Preparing and Characterizing Carbonaceous Chondrite Standards for Verification of ESA's 'PROSPECT' Package

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#2113

1: Introduction:

This work was carried out in the context of the planned Russian Luna-27 mission to the lunar surface, for which the European Space Agency (ESA) are providing the 'PROSPECT' package which will drill, collect, and analyse samples of icy regolith for water and other volatile species abundances and isotopic compositions. Since carbonaceous chondrites (CCs) are thought to be major contributors of volatiles to the Moon, CCs have been used to produce a set of well-defined meteorite standards, using an array of high precision/high sensitivity instruments available within a modern laboratory setting. These standards will be used to test and refine the ProSPA bench development model (BDM) as it becomes increasingly flight-ready.

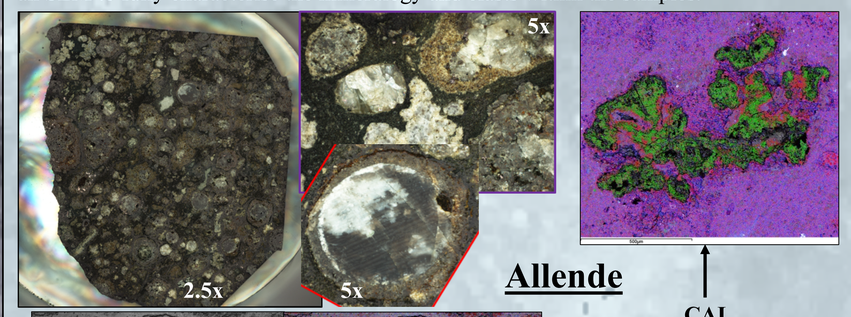
2: Sample Acquisition:

Large hand specimens of Murchison (CM2) and Allende (CV3) were purchased from a well-known and trusted source in September 2016.

Murchison	Allende
CM2	CV3
Fall (Sept. 28th 1969, Australia)	Fall (Feb. 8th 1969, Mexico)
Original Collected Mass: > 100 kg	Original Collected Mass: 2-3 tonnes
Acquired Mass: 57.54 g	Acquired Mass: 692 g

3: Optical Petrography:

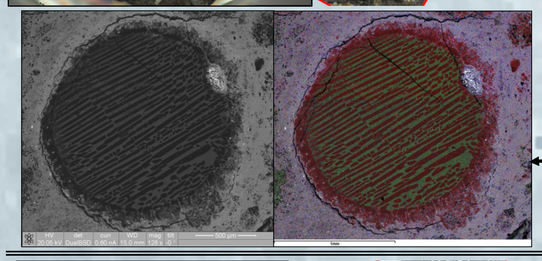
polished mounts of both meteorites were prepared as 1 inch diameter blocks and photographed up to 20x magnification and then mapped using an SEM to fully characterise the mineralogy and clasts within the samples.



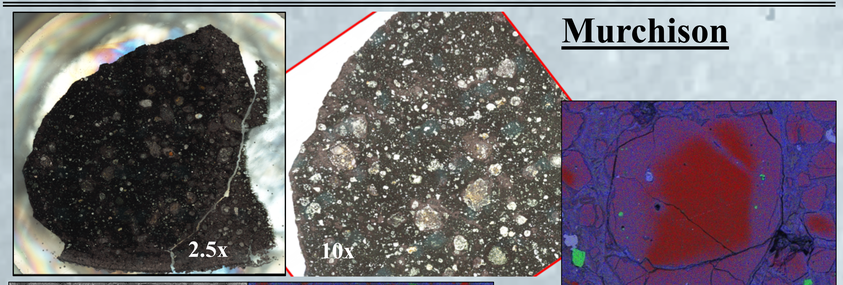
Allende

CAI

(Mg = Red; Al = Green; Fe = Blue)

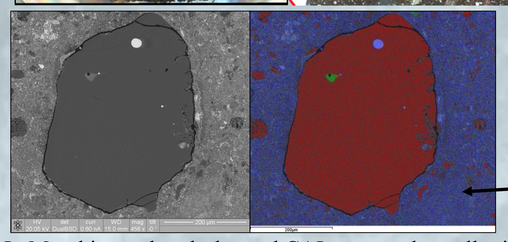


Barred Olivine Chondrule



Murchison

(Mg = Red; Cr = Green; Fe = Blue)



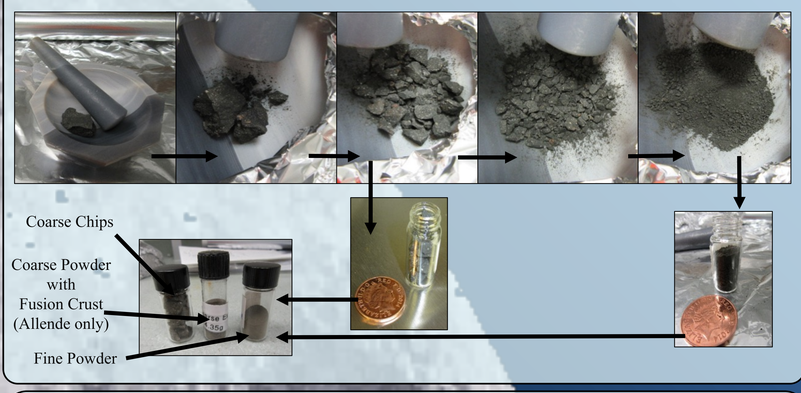
Chondrules

(Mg = Red; Al = Green; Fe = Blue)

In Murchison, chondrules and CAIs are much smaller in size than in Allende, and CAIs are less abundant. Therefore, although both are inherently heterogeneous meteorites, the scale of this heterogeneity differs between them. This impacts both the amount of material required, and also the amount of powdering needed, to ensure thorough homogenisation.

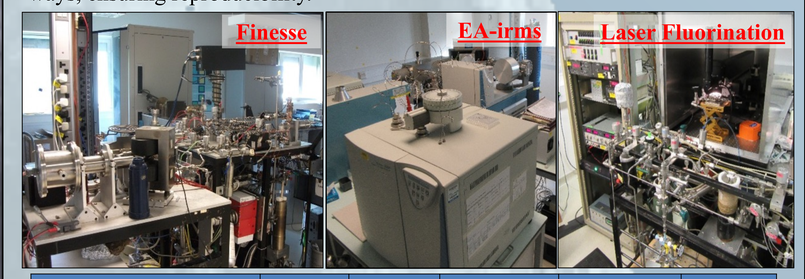
4: Sample Homogenisation:

several grams powdered using agate mortars and pestles (+ several grams as chips for additional analyses to check powdering process did not introduce terrestrial contaminants).



5: Analytical Techniques:

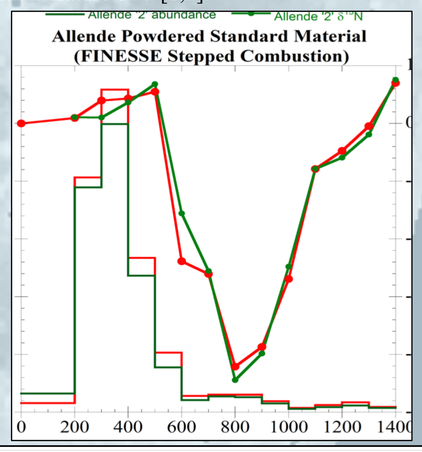
A range of custom-built and commercial laboratory instruments were used to measure multiple isotope systems in different ways, ensuring reproducibility.

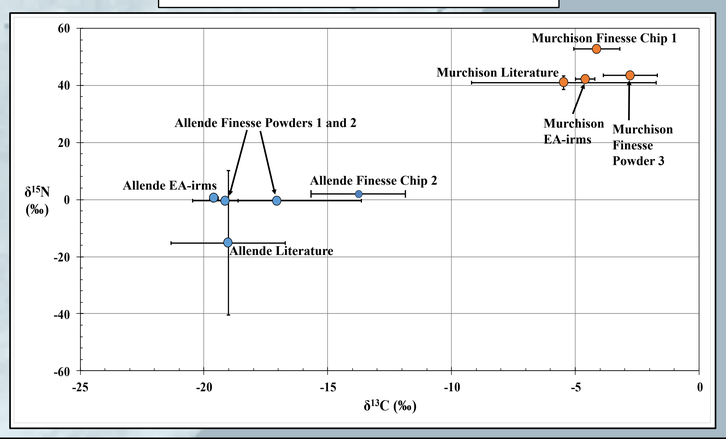


	EA-irms	Stepped Heating (Finesse)	Continuous Heating (Finesse)	Laser Fluorination	ICP-AES
Carbon	■	■	■		
Nitrogen	■	■	■		
Hydrogen	■		(as water)		
Oxygen	■			■	
Noble Gases (He, Ne, Ar, Xe)		■	■		
Major and Trace Elements (eg. Si, Mg, Na etc)					■

6: Carbon and Nitrogen:

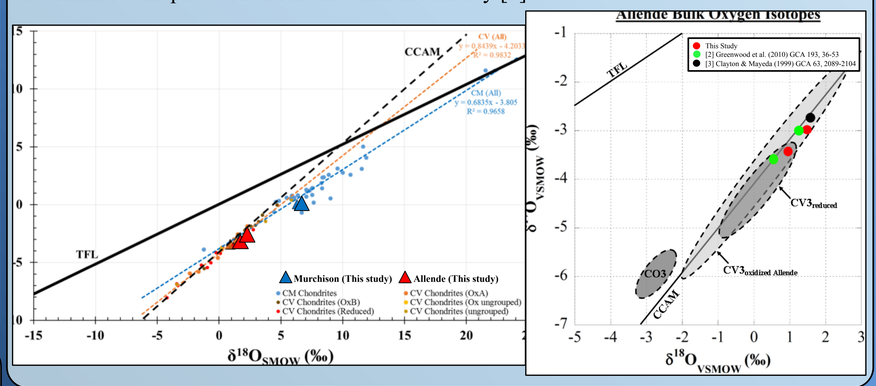
Repeat analyses of aliquots of the same powdered standard materials are both highly reproducible (internally, using the same technique) and also give identical results (within error) between different techniques (e.g. EA-irms and Finesse results are comparable to each other). Further, there is good agreement with literature data [1,2].





8: Oxygen:

2 mg aliquots of the powdered meteorites were analysed for oxygen triple isotopes. Both Murchison and Allende are in agreement with previous literature data for these samples [4], and although there is a small difference between repeat analyses of the Allende powder, both sets of isotopic values are in agreement with previous repeat analyses of Allende bulk powders run in the same laboratory [3].



9: Bulk Geochemistry:

carried out at the Natural History Museum (London, UK) on approximately 150 mg of both powdered meteorite standard materials. Samples were run in triplicate for major oxides and trace elements. Although the totals for major element oxides are very low, they can be explained by the volatile-rich nature of these meteorites, containing significant abundances of water, carbon, nitrogen etc. These volatiles are not included in such a geochemical analysis, hence the low totals for the major elements that were measured. Bulk geochemical results are also in agreement with published literature data for the same samples [5].

			ALLENDE			MURCHISON		
			n = 3		Literature	n = 3		Literature
			This Study		(Jarosewich 1990)	This Study		(Jarosewich 1990)
Method			(Average)	sd		(Average)	sd	
ICP/Li	Al_2O_3	wt%	2.99	0.083	3.27	2.19	0.011	2.15
ICP/Li	CaO	wt%	2.38	0.062	2.61	1.82	0.010	1.89
ICP/Li	Fe_2O_3	wt%	31.60	0.797	27.15	28.70	0.079	22.39
ICP/Li	K_2O	wt%	<	<	0.03	<	<	0.04
ICP/Li	MgO	wt%	23.27	0.416	24.62	19.45	0.064	19.94
ICP/Li	MnO	wt%	0.18	0.005	0.18	0.22	0.001	0.20
ICP/Li	Na_2O	wt%	0.12	0.003	0.45	0.64	0.001	0.24
ICP/Li	P_2O_5	wt%	0.27	0.004	0.23	0.25	0.002	0.23
ICP/Li	SiO_2	wt%	33.50	0.288	34.23	29.00	0.182	29.07
ICP/Li	TiO_2	wt%	0.13	0.004	0.15	0.01	0.001	0.13
ICP/Li	NiO	wt%	0.88	0.006	0.85	1.86	0.018	-
	Total	wt%	95.27		93.77	84.21		76.28
ICP/Li	Ba	ppm	16.10	0.284		5.91	0.038	
ICP/Li	Co	ppm	255	1.356	100	539	3.278	
ICP/Li	Cr	ppm	3425	18.964	5200	3058	25.734	4800
ICP/Li	Ni	ppm						
ICP/Li	Sr	ppm	12.10	0.371		10.60	0.285	
ICP/Li	Zr	ppm	<	<		<	<	

10: Conclusions:

- Results from these new carbonaceous chondrite standards are both self-consistent between different techniques and reproducible after multiple analyses on the same instrument, and in agreement with previous literature data.
- The 'internal' reproducibility of these standard powders is of greater importance than their agreement with previous literature data from the perspective of their primary intended use as standards with which to test the performance of the ESA 'ProSPA' miniaturised chemical laboratory development models.
- However, 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, within a scientific context in addition to their primary intended use.
- This scientific importance is enhanced by the contextual information gained through techniques like X-ray CT scanning, especially considering the relatively rare large sizes of these samples.
- 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. Therefore, the data and sample processing records and media derived from this characterisation study form the basis of what is anticipated to be a useful resource for the wider community long into the future.

11: Acknowledgements:

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References

[1] Kerridge, J. F. (1985) *GCA 49*, 1707-1714. [2] Grady, M. M. et al. (2002) *MaPS 37*, 713-735. [3] Greenwood, R. C. (2010) *GCA 74 (5),* 1684-1705. [4] Clayton, R. N. and Mayeda, T. K. (1999) *GCA 63 (13/14)*, 2089-2104. [5] Jarosewich, E. (1990) *Meteoritics 25*, 323-337.