EVIDENCE FOR MULTIPLE FLUID PULSES IN THE CM1 CARBONACEOUS CHONDRITE PARENT BODY. P. Lindgren, M. R. Lee and M. Sofe. School of Geographical and Earth Sciences, University of Glasgow, Glasgow G12 8QQ, U.K. email: paula.lindgren@glasgow.ac.uk

Introduction: The CM carbonaceous chondrites have been aqueously altered to various degrees to produce a range of secondary minerals [1,2]. The CM1s are the most heavily aqueously altered, and nearly all their primary anhydrous minerals have been replaced [3]. The mechanisms of aqueous alteration are still debated, but it probably took place mainly in a parent body environment with some preaccretionary alteration in the solar nebula also possible [4,5]. Aqueous processing may not have been a continuous process, but could have occurred in separate pulses. All of the known CM1s are Antarctic finds and have therefore been subjected to terrestrial weathering. This is important because the products of weathering may be difficult to distinguish from the indigenous asteroidal secondary mineralogy [6]. We have studied the two Antarctic CM1s, MET 01070 and SCO 06043, to determine if multiple episodes of fluids can be observed here, and if we can distinguish between pre- and post-terrestrial alteration products.

Methods: One polished thin section each of MET 01070 and SCO 06043 were coated with 10 nm of carbon, prior to backscatter electron (BSE) imaging and qualitative energy dispersive (ED) X-ray point analyses and mapping using a Zeiss Sigma field emission SEM operated at 20 kV. Electron microprobe analyses were acquired using a CAMECA SX 100 EPMA at 15 keV.

Results: MET 01070 has been described by [7,8]. It has a fine-grained phyllosilicate matrix and contains pseudomorphs after chondrules but no preserved primary mafic silicates. Sulphides are abundant and have been quantified to 1.2-3.3 % [12]. The most prominent large scale feature is a 12 mm long lens of sulphides that crosses the whole thin section and is elongate parallel to a weak fabric. The lens sulphides are composed of ~1-10 µm thin films which are finely intergrown with the matrix phyllosilicates (Fig. 1a;b). The sulphide is pentlandite with a composition of ~52 wt% Fe, 17 wt% Ni and 35 wt% S (average of 19 analyses, totals are ~96%) but some intergrowths are more Ni-rich in composition. The sulphide lens separates into two ~100 µm wide branches enclosing a portion of the matrix. The matrix between the branches shows a prominent depletion of Ca-rich carbonates, which is highlighted by the Ca X-ray map (Fig. 1b;c). Carbonates are scattered throughout the matrix outside the lens and occur as ~10-60 µm sized angular-subrounded calcite and dolomite grains. Both monomineralic calcite and dolomite grains, and bimineralic calcite-dolomite grains have been found. Some of the calcite grains are intergrown with sulphide grains with a composition similar to the lens sulphides (Fig. 1d). Many of the carbonate grains have highly irregular margins where in contact with the matrix and are surrounded by gypsum and iron oxide (Fig. 1e;f). Also, some pits in the thin section have similar sizes and shapes to the carbonates and are filled by gypsum and iron oxide. Aggregates of gypsum and iron oxide also occur in fractures cross-cutting the sulphide lens (Fig. 1b).

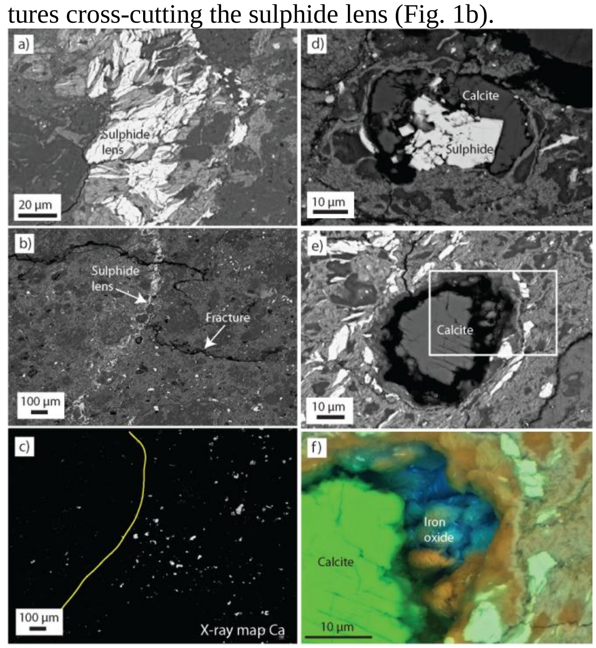

Fig. 1a) SEM-BSE micrograph showing crystal films of sulphide (white) finely intergrown with phyllosilicates (grey) in the sulphide lens. **b)** SEM-BSE micrograph of part of the sulphide lens, cross-cut by a fracture. **c)** ED X-ray map of Ca (corresponding to b) showing the distribution of carbonates in the matrix surrounded by the sulphide lens (left), and outside the lens (right). The location of the sulphide lens is marked with a line. **d)** SEM-BSE micrograph of a euhedral sulphide grain intergrown with calcite. **e)** SEM-BSE micrograph showing a calcite grain with rugged edges. **f)** A false coloured X-ray map of the area inside the white box of e) showing iron oxide around the rugged edge of the calcite grain. All are from MET 01070.

SCO 06043 is also composed of a fine grained matrix mainly containing phyllosilicates and sulphides. This meteorite is highly altered and the chondrules have been completely replaced by phyllosilicates. The chondrule pseudomorphs are flattened and elongated in a common direction to give the sample a fabric. The carbonates are calcite and dolomite, occurring as monomineralic and bimineralic, angular-subrounded

~10-60 µm grains distributed throughout the matrix. In the bimineralic grains, inclusions of dolomite in the calcite indicate that calcite is replacing dolomite (Fig 2a;b). The carbonates have irregular edges, and are sometimes lined with iron oxides. SCO 06043 has several ~10 µm wide and 500 µm long veins of dolomite which have a composition of $Ca_{1.08}Mg_{0.92}(CO_3)_2$ (1 analysis). The dolomite veins are cross-cut by the fusion crust (Fig. 2c;d). The thin section also contains several ~10 µm wide and up to 2 mm long irregular fractures filled with gypsum and iron oxide (Fig. 2e;f).

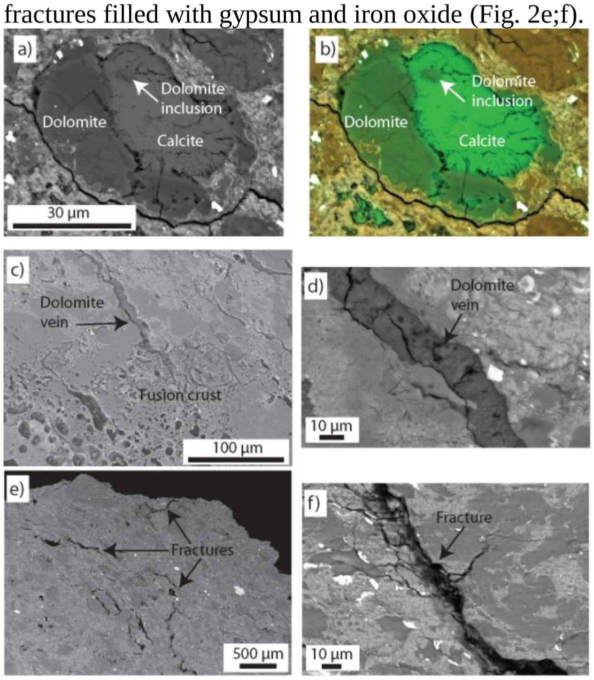

Fig. 2. SEM-BSE micrographs of **a)** bimineralic dolomite-calcite grain. Arrow indicates a dolomite inclusion. **b)** False-coloured X-ray map corresponding to a) **c)** dolomite vein that is cross-cut by the fusion crust, **d)** close-up of dolomite vein, **e)** Irregular fractures filled with gypsum and iron oxide, and **f)** close-up of fracture. All from SCO 06043.

Discussion: The onset of aqueous alteration was within the first 5 Ma of solar system formation, and alteration within parent bodies is believed to have been the outcome of melting of water ice by radiogenic heating [e.g. 9]. However, aqueous processing may not have been a continuous process, and could have occurred in discrete pulses. There is increasing evidence for multiple pulses of fluids on CM parent body(ies); e.g. [10] distinguished two populations of calcite within the same CM2 sample via O isotopes. Here we speculate that impacts on the parent body(ies) could have been another process of melting ice which then triggered the separate fluid pulses. In our samples, evidence for discrete fluid pulses in the CM1 parent body(ies) include the large scale sulphide lens in MET 01070, and the dolomite veins in SCO 06043 that cross-cut the phyllosilicate matrix. Dolomite veins have also been reported from a CM1 by [11]. The pulse of sulphide crystallization in MET 01070 must postdate carbonate crystallization since the carbonate grains inside the sulphide lens are absent owing to dissolution, and the carbonates outside the sulphide lens have been partially replaced by sulphides. The sulphide lens has previously been reported in other thin sections of MET 01070 [7,8], implying that it is a widespread and a quite large scale feature in this sample. In SCO 06043 calcite is replacing dolomite, and the same dedolomitization reaction has been observed in QUE 93005 (CM2) [13]. We suggest that there is a link between this late-stage precipitation of calcite in SCO 06043 and QUE 93005, and the dissolution of calcite in MET 01070. Thus, we speculate that calcite is dissolved in some regions of the parent body(ies) to be redistributed and precipitated in other areas. In both of the CM1s studied the carbonate grains have been partially etched and their rugged edges are sometimes coated by iron oxide and gypsum. This is most likely also a result of carbonate dissolution, but in this case due to terrestrial weathering under oxidizing conditions. Also, terrestrial gypsum and iron oxide occur in fractures in both samples and these two minerals are common signatures of Antarctic weathering [6].

Conclusions: MET 01070 and SCO 06043 (CM1s) show evidence for multiple pulses of fluids within their parent body(ies). This is demonstrated by dissolution and re-precipitation of calcite, the formation of a sulphide lens and dolomite veining. The discrete fluid pulses could have been triggered by the melting of ice via impacts after the parent body had cooled following the decline in radiogenic heating. Both samples also contain a tertiary mineralogy inherited from oxidizing conditions during terrestrial weathering.

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