

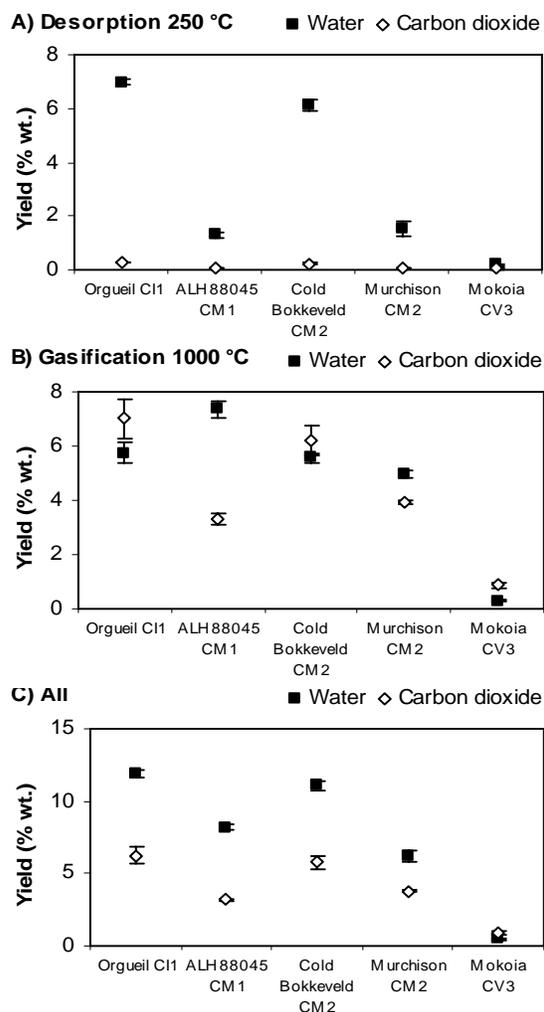
**VOLATILE YIELDS UPON PYROLYSIS OF CARBONACEOUS CHONDRITES AS DETERMINED BY QUANTITATIVE PYROLYSIS-FOURIER TRANSFORM INFRARED SPECTROSCOPY.** R. W. Court<sup>1</sup> and M. A. Sephton<sup>1</sup>, <sup>1</sup>Impacts and Astromaterials Research Centre, Department of Earth Science and Engineering, Imperial College London (r.court@imperial.ac.uk).

**Introduction:** The delivery of extraterrestrial material to a planet is an energetic event, with small fragments subjected to rapid deceleration and heating in the atmosphere, causing thermal ablation and pyrolysis of the organic and mineral components contained within [1], with the potential to alter atmospheric and hydrospheric chemistry. Here, we have used the recently developed technique of quantitative pyrolysis-Fourier-transform infrared spectroscopy (FTIR) [2,3] to investigate and quantify the volatile products of the pyrolysis of five carbonaceous chondrites. Two-step analyses reveal the total yields of volatiles, while stepped pyrolysis at 100 °C intervals allows inferences to be drawn regarding the sources of the volatiles. The results allow the estimation of the contribution of pyrolysed extraterrestrial dust to the atmosphere of Earth.

**Experimental:** Powdered samples of the carbonaceous chondrites Orgueil (CI1), ALH 88045 (CM1), Murchison (CM2), Cold Bokkeveld (CM2) and Mokoia (CV3) were subjected to two-step analysis, with desorption at 250 °C followed by gasification at 1000 °C, using a CDS Analytical Pyroprobe 2500 in a helium atmosphere within a CDS Analytical Brill Cell™, held at 250 °C to prevent condensation of volatiles. Infrared spectra of the products of desorption and gasification were accumulated using a Thermo-Nicolet 5700 FTIR spectrometer and a liquid nitrogen-cooled mercury cadmium telluride (MCT-A) detector. Subsequently, further samples of each meteorite were subjected to multistep pyrolysis, with pyrolysis performed at 100 °C intervals from 300 °C to 1000 °C, with the Cell being purged with helium after accumulation of spectra at each temperature step. Calibration curves were created by the thermal decomposition of known masses of sodium hydrogencarbonate under the same conditions as used for the analysis of the meteorite samples. Carbon dioxide and water were quantified using the areas of the prominent absorption bands at 669 and 3853 cm<sup>-1</sup>, respectively.

**Two-step analysis:** Figure 1 displays the means and standard deviations of the water and carbon dioxide yields (% wt.) of three samples of each meteorite, following desorption at 250 °C and gasification at 1000 °C, and the total yield. The yield of water during the desorption step at 250 °C is substantially greater than the yield of carbon dioxide. However, the production of water and carbon dioxide during the 1000 °C gasification step is more similar to each other. It is

unclear whether the water produced during the 250 °C desorption step represents the release of an indigenous component or the release of greater amounts of atmospheric water adsorbed to the more porous, more aqueously altered Orgueil and Cold Bokkeveld chondrites. The much greater yield of water, relative to carbon dioxide, resembles atmospheric abundances; however, the increased yield of water from the more aqueously altered CI and CM samples suggests an indigenous component.



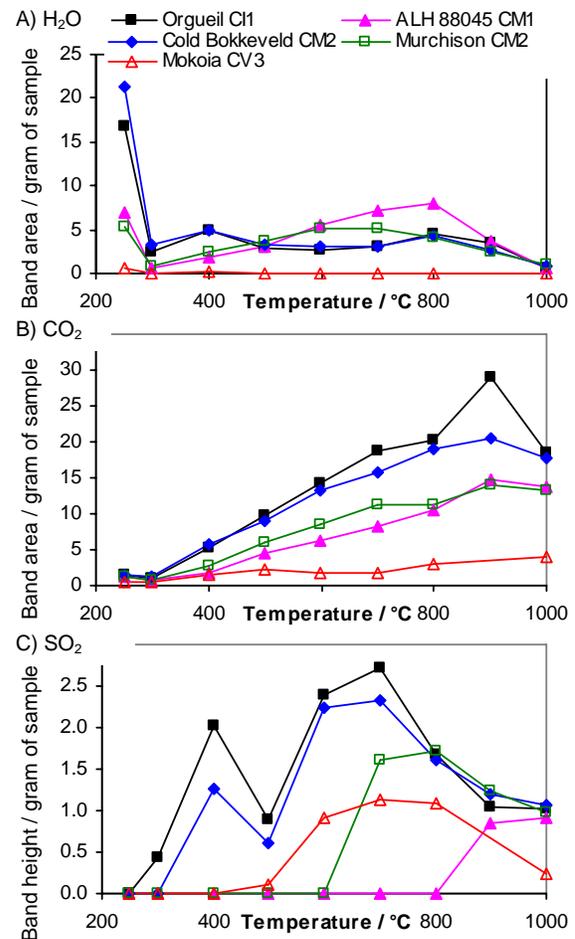
**Figure 1.** Means and standard deviations of three analyses of the yields (% wt.) of water and carbon dioxide produced upon desorption (A) and gasification (B) of the five carbonaceous chondrites, summed to produce a total yield (C).

Overall, there is a general increase in the yields of water and carbon dioxide with increasing degree of aqueous alteration, as denoted by decreasing petrographic type, reflecting the generally increased abundance of organic matter and mineral phases such as clays and carbonates in more aqueously altered chondrites. The CM1 chondrite, ALH 88045, does not fit into this general trend, with total yields of water and carbon dioxide that better resemble those of the CM2 chondrite, Murchison. This is interpreted in terms of the depletion of gas-prone phases during its long lifetime on the Antarctic ice [4].

The long-term delivery rate of dust since ~3 Ga is estimated to be around  $30,000 \pm 20,000$  tonnes  $\text{yr}^{-1}$  [5]. If it is assumed that 4% of a 30,000-tonne mass flux has the composition of carbonaceous chondrite [6], that Murchison is representative of carbonaceous chondrites in general and that all such dust is subjected to heating and ablation in the atmosphere, then the long-term contribution to the volatile budget of the Earth from the pyrolysis and decomposition of organic matter and hydrated minerals during energetic impacts, including the material produced by the desorption step at 250 °C, can be calculated as around 75 tonnes  $\text{yr}^{-1}$  of water and 45 tonnes  $\text{yr}^{-1}$  of carbon dioxide.

**Multistep analysis:** Figure 2 displays the yields of water, carbon dioxide and sulphur dioxide, corrected to the mass of each sample, produced during stepped pyrolysis. Significant quantities of water were evolved at the initial 250 °C temperature step, with the more aqueously altered chondrites such as Orgueil and Cold Bokkeveld again releasing more water than the other samples. Bimodal release of water, at 400 °C and 800 °C, is apparent from Orgueil and Cold Bokkeveld. This is attributed to the decomposition of organic matter and the dehydration of hydrated mineral phases such as clays, respectively. ALH 88045 and Murchison produce rather less water at the 400 °C step. The thermally processed CV3 Mokoia produced very little water. Carbon dioxide yields from all samples show a tendency to increase with increasing temperature from 300 °C, interpreted as the merged contributions of organic species such as carboxyl groups at lower temperatures, and the decomposition of phases such as carbonates at higher temperatures. Sulphur dioxide yields show a strong bimodal distribution in the cases of Orgueil and Cold Bokkeveld, with the peak at 400 °C matching that observed for their release of water, interpreted as the decomposition of sulphur-bearing organic phases and sulphates. The higher-temperature release of sulphur dioxide occurs around 700 °C and likely reflects the production of sulphur dioxide from sulphides and elemental sulphur. Overall, the lowest volatile yields come from the thermally metamor-

phosed Mokoia Chondrite (CV3), while the greatest yields come from the two most aqueously altered samples, Orgueil and Cold Bokkeveld. Murchison has sustained rather less aqueous alteration than its CM2 counterpart, Cold Bokkeveld [7,8]; this is reflected by the volatile yields. Quantitative pyrolysis-FTIR appears to be a valuable technique for understanding actual and potential volatile contents of meteorites and their contribution to planetary atmospheres.



**Figure 2. Yields of volatiles, corrected to the mass of sample present, produced upon stepped pyrolysis of the five carbonaceous chondrites**

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