number of samples. Consolmagno et al. [4,5] report grain density and porosity for nine separate enstatite chondrites (a mixture of falls and finds) and found a slightly higher average grain density for EH compared with EL (3.70 ± 0.03 g/cm$^3$ for EH vs 3.61 ± 0.07 g/cm$^3$ for EL), but with considerable overlap in the two groups. It was unclear whether the difference was actual or only the result of insufficient statistics.

As part of a larger survey of meteorite physical properties, we measured density, porosity and magnetic susceptibility of 26 hand-sized stones (10-140g) from 16 different enstatite chondrites. Measurements were made on samples from the American Museum of Natural History in New York and the National Museum of Natural History in Washington, DC. This includes a mix of EH and EL chondrites, as well as a mix of falls and finds. We report here the results of that study, including our attempts to determine whether EH and EL chondrites are at all distinguishable by these properties, and whether they may be distinguished from H chondrites purely by density, porosity or magnetic susceptibility.

**Method:** We utilized well-established, non-destructive and non-contaminating methods for measurements of the meteorite samples. Grain densities were determined via helium ideal-gas pycnometry, for which we employed a commercially-available instrument (Quantachrome Ultrapycnometer 1000). Bulk densities were determined using the Archimedean glass bead method [6], with small corrections made for systematic error according to measurements conducted at NMNH. Magnetic susceptibility was measured using a hand-held device, the ZH-Instruments SM-30 magnetic susceptibility meter. Adjustments were made for the geometry of the small samples based on an algorithm developed by Gattacceca et al. [7] for the same device. From bulk and grain densities, porosity was then calculated directly.

Our measurements included 7 EH (4 falls, 3 finds) and 9 EL (5 falls, 4 finds). We have found based on ordinary chondrite data [3] that due to weathering, finds tend to have reduced porosity, grain density and magnetic susceptibility when compared with falls. We did not observe a significant weathering-related effect on these properties in enstatite chondrites. Given the scarcity of samples we found it necessary to include both sets in our analysis.

**Results:** Our results are plotted in figure 1 (grain density vs. magnetic susceptibility) and figure 2 (porosity vs. grain density).

*Grain density:* We found that the majority of the samples grouped between 3.45 and 3.75 g/cm$^3$, with a few outliers at slightly lower density (Happy Canyon [EL] and Bethune [EH]) and one with a high density of 4.17 g/cm$^3$ (Khairpur [EL]). Average grain density for EH is 3.61± 0.14 g/cm$^3$, and for EL is 3.65 ± 0.24 g/cm$^3$, indicating no significant different between the two groups. Considering only falls, the average grain density for EH is 3.66 ± 0.06 g/cm$^3$, while for EL it is 3.75 ± 0.25 g/cm$^3$. However, this includes outliers such as Khairpur that significantly skew the results. Considering only those meteorites from the main group, both EH and EL have an average grain density of 3.64 g/cm$^3$.

*Magnetic susceptibility*: The majority of samples grouped between a log $\chi$ of 5.35 and 5.64, with three meteorites having much lower magnetic susceptibilities (Bethune: log $\chi$ = 4.53; Happy Canyon: log $\chi$ = 4.64; Adhi Kot [EH]: log $\chi$ = 4.57±0.95). Average log $\chi$ for EH is 5.21±0.46 and for EL is 5.38±0.30. Eliminating outliers, average log $\chi$'s for EH and EL agree at 5.45.

*Porosity:* Consolmagno et al. [5] observed two porosity groupings for their enstatites, with most samples between 0.3% and 6.4%, and three meteorites

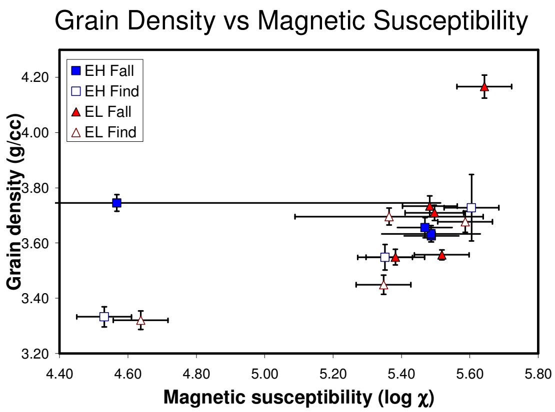


Figure 1: Grain density vs magnetic susceptibility of enstatite chondrites. With the exception of four "outliers," most are grouped tightly in one region on the plot. The considerable overlap between EH and EL chondrites, and that the anomalous sample in the upper right (indicative of the highest concentration of unoxidized iron) is an EL: Khairpur.

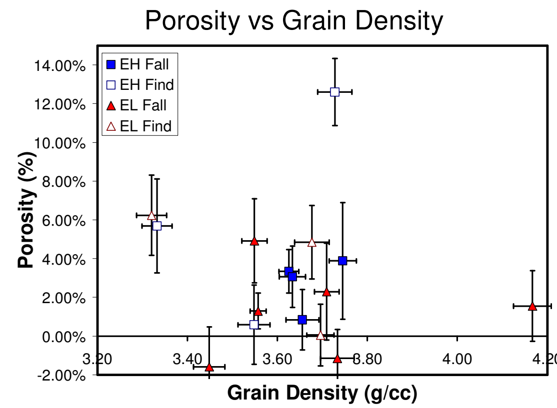


Figure 2: Porosity vs grain density of enstatite chondrites. With the exception of four "outliers," most are grouped tightly in one region on the plot. However, the outliers are not all identical with the outliers in fig. 1: The high-porosity meteorite (Sahara 97096) exhibits "normal" grain density and magnetic susceptibility.

with higher porosity (11.7% to 12.6%). Our results are compatible. All but one of our meteorites measured between 0 and 6.4%, and one (Sahara 97096) had a higher porosity of 12.6%±1.7%.

**Discussions and Conclusions:** Our data show considerable overlap between EH and EL chondrites in all of the physical properties tested, and even on average they have the same densities, magnetic susceptibilities and porosities. Based on these results, there is no apparent difference in iron content between EH and EL chondrites. In fact, the highest-density, highest-magnetic-susceptibility meteorite in this survey (Khairpur) is an EL chondrite, and among the lowest-density, lowest-susceptibility samples is an EH (Bethune).

Density and magnetic susceptibility cannot be used for classification to distinguish EH and EL chondrites. Likewise, there is insufficient difference to distinguish enstatites from ordinary H chondrites based on these criteria (figure 3), though the average magnetic susceptibility for enstatite chondrites is slightly higher than that for H chondrites. We look forward to continuing this study on further Enstatite chondrites, to determine (1) how consistent the grouping is and (2) whether the "outliers" themselves represent significant groups of enstatites.

**Acknowledgments:** We would like to thank the curatorial staff at both the American Museum of Natural History and the National Museum of Natural History for their willingness to allow access to their collections and their support of this research. In particular, we would like to thank Dr. Denton Ebel, Dr. Joe Boesenberg, Dr. Glenn MacPherson and Linda Welzenbach. This research is supported by NASA grant NNG06GG62G. Robert Macke's research at NMNH was sponsored by a Smithsonian Institution Graduate Student Fellowship.

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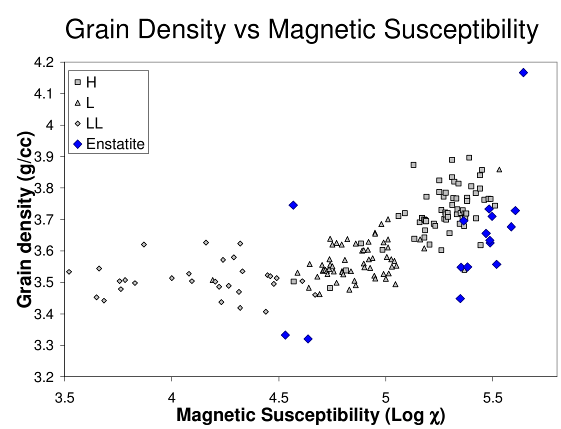


Figure 3: Grain density vs magnetic susceptibility of enstatite chondrites and ordinary chondrite falls.