Bulk Density and Magnetic Susceptibility of the Buzzard Coulee Meteorite. C. Fry[1], C. Samson[1], P.J.A. McCausland[2], and R.K. Herd[1,3], [1]Department of Earth Sciences, Carleton University, Ottawa, Ontario, Canada, K1S 5B6, [2]Department of Earth Sciences, University of Western Ontario, London, Ontario, Canada N6A 5B7, [3]Earth Sciences Sector, Natural Resources Canada, Ottawa, Ontario, Canada K1A 0E8.

Introduction: The Buzzard Coulee meteorite fell near the Saskatchewan-Alberta border south of Lloydminster, Canada, in November of 2008 producing numerous fragments from the original 10-tonne meteoroid that entered the Earth's atmosphere[1]. The meteorite has been classified as an H4 chondrite[2]. The National Meteorite Collection of Canada has obtained 18 individual fragments of Buzzard Coulee, ranging in mass from 109.14 g to 8.80 g, collected within three weeks of the fall event, before the winter of 2008-9. In the interest of preserving these samples in their original condition, they are being characterized using a number of non-destructive techniques. In this abstract, we report preliminary density and magnetic data (Table 1).

Properties: Bulk density is the ratio of the mass over the volume of each fragment, including internal pore spaces. Magnetic susceptibility is the ratio of the induced magnetization of a material to the strength of an externally applied magnetic field, and is sensitive to the type and amount of magnetizable material in a sample. This measurement is related to the quantity of iron-rich minerals present, and should be high in H-chondrites because of abundant metallic iron and sulphides[3]. The 18 fragments in this study have experienced only minor weathering, and so their bulk physical properties may provide the least biased representation of the original meteoroid.

Methods: We used a non-destructive method of measuring bulk volume using Archimedes' principle by burying each fragment under 100 micrometre silica beads in a container of known volume[4]. The beads imitate the flow of a liquid, and closely surround the fragment being measured. The beads do, however, suffer from un-fluidlike errors due to variable compaction. The formally calculated errors increase as the fragments get smaller, making the approach impractical for fragments smaller than 5 cm^3 [4].

We also sought an alternative means of measuring bulk density using 3D laser imaging[5]. We used a Konica-Minolta Vivid 9i non-contact 3D laser camera to take 52 images of each fragment at a resolution of 640 by 480 voxels. These images provide comprehensive coverage of a fragment as it is rotated on a turntable and flipped so all surfaces can be captured. The images are imported into visualization software that allows an operator to assemble them into highly accurate 3D models. The software calculates volume automatically. This approach has been demonstrated for fragments as small as 0.6 cm^3.

The magnetic susceptibility of each fragment was measured using a SM-30 field-type handheld magnetic susceptibility meter manufactured by ZH instruments. Multiplying the meter reading by the fragment volume yields the magnetic susceptibility.

Discussion: The Archimedean bead densities for 17 of the 18 fragments average 3.50 g/cm^3 with a standard deviation of 0.08 g/cm^3. Two slightly discrepant measurements, for fragments A6 and A8, increase the scatter in the data. The densities determined using laser imaging are more consistent, with an average of 3.46 g/cm^3 and a much smaller standard deviation of 0.03 g/cm^3. These values are consistent with the findings of other researchers using the Archimedean bead method (3.26 g/cm^3 to 3.45 g/cm^3 for six fragments[1]) and 3D laser imaging (3.5 g/cm^3 for one 151.7g fragment[6]), and are typical values for a H chondrite[7].

The percentage difference between the results of the two methods of measuring density has been calculated (Table 1). The average difference is found to be 1.1%, even taking into account the results for fragments A6 and A8. This is less than the difference reported in previous studies [5], attesting to the high accuracy of the laser camera used.

The magnetic susceptibility is found to have an average value of 5.2×10^{-9} m^3/kg with a standard deviation of 0.062×10^{-9} m^3/kg. Since the laser densities are more consistent, they were used to calculate magnetic susceptibility. These values are typical of H chondrites[3,8,9].

When densities determined using 3D laser imaging are plotted against magnetic susceptibility values, all the data cluster within two standard deviations, forming a single population (Figure 1). The physical properties of the 18 fragments of Buzzard Coulee we have studied have a fairly homogeneous composition, with no evidence to support the bimodal density distribution reported by Hildebrand and others[1].

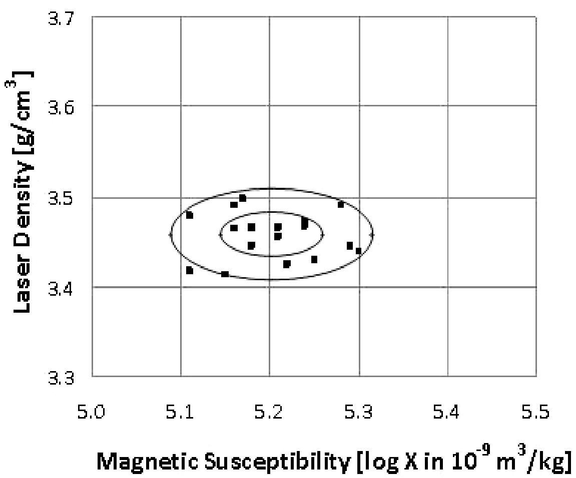

Figure 1. Bulk density versus magnetic susceptibility of 18 Buzzard Coulee fragments.

Future work includes measuring the magnetic susceptibility at different frequencies and identifying any anisotropy in magnetic susceptibility. In addition, the fragments will undergo X-ray micro-computed tomography to determine the density distribution within each sample.

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References: [1] Hildebrand A.R. et al. (2009) *LPSC XXXLX*, Abstract #1893. [2] Weisberg M.K. et al. (2009) *Meteoritics & Planet. Sci.* 44, 1-33. [3] Smith D.L. et al. (2006) *Meteoritics & Planet. Sci.* 41, 355-373. [4] Macke R.J. et al. (2009) *Planet. Space Sci.*, doi: 10.1016/ j.pss.2009.11.006. [5] Smith D.L. (2006) *JGR*, doi: 10.1029/ 2005JE002623. [6] Walton E.L. et al. (2009) *LPSC XXXLX*, Abstract #2072. [7] Consolmagno G.J. and Britt, D.T. (1998) *Meteoritics & Planet. Sci.* 33, 1231-1241. [8] Rochette P. et al. (2003) *Meteoritics & Planet. Sci.* 38, 251-268. [9] Rochette P. et al. (2009) *Elements* 5, 223-228.

Table 1. Bulk volume, bulk density and magnetic susceptiblity of 18 Buzzard Coulee fragments

Fragment	Mass	Archimedean bead method		3D laser imaging		Comparison between methods		Magnetic susceptibility
		Bulk volume	Bulk density	Bulk volume	Bulk density	Volume comparison	Density comparison	log X (using laser volume)
	[g]	[cm^3]	[g/cm^3]	[cm^3]	[g/cm^3]	[%]	[%]	[10^{-9} m^3/kg]
B1	109.14	31.58	3.46	31.47	3.47	-0.35	-0.35	5.24
A1	67.32	19.15	3.52	19.54	3.45	2.01	1.97	5.29
B2	61.67	17.47	3.53	17.90	3.45	2.44	2.38	5.18
A2	51.30	14.82	3.46	14.80	3.47	-0.14	-0.14	5.21
A3	50.50	14.67	3.44	14.43	3.50	-1.61	-1.64	5.17
C	48.82	13.77	3.55	13.99	3.49	1.57	1.54	5.16
A4	47.28	13.88	3.41	13.59	3.48	-2.09	-2.13	5.11
A5	46.66	13.39	3.48	13.44	3.47	0.34	0.34	5.24
A6	45.22	12.37	3.66	12.96	3.49	4.75	4.53	5.28
B3	42.07	12.14	3.47	12.17	3.46	0.26	0.26	5.21
B4	38.18	10.94	3.49	11.02	3.47	0.72	0.71	5.16
B5	37.38	10.75	3.48	10.78	3.47	0.31	0.31	5.18
A7	36.59	10.45	3.50	10.67	3.43	2.07	2.03	5.25
A8	35.50	9.62	3.69	10.37	3.42	7.74	7.19	5.22
B6	28.74	8.22	3.50	8.42	3.41	2.41	2.36	5.15
B7	25.19	7.35	3.43	7.27	3.46	-1.09	-1.10	5.18
A9	20.60	5.99	3.44	6.03	3.42	0.62	0.61	5.11
A10	8.80	Fragment too small		2.56	3.44	N/A	N/A	5.30
Average			3.50		3.46			5.20
Std. Dev.			0.08		0.03			0.06