Porosity Adjustments of Carbonaceous Chondrite Analogs

S. N. Congram[1], B. A. May[1], M. M. Strait[1].

[1]Alma College, Alma, MI, USA. Email: congram1sn@alma.edu.

Introduction

The most common type of meteorites found on Earth are stony meteorites called ordinary chondrites. These are composed of chondrules in a matrix of different minerals and silicates [1]. Carbonaceous chondrites, another type of meteorite, contain more complex silicates and hydrated minerals. These are rarer than their ordinary chondrite counterparts. Access to these rare meteorites is difficult due to the nature of this work, therefore this project has embarked on a project to create carbonaceous chondrite analogs [2].

Samples of carbonaceous chondrite analogs made in the past have densities around 2.0 g/cm^3 [3]. The target density is around 1.6 g/cm^3 [4]. Decreasing the density of these samples became a question of increasing the porosity. Five experiments were designed to adjust the porosity of the samples. Two control samples were also used for comparison.

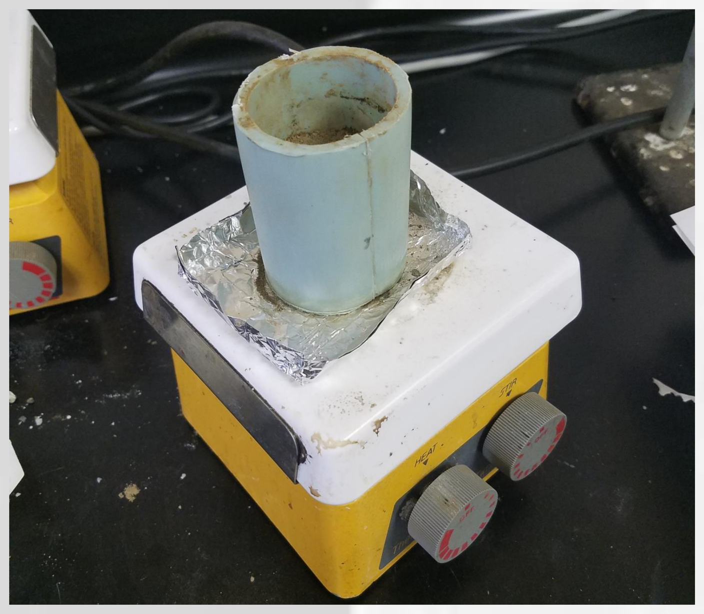

Figure 1: The hydrated NWA 869 (L3-6) material was placed in a 2.5 inch length by 1.5 inch diameter PVC mold. Aluminum foil boats were used to capture any excess $NaOH_{(aq)}$ and evenly conduct heat across the bottom of the sample.

Methodology

The experiments outlined in Table 1 were each composed of 86 g of hydrated North West Africa (NWA) 869 (L3-6) material. This material was ground to less than 2 mm in diameter and placed into 2.5 inch length by 1.5 inch diameter PVC molds (Figure 1). Unless otherwise changed, each sample was saturated with 20 mL of 0.5 M $NaOH_{(aq)}$, placed in aluminum foil "boats", and heated to 60^{o}C for 6 weeks.

After the 6 week period, the molds were removed from the hot plates and cooled for 1 day (Figure 3). The volume of the samples and the mass of the samples were measured. The densities of the samples were calculated and recorded in Table 2.

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Table 1: The variations to the base procedure as described in the Methodology section

Sample	Experiment
Control 1 (C1)	Nothing changed from the base procedure.
Control 2 (C2)	Nothing changed from the base procedure.
More Water (MW)	An extra 10 mL of $NaOH_{(aq)}$ was added.
High Concentration (HC)	$NaOH_{(aq)}$ molarity was increased from 0.5 mol/L to 2.0 mol/L.
Larger Particles (LP)	Particles were not ground to less than 2.0 mm before put into the mold.
Smaller Particles (SP1)	Particles were ground to less than 0.5 mm in diameter.
Ammonium Carbonate ($NH_4CO_{3(s)}$)	A 1:10 $NH_4CO_{3(s)}$ to meteorite ratio was used for this sample.

Results

The average density for the control samples was calculated to be 1.97 g/cm^3 with a standard deviation of 0.10 g/cm^3 (Table 2). Only two of the experiments had any noticeable change (less than 1 standard deviation) from the average: the SP1 sample and the LP sample. The SP1 sample was the only experiment to have a very significant drop in density.

Figure 2: The sample on the left contains only particles > 0.5 mm in diameter. The sample on the right contains an average distribution of particles [5] used in the control samples.

A follow-up experiment was run to validate the results. A third control sample (calculated into the control average) was made along with four more small-particle samples. Each new sample followed the same recipe outlined in Table 1 and Methodology. The results (Table 2) followed the trend of a significant density drop between the small particle samples and the controls.

Table 2: Adjustments to the density of each sample, and a comparison to the control average.

Sample	Density (g/cm^3)	St. Dev. (g/cm^3)	% Drop
Control Average	1.97	0.00	0.00%
MW	1.89	0.79	4.21%
HC	1.89	0.79	4.21%
LP	1.79	1.78	9.28%
SP1	1.42	5.45	28.03%
$NH_4CO_{3(s)}$	1.96	0.01	0.66%
Smaller Particles			
SP2	1.55	4.16	21.44%
SP3	1.61	3.56	18.40%
SP4	1.42	5.45	28.03%
SP5	1.38	5.84	30.06%

A one sample t-test was run for significance of the small particle data. The p-value was found to be 0.0004, implying extreme statistical significance of the data.

Figure 3: A sample after the 6 week drying period. The individual particles are locked together in a matrix formed by the evaporated $NaOH_{(aq)}$.

Conclusion

The change in particle sizes has a noticeable affect on the density of the sample. Using smaller particles has a much more significant impact on the change in density than using larger particles. Further experiments will be done to explore the characteristics of this trend and to further validate these results.

References: [1] Smith C. et al. (2009) Meteorites¸ Natural History Museum. [2] Strait M. M. et al. (2012) Met Soc LXXV, Abstract #5363. [3] Molesky M. J. et al. (2015) Met Soc LXXVIII, Abstract #5300. [4] Macke R. J. et al. (2011) Meteoritics and Planet. Sci., 46, 1842-1862. [5] May B. A. et al. (2017) *LPSC XLVIII*, Abstract #2529.