

INVESTIGATING AMINO ACID HETEROGENEITY IN MILLIGRAM-SCALE SAMPLES OF THE MURCHISON CM2 CARBONACEOUS CHONDRITE. A. S. Burton¹ and E. L. Berger¹, ¹NASA Johnson Space Center, Houston, TX 77058; aaron.burton@nasa.gov.

Introduction: Analyses of different aliquots of the Tagish Lake meteorite have resulted in amino acid abundance variations of an order of magnitude or more, even when performed using the same techniques, by the same personnel, in the same laboratories (e.g., [1] Simkus et al. 2019). Up to ~five-fold variations have been observed for specific amino acids in different samples of the same meteorite, such as α -aminoisobutyric acid (AIB) in Murchison [2, 3]. These variations are often attributed differing sample composition or differing alteration history, neither of which is mutually exclusive. Distinguishing between these two explanations is challenging and time-consuming, requiring detailed mineralogical analyses to be performed in conjunction with high precision organics analysis. The potential for innate sample-level heterogeneity presents a significant complication when parsing the effects of different processes or conditions during preparation of meteorite samples for analysis, as differences in organic yields or abundances could be due to differences in laboratory processing or differences among the samples themselves. In this work, we investigated the degree of innate organic heterogeneity present in a single ~250 mg chip of divided into 21 samples.

Materials and Methods: A 247.1 mg chip of the Murchison meteorite was gently disaggregated and partially powdered with a porcelain mortar and pestle. Sub-samples of powders were transferred to a glass slide and characterized using a petrographic microscope. Samples were collected as one of three classes of material: 1) matrix samples, which consisted primarily of matrix material, with minor attached phases included; 2) non-matrix samples, which were collected as either single grains or as multiple grains that appeared visually similar (i.e., olivine or pyroxene crystals, chondrules, etc.) or 3; “mixed samples”, comprised of individual grains or phases with significant amounts of matrix adhering to them (Table 1). Samples were transferred to individual 2mL glass ampoules.

Glassware (e.g., ampoules), foil, and the porcelain mortar and pestle were pyrolyzed in air at 500 °C for at least 18 hours. Sample handling tools (e.g., tweezers) were sonicated for 30 minutes in water (Millipore Milli-Q IQ 7005 water purification system, 18.2 M Ω ·cm resistivity, <3 ppb total organic carbon) followed by a 30 minute sonication in methanol (Fisher Optima LC/MS grade), before being stored in foil. A volume of 1 mL of ultrapure water (Fisher Optima LC/MS grade)

was added to each ampoule, which was then flame sealed. Samples were hot water extracted for 24 h at 100 °C. For all samples with masses <10 mg, the supernatant was collected, the ampoule rinsed twice with 500 μ L water, and the sample was then dried down for concentration and rehydrated for analysis. For the three samples >10 mg in mass, the supernatant was collected, and the powdered residue rinsed twice with 500 μ L water. 50% of the extract was subjected to acid vapor hydrolysis with 1 mL of 6M double distilled HCl. Both the hydrolyzed and non-hydrolyzed fractions were purified by cation exchange chromatography (BioRad PolyPrep Columns, AG-50W-X8 resin, 100 – 200 mesh) and eluted with 2M ammonium hydroxide. Immediately prior to analysis, samples were derivatized with *o*-phthalaldehyde / *N*-acetyl-L-cysteine and analyzed by liquid chromatography quadrupole time of flight mass spectrometry as described elsewhere [4]. After initial sample injection, samples were stored at -80 °C to permit multiple injections from the same sample.

Table 1: The samples of each type that were analyzed in this study, in order of increasing mass.

Matrix:		Non-Matrix:		Mixed:	
#17	<10 μ g	#1	<10 μ g	#8	930 μ g
#18	70 μ g	#2	<10 μ g	#10	3.880 mg
#6	150 μ g	#4	<10 μ g		
#3	340 μ g	#5	<10 μ g		
#13	340 μ g	#11	<10 μ g		
#7	1.070 mg	#12	<10 μ g		
#16	3.650 mg	#14	<10 μ g		
#9	4.280 mg	#15	820 μ g		
#19	14.960 mg				
#20	55.600 mg				
#21	135.160 mg				

Results: A total of ~35 different amino acid isomers and enantiomers ranging from two to five carbons were searched for in the sample extracts. Preliminary data from four of the matrix samples (with masses <10 mg; samples 6, 9, 13, and 16) generally revealed similar amino acid distributions, with relative amino acid abundances within a factor of two among the samples (Figure 1; amino acid abbreviations are defined: gly =

glycine; D-ala = D-alanine; L-ala = L-alanine; B-ala = β -alanine; DL-A-ABA = D+L- α -n-butyric acid; AIB = α -aminoisobutyric acid; D-B-ABA = D- β -amino-n-butyric acid; L-B-ABA = L- β -amino-n-butyric acid; B-AIB = β -aminoisobutyric acid; G-ABA = γ -amino-n-butyric acid; D-iva = D-isovaline; L-iva = L-isovaline). In contrast, the chondrule sample that was analyzed contained lower abundances of amino acids in general and had an amino acid distribution profile that noticeably differed from those of the matrix samples. Amino acid analysis of the remaining samples is underway. The post residue sample extracts of the smaller samples were transferred to aluminum mounts for scanning electron microscopy (SEM) analyses on the JEOL 7600F field emission SEM. Figures 2 and 3 are back-scattered electron images of Murchison mineral separates 13 and 15. Energy dispersive x-ray analyses were done to qualitatively identify mineral components. Murchison 15 is a forsterite/enstatite chondrule; fig 2a and 2b show the

exterior and interior, respectively. Murchison 6, 9, 13, and 16 are, by and large, matrix material (phyllosilicates and associated accessory minerals) with minor additional components; e.g., figure 2 shows Murchison 13, which is mainly matrix with one olivine grain, indicated by the arrow.

Acknowledgments: The authors acknowledge funding from NASA's Planetary Science Division Internal Scientist Funding Model as well as through the Goddard Center for Astrobiology.

References: [1] Simkus D. N. et al. (2019) *Meteoritics & Planet. Sci.* 54, 1283–1302. [2] Glavin D. P. et al. (2010) *Meteoritics & Planet. Sci.* 45, 1948–1972. [3] Glavin D. P. et al. (2021) *Meteoritics & Planet. Sci.* 56, 148–173. [4] Aponte J. C. et al. (2021) *Meteoritics & Planet. Sci.* 11, 2422 – 2439.

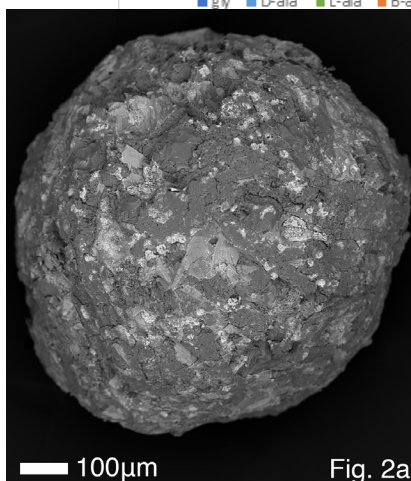
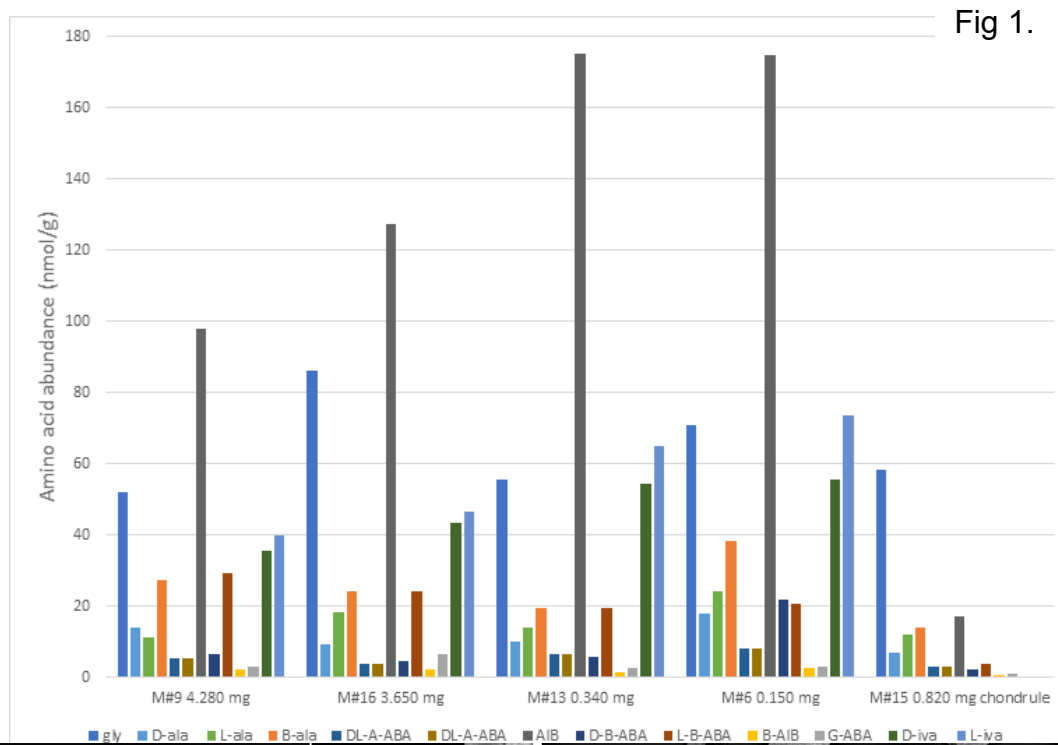


Fig. 2a

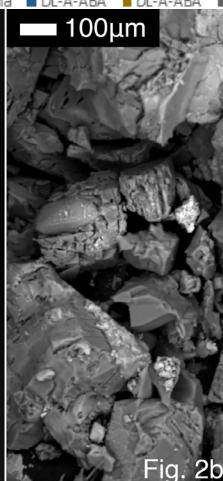


Fig. 2b

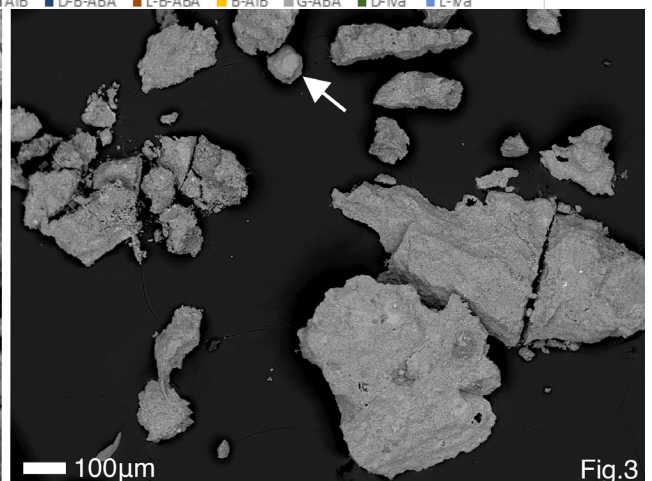


Fig.3