MAKING AN ASTEROID: EFFECTS OF THERMAL METAMORPHISM ON CO3 METEORITES AS DETERMINED BY XRD

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Introduction: Carbonaceous chondrites are amongst the most primitive extra-terrestrial samples available for study. They consist of chondrules and calcium-aluminium-rich inclusions (CAIs) +/- metal set within a matrix of fine-grained (<1 μm) materials and may have an amorphous silicate groundmass [1]. Amorphous silicates could be a product of nebula condensation and processing, or result from later parent body alteration [2], and they are considered important tracers for the formation and early evolution of asteroid parent bodies. Recent studies have examined how the highly reactive amorphous silicates were affected by low temperature (<100°C) aqueous alteration [3]. To investigate the effects of thermal metamorphism we are now systematically characterizing amorphous silicates in the CO chondrites, which span a petrologic range from 3.0 – 3.8. Our aim is to better understand the initial formation conditions of the amorphous silicates, and to quantify how the degree of heating influences their abundance, structure, chemistry and transformation behaviour.

Experimental: We are studying amorphous silicates in CO chondrites (3.0 – 3.8) at the grain scale by collecting element maps of matrix areas in thin sections using an FEI Quanta 650 scanning electron microscope (SEM), and quantifying elemental compositions using an electron microprobe (EPMA). Ultrathin foils will be extracted from the matrix areas and characterized using transmission electron microscopy (TEM) and scanning transmission X-ray microscopy (STXM). Changes at the bulk scale have been determined through modal mineralogy using position-sensitive-detetector X-ray diffraction (PSD-XRD). Copper $K\alpha_1$ radiation is preferentially used in these measurements in order to simultaneously measure the X-ray fluorescence from the sample that is useful to both perform an Fe mass balance and to assess the abundance of Fe-bearing amorphous materials that may be present. Quantitative phase analysis (QPA) is performed by pattern subtraction [4] using the same methodology successfully applied to meteorites [5, 6].

Results and Discussion: Here we focus on initial results from the PSD-XRD analyses. Previous PSD-XRD studies show that the bulk 'crystalline' mineralogy of the CO 3.0 chondrites are dominated by olivine, pyroxene and magnetite, with minor amounts of Fe metal, sulphide and feldspar [7]. In general the olivine is well matched to the diffraction pattern of San Carlos olivine, $(Mg_{0.92}Fe_{0.08})SiO_4$ (Fo92). The CO 3.0 chondrites also contain up to ~40 vol% amorphous Fe-bearing material [7]. This amorphous component is not identifiable directly from the XRD pattern, but it's presence can be confirmed and quantified using QPA. The bulk XRD data for Kainsaz (3.2), Felix (3.3) and Isna (3.8) are similar to the CO 3.0 chondrites although there are clear differences in the modal proportions of the minerals present. Both Kainsaz and Felix show two distinct olivine chemistries, with Kainsaz containing approximately equal proportions of Fo92 and a more Fe-rich olivine (~Fo70). In Felix the Fo92 is only present as a trace phase with the majority of the olivine being ~Fo70, and Isna has a single olivine composition close to ~Fo70. With thermal metamorphism olivine in chondrules, which make up ~50 vol% of CO chondrites [8], becomes increasingly Fe-rich due to exchange with the matrix [9]. Magnetite is far less abundant (possibly 50% less) in Kainsaz and Felix in comparison to CO 3.0 chondrites (up to ~8 vol%, [7]), and Kainsaz contains significantly less than Felix. The proportion of pyroxene is similar in Kainsaz and Felix, although there appears to be significantly more Fe-metal in Kainsaz. The proportion of Fe-metal in Felix is similar to the most metal-rich samples (~1 vol%) reported in [7], however there may be up to four times more in Kainsaz. In contrast there is more troilite and pyrrhotite in Felix. Isna contains similar proportions of troilite, pyrrhotite, magnetite and Fe metal to Kainsaz. We will present full QPA results for CO 3.0 – 3.8 chondrites, and relate these to our on-going grain scale observations of matrix in the same meteorites.

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