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**PREPARING AND CHARACTERIZING CARBONACEOUS CHONDRITE STANDARDS FOR VERIFICATION OF ESA'S 'PROSPECT' PACKAGE.** James Mortimer<sup>1</sup>, Mahesh Anand<sup>1,2</sup>, Sasha Verchovsky<sup>1</sup>, Simona Nicoara<sup>1</sup>, Richard C. Greenwood<sup>1</sup>, Jenny Gibson<sup>1</sup>, Ian A. Franchi<sup>1</sup>, Farah Ahmed<sup>2</sup>, Stanislav Strekopytov<sup>2</sup>, James Carpenter<sup>3</sup>. <sup>1</sup>School of Physical Sciences, The Open University, Walton Hall, Milton Keynes, Buckinghamshire, United Kingdom, MK7 6AA, UK. (James.Mortimer@open.ac.uk), <sup>2</sup>The Natural History Museum, London SW7 5BD, UK., <sup>3</sup>ESA ESTEC, Keplerlaan 1, 2401 AZ, Noordwijk, The Netherlands.

**Introduction:** This work has been carried out in the context of a planned Russian mission to the lunar surface, near to the south pole (Luna 27/Luna-Resurs Lander), for which the European Space Agency (ESA) are providing a sample acquisition and delivery drill system (ProSEED) and a miniaturized mass spectrometer sample analysis package (ProsPA). Together, this PROSPECT package aims to drill down up to 2 m below the lunar surface, collect samples of icy regolith, and analyze the samples for water and other volatile species abundances and isotopic compositions. This will provide much-needed ground truth measurements to clarify previous orbital observations and measurements of hydrogen and water ice at the lunar surface and particularly in cold regions at the lunar south pole.

Since carbonaceous chondrites (CCs) are thought to be major contributors of volatiles to the Moon [e.g. 1-3], it was decided to use CCs to produce a set of well-defined meteorite standards, using an array of high precision/high sensitivity instruments available within a modern laboratory setting to characterize the H, O, C, N, noble gases, bulk geochemistry, and petrological characteristics of the meteorites, all from the same stones. These standards will then be used to test and refine the ProsPA bench development model (BDM) as it becomes increasingly flight-ready.

**Samples:** CCs are inherently chemically heterogeneous, with coarser-grained objects (chondrules, CAIs, AOA, mineral fragments) enclosed in a finer-grained matrix. Therefore, in order to produce meaningful standards, relatively large amounts of sample were required to provide enough well-homogenized material for multiple analyses. Unfortunately, since a fundamental requirement of the mission requires that the materials should be curated in perpetuity following these measurements, samples could not be acquired on a loan basis from the conventional museum and university curated collections. This prompted a decision to purchase instead large hand specimens of two well-studied CCs from a trusted source, thus ensuring authenticity by comparison of new results with published data. As a result, a 57.54 g stone of Murchison (CM2) and a 692 g stone of Allende (CV3) were acquired in September 2016 (Fig. 1). These sample masses are large enough to provide ample material for standard preparation and characterization, with a large amount

of material left intact for curation and future processing and scientific analysis.



**Figure 1: Stones of Allende (CV3) and Murchison (CM2) as purchased for this work**

**Analytical Techniques:** A wide range of both non-destructive and destructive techniques have been employed to fully characterize these samples. Most of the analyses have been conducted at the Open University (Milton Keynes, UK), with additional work carried out at the Natural History Museum (London, UK). Space constraints in this abstract mean that only some of the collected data are shown here.

*X-Ray CT Scanning (NHM).* This was the first technique used in early October 2016, prior to any processing for other analytical methods. Such scans on these large sample masses allow us to build up a much clearer understanding about the internal structure and distribution of chondrules and CAIs within the meteorites, providing additional context to traditional optical petrography, which is limited to a two-dimensional view of structures and internal relationships. Figure 2 is a scan taken from the middle of the mass of Murchison, and clearly shows how cracks penetrate the sample, as well as the internal distribution of chondrules.

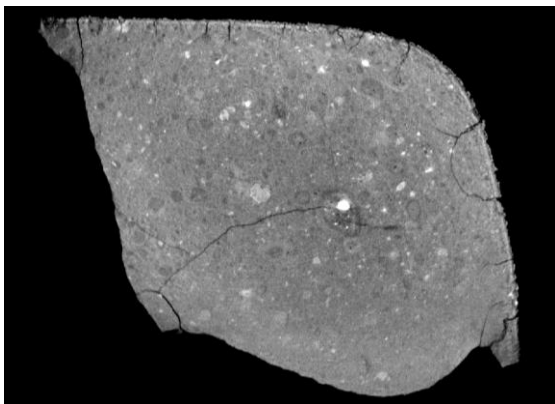


Figure 2: X-Ray CT Scan of Murchison

**Optical Petrography (OU).** When several grams of both samples were cut from the main masses for further processing to form the standards, slices were also taken and made into polished blocks and thin sections for detailed petrographical study.

**Bulk Geochemistry (NHM).** Well-homogenized powders of both samples are being analyzed to provide bulk-rock major- and trace-element data.

**Continuous Heating (OU).** Ongoing work includes ramped pyrolysis of sample material from 200 °C to 1400 °C, with real-time determination of extracted gas species in the range 2-200 AMU at sub-ppm level sensitivities. This will provide important information about the relative abundances of all of the different volatile species released from CCs, not just those for which isotopic data was collected.

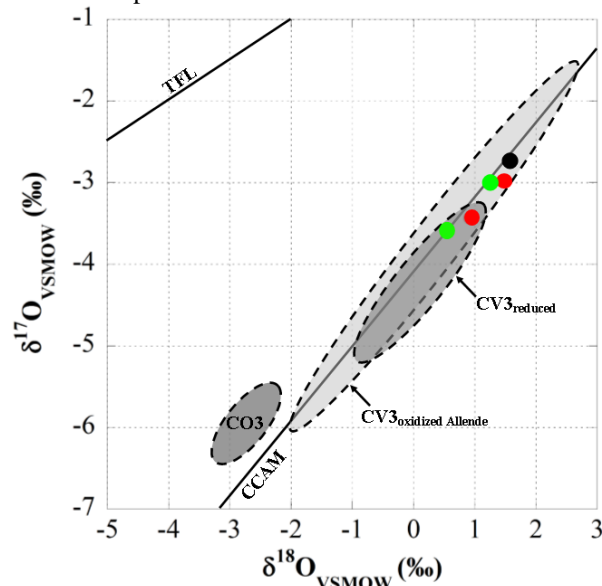


Figure 3: Allende bulk oxygen isotopic data (Red = this study (errors are smaller than symbol sizes); Green = [4]; Black = [5]; Grey fields of data taken from [4] and references therein)

**Laser Fluorination (OU).** Oxygen triple isotopes are being measured by laser fluorination for multiple

aliquots of well-homogenized bulk powders of the two samples. The results for bulk Allende are shown in red on Figure 3, compared to the TFL and CCAM lines and fields of CC data from literature.

**Stepped Combustion (OU).** Both chips and homogenized powders of the samples were analyzed using ‘FINESSE’, a custom-built triple mass spectrometer system to measure C, N, and noble gases in increments of 100 °C from 200-1400 °C.

**Elemental Analyzer-isotope ratio mass spectrometry (EA-irms) (OU).** Homogenized powders of the two meteorites were measured for C and N by flash heating in an EA connected to a Thermo MAT253 mass spectrometer. Further measurements for H and O are also planned using the same technique.

	C (wt.%)	$\delta^{13}\text{C}$ (‰)	N (wt.%)	$\delta^{15}\text{N}$ (‰)
<b>Stepped Combustion</b>	1.95 ± 0.02	-4.3 ± 0.5	0.08 ± 0.01	43.4 ± 1
<b>EA-irms</b>	1.73 ± 0.09	-4.59 ± 0.39	0.08 ± 0.007	42.14 ± 1.10
Literature Average	1.93 ± 0.38	-5.46 ± 3.74	0.07 ± 0.019	41 ± 2.35

Table 1: Bulk C and N results for Murchison.

(Literature average values were calculated from [6-10])

**Summary:** Results from these new CC standards are both self-consistent between different techniques, and in excellent agreement with previous literature data (Table 1). Having an integrated approach, where multiple isotope systems are measured within the same individual stones means that the results are directly comparable to each other and can be considered together. The large sample masses purchased for these standards means that material can be curated for future use, either as standards for other instrument verification studies, or in their own right as scientific samples.

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