

LIGHT ELEMENT GEOCHEMISTRY AND SPECTROSCOPY OF THE SUTTER'S MILL CARBONACEOUS CHONDRITE. Monica M. Grady^{1,2}, C. D. Fernandes³, I. Gilmour¹, A. Harker⁴, L. Preston¹ and A. B. Verchovsky¹, ¹Dept. Physical Sciences, The Open University, Walton Hall, Milton Keynes MK7 6AA, UK (monica.grady@open.ac.uk), ²Dept Earth Sciences, the Natural History Museum, Cromwell Road, London SW7 5BD, UK; ³University of Leicester; ⁴University of Bristol

Introduction: The Sutter's Mill carbonaceous chondrite fell in California in April 2012, and material was collected and curated very quickly after its fall [1]. Because of its fresh state, we are interested in the light element geochemistry of this meteorite, for comparison with other carbonaceous chondrites, particularly CM chondrites and the unusual Tagish Lake. The abundance and isotopic composition of carbon, nitrogen, argon and xenon was determined by stepped combustion-mass spectrometry on the Finesse instrument at the OU on a 6.34 mg chip of whole-rock meteorite from specimen SM43. A second chip from SM43 has been prepared for determination of the hydrogen content and isotopic composition.

Although the light element geochemistry of a meteorite is a good indicator of how an individual sample might relate to other specimens in a group, and is a valuable determinant of the processes that an asteroidal parent may have experienced, it does not, of itself, link a meteorite to a specific parent object (or class of parent objects). Failing direct return of material, the most successful technique to connect meteorites to potential parent objects is by reflectance spectroscopy. As part of a continuing investigation into the spectroscopy of meteorites, we have determined the UV-Vis (250 – 800 nm) and mid-infra-red (4 – 15 μm) spectra of Sutter's Mill, for comparison with CI and CM chondrites.

Carbon and nitrogen isotopic composition: The chip was wrapped in platinum foil, then heated under excess oxygen in increments from room temperature to 1400 °C. Data were corrected for system blank.

Carbon. The sample contained 2.20 wt. % carbon (total $\delta^{13}\text{C} \sim +6.4$ ‰), distributed between several components. Almost 95 % of the carbon combusted below 650 °C (Figure 1a). The isotopic composition of the material increases almost monotonically with temperature, from -20 ‰ to +60 ‰. Three discrete carbon-bearing components are represented in this temperature increment: two separate organic components, with the lower temperature (more volatile) component being isotopically lighter ($\delta^{13}\text{C} \sim -20$ ‰) than the more cross-linked, less volatile material ($\delta^{13}\text{C} \sim -6$ ‰). Added to these components is CO_2 from the decomposition of carbonates. By analogy with results from other carbonaceous chondrites, the maximum in $\delta^{13}\text{C}$ of +60 ‰ is likely to be from decomposition of calcite, rather than

dolomite, breunnerite or ankerite. Because the release overlaps with combustion of an isotopically-lighter organic component, the actual isotopic composition of the carbonate is probably even more enriched in ^{13}C . Above 1000 °C, ~ 2 % of the total carbon combusts, reaching a $\delta^{13}\text{C}$ of +100 ‰. This is a well-known feature of carbonaceous chondrites, and is from combustion of ^{13}C -enriched presolar silicon carbide grains.

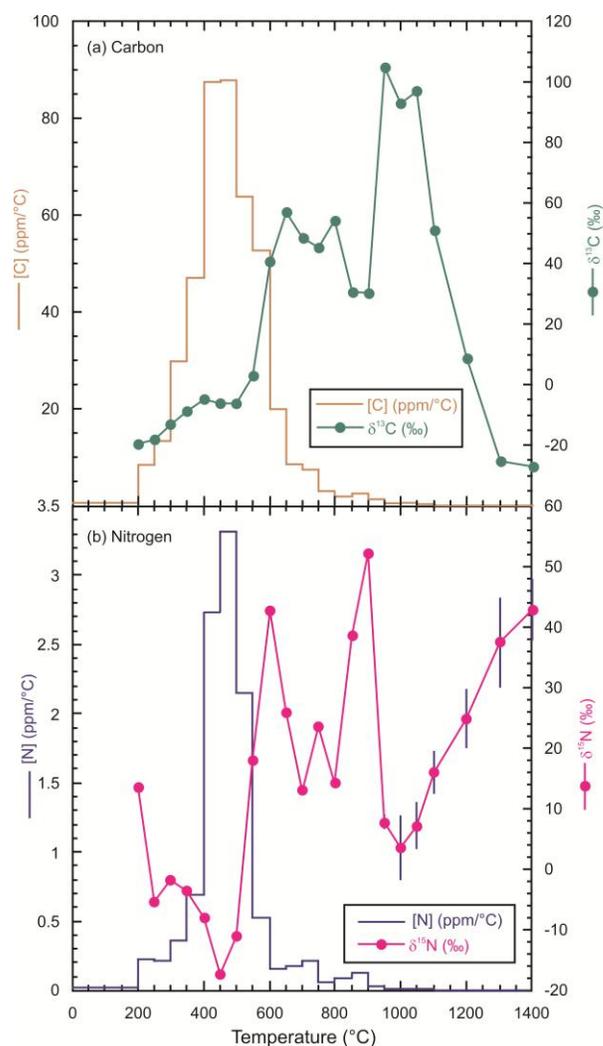


Figure 1: Profiles of (a) carbon and (b) nitrogen from stepped combustion of a single 6.34 mg chip of Sutter's Mill. Errors on isotopic composition are less than the size of the symbol unless shown otherwise.

Nitrogen. The sample contained 559 ppm nitrogen (total $\delta^{15}\text{N} \sim -0.6$ ‰), again distributed between sever-

al components. A similar proportion of nitrogen as carbon combusted below 650 °C (Figure 1b). The isotopic composition of the material drops from $\delta^{15}\text{N} \sim +13.5\text{‰}$ to -17‰ , again interpreted as a from two organic components of different relative volatility. We are not yet certain of the identification of the nitrogen-bearing components that combust above 650 °C. The drop in $\delta^{15}\text{N}$ to almost 0 ‰ at 1000 °C is characteristic of presolar silicon carbide. Overall, the carbon and nitrogen data are fairly typical of CM chondrites.

Reflectance spectroscopy: We used an optical microspectrophotometer system supplied by Craic Technologies (San Dimas, Ca). The system is based on a Leica DMR microscope, with the regular objective lenses removed and fitted with Cassegrain reflecting mirrors. The viewing geometry is such that light enters and leaves the system normal to the sample. The light source is a 75W xenon lamp. The square aperture through which light was focussed was $10 \times 10 \mu\text{m}$. The system allows non-destructive measurement of spectra across the UV-visible range in both transmittance and reflectance of samples presented as powders, single grains or polished mounts. Measurements were made over the range 250 to 800 nm at a spectral resolution of 2 nm. Prior to every period of data collection, the system was calibrated using NIST white Halon standard. We report relative reflectance data, rather than absolute reflectance, with spectra normalized to 1 at 550 nm to allow intercomparison between spectra. A chip of Sutter's Mill was placed on a quartz glass slide, and orientated until a relatively flat surface could be seen in the microscope; it was assumed that at the scale of $10 \times 10 \mu\text{m}$, this was sufficiently flat to allow adequate spectra to be acquired. Twenty spectra were taken at several different locations across the chip. Shown in Figure two are the average of 60 spectra acquired from three separate locations. Also shown in the figure are spectra acquired from powdered (grain size $\sim 50 \mu\text{m}$) samples of Murchison and Cold Bokkeveld.

At wavelengths above $\sim 420 \text{ nm}$, all three spectra are very similar, becoming bluer (reflectance decreases as wavelength increases), reaching a minimum at around 620 nm. Above this, the spectra all become redder (reflectance increases with wavelength). Below 420 nm, Sutter's Mill exhibits a slightly different behavior from Murchison and Cold Bokkeveld. It is brighter (as shown in the normalized spectrum, and also apparent in the absolute spectrum, where it has a reflectance of almost 50% at 300 nm) than the other two chondrites, possibly because there clearly were grains of oxides and sulphides in the chip analysed.

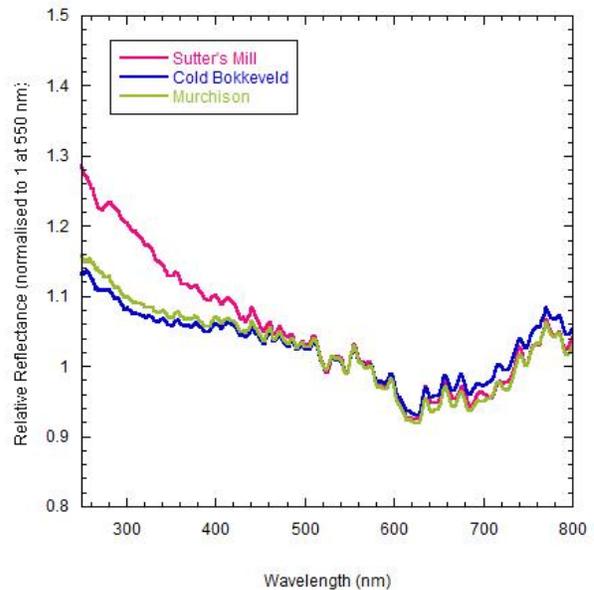


Figure 2: UV-Vis reflectance spectroscopy of Sutter's Mill, compared with that of Murchison and Cold Bokkeveld. Spectra are normalized to 1 at 550 nm.

The pronounced dip in Sutter's Mill spectrum at 260 nm is most likely to be an absorption band from Fe^{2+} and/or Fe^{3+} in octahedral co-ordination in magnetite [2], which is relatively common in Sutter's Mill [1]. Once we have acquired equivalent spectra of the meteorites in the MIR, we will be more confident in assigning features to the UV-Vis spectra.

References: [1] Jenniskens P. et al. (2012). *Science* 338, 1583-1587; [2] Cloutis E. et al. (2008). *Icarus* 197, 321-347.

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