MINERAL FINGERPRINTS OF THE POST-HYDRATION HEATING OF CM CARBONACEOUS CHONDRITES: IMPLICATIONS FOR UNDERSTANDING RYUGU AND BENNU.

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Introduction: Recent results from Hayabusa2 and OSIRIS-Rex have shown that the surfaces of Ryugu and Bennu are spectroscopically analogous to carbonaceous chondrites that have undergone both aqueous alteration and heating [1,2]. In preparation for studying the returned samples it is therefore very important to understand the processes and products of heating of carbonaceous chondrites - either by characterising meteorites that have been naturally (i.e., pre-terrestrially) heated [e.g., 3] or by simulating heating in the laboratory [e.g., 4]. Here we have taken the latter approach because it enables pre- and post-heating samples to be compared so that the thermal evolution of various constituents can be tracked. We are especially interested in the behaviour of carbon-containing phases, namely organic matter and carbonates.

Meteorites and methods: We used the CM carbonaceous chondrite Allan Hills (ALH) 83100. It has been highly aqueously altered (classified as CM2.1 [5]) yet has escaped natural post-hydration heating [6]. Chips and powders were heated to 400 °C and 800 °C in a tube furnace under vacuum for 24 hours. The powder and chip both lost 9% of their original mass in the 400 °C experiment whereas heating to 800 °C resulted in mass losses of 18.4% and 19.0 % from the powder and chip, respectively. Polished thin sections were made from the unheated and heated chips for SEM work at the University of Glasgow, and the mineralogy of the unheated and heated powders was determined by X-ray diffraction (XRD) at the Natural History Museum.

Results and discussion: Here we focus on changes to the mineralogy of bulk samples, as determined by XRD, and on thermal alteration to carbonate mineral grains, as revealed by SEM. XRD patterns of the unheated sample are consistent with results from previous studies of highly altered CM chondrites [7, 8]. They contain sharp peaks from well ordered Fe-rich serpentines (e.g., cronstedtite) and broad reflections from finer grained, poorly crystalline intergrown Mg-serpentines. Olivine, enstatite, tochilinite, magnetite, calcite and pyrrhotite were also detected (Table 1). Patterns from the 400 °C sample are subtly different. Fe-rich serpentines produce only a single peak rather than the double feature often observed in the highly altered CM chondrites [8]. The Mg-serpentine reflection is smaller but there is no evidence of 'amorphous scattering' that would be consistent with the presence of a highly disordered, dehydrated phyllosilicate. Tochilinite is absent, while pentlandite and oldhamite occur, and the pyrrhotite peak is broader (Table 1). The 800 °C samples yield quite different XRD patterns, with peaks from olivine, enstatite, Fe-sulphides and metal (Table 1). The olivine and Fe-sulphide peaks are more intense and broader than the unheated and 400 °C sample, suggesting that these phases are fine-grained and/or poorly crystalline. There is also no "amorphous scattering", which would be expected from a highly disordered, dehydrated phyllosilicate phase.

Table 1. Modal mineralogy of the ALH 83100 samples determined by XRD (vol. %)

	Phyllosilicate	Olivine	Pyroxene	Magnetite	Fe-sulphide	Carbonate	Metal	Total
Unheated	82.8	5.8	3.3	4.1	2.1	2.0	----	100.1
400 °C	80.3	4.4	3.8	4.9	4.5	2.2	----	100.1
800 °C	----	88.1	4.2	----	7.6	----	0.1	100.0

SEM imaging shows that unheated ALH 83100 contains tens of micrometer size grains of calcite and dolomite. Both minerals appear to be unaltered in the 400 °C sample but are destroyed by 800 °C. In the place of calcite are ~1-3 μm size grains of a material containing S (~19 wt. %), Ca (~24 wt. %) and Fe (~42 wt. %). There is no mineral with this composition, but it is consistent with an intergrowth of oldhamite (CaS) with magnetite (Fe_3O_4). Although further work is needed for a definitive identification, the presence of oldhamite would agree with its occurence in the naturally heated Tagish Lake carbonaceous chondrite [9], and in samples of Murray (CM2) that have been experimentally heated to 800 °C [10].

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