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A Combined WDS, EDS and Cathodoluminescence Study of Carbonate Grains in Water-Rich Meteorites

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Currently, over 60,000 named meteorites are listed in the Meteoritical Bulletin Database [1] of the Meteoritical Society. Each meteorite provides another piece of the jigsaw puzzle that allows us to build up a picture of our Solar System. Some meteorites were blasted off the surface of Mars, some come from the Moon, but the most common meteorites in our collections come from the asteroid belt between Mars and Jupiter. Often these meteorites are remnants of small asteroids that never underwent differentiation (the full-scale melting that caused denser iron to settle out and form a core, as happened on Earth and Mars), and so are relatively pristine remnants of the very earliest material to have formed in our Solar System. Some of these meteorites contain up to 22% water bound into the structure of their minerals [e.g. 2]. This water was incorporated as ices into the host asteroid when it accreted, and was subsequently melted when the asteroid suffered heating from impacts or by the decay of radioactive elements also contained within the asteroid, forming new minerals.

The meteorites included in this study are classified as CM chondrites, and clearly show evidence of alteration by fluids during their residence time in space. CM chondrites contain abundant clay minerals (phyllosilicates such as serpentine), in addition to olivine, pyroxene, metal, sulfides and carbonates [e.g. 3]. It is this latter mineral that we focus on in this work. Carbonate minerals form in the presence of water, and are easily decomposed by heat, providing information on the environment on the asteroid in which the aqueous alteration took place. The major carbonate minerals found in these rocks are calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$), and contain small quantities of other elements such as Mn, Fe and Sr that may provide additional clues to their formation environment. Previous work has explored the chemistry of these minerals in CM chondrites; however, carbonates are highly beam sensitive, and burn easily under an electron beam. In this work, we use a defocused beam to minimize sample damage, and use combined energy dispersive (EDS) analysis for major elements (Mg, Ca, Mn and Fe) and wavelength dispersive (WDS) analysis for minor elements (Cr, Pb, Na, Si and Sr) in order to minimize exposure to the electron beam. In addition, we collect a cathodoluminescence (CL) spectra at each point, as this can provide additional information on the presence of trace elements.

Thin sections of two CM chondrites (ALH 83100 and MET 01070) were studied using a JEOL 8530F electron probe at the Carnegie Institution for Science. The probe is equipped with 5 WDS spectrometers, a ThermoScientific EDS system running the Pathfinder software, and the Ocean Optics CL system running the xCLent v4 software package. The probe was operated at 15kV and 10nA, and data was collected using Probe for EPMA software. Standards used include natural and synthetic carbonates and silicates, and pure metals. CO_2 was calculated by stoichiometry.

The results are consistent with data obtained previously from CM carbonaceous chondrites. These two particular meteorites are extensively aqueously altered, as witnessed by abundant phyllosilicates, and the presence of carbonate grains. The abundance of carbonate grains is higher in MET 01070, with many large grains observed, whereas in ALH 83100 the grains are generally smaller and more sparsely distributed. In both meteorites, calcite is the dominant carbonate, with several grains of dolomite found in ALH 83100 but only one large enough to be analyzed in MET 01070. Calcite in both meteorites contains low concentrations of Mg and Fe (up to ~1.5 wt%), and variable quantities of Mn (up to ~1 wt%). The single grain of dolomite in MET 01070 contains 4 wt% MnO_2 and 3.3 wt% FeO, while the dolomite in ALH 83100 ranges from 1.5 wt% to 7 wt% MnO_2, and FeO ranges from 2 wt% to 7.2 wt%. All of these compositions are consistent with those found previously in this type of meteorite [4,5].

The CL spectra of the carbonate grains provide a useful method for determining small differences in minor element chemistry within carbonate grains. For example, one carbonate grain in MET 01070 shows a minor variation in back-scatter contrast across it, but almost no difference in chemistry (fig. 1). The CL spectra are strikingly different though, with the area on the left showing emission in both the blue (~450nm) and red (650nm) regions, while the right-hand region shows emission only in the red. This suggests the presence of trace elements such as Ce and Eu.

Some carbonate grains are intimately associated with phyllosilicates, indicating changes in fluid composition over time on the parent asteroid. The presence of calcite grains located within dolomite domains also points to evolving fluid compositions over time. The use of a broad beam and combined EDS-WDS analysis reduced the exposure of grains to the electron beam, but there was still some damage witnessed. Collecting CL spectra simultaneously with the chemical analysis provides a simple method of determining whether other trace elements are present at very low levels, in addition to the major and minor elements analyzed by WDS and EDS respectively.

References:
[1] https://www.lpi.usra.edu/meteor/ (accessed February 20, 2019).
[2] RO Norton in “The Cambridge Encyclopedia of Meteorites”, (Cambridge University Press) p. 121.
[3] KT Howard et al., Geochimica et Cosmochimica Acta **75** (2011), p. 2735.
[4] C Johnson and M Prinz, Geochimica et Cosmochimica Acta **57** (1993), p. 2482.
[5] S De Leuw et al., Meteoritics and Planetary Science **45** (2010), p. 513.

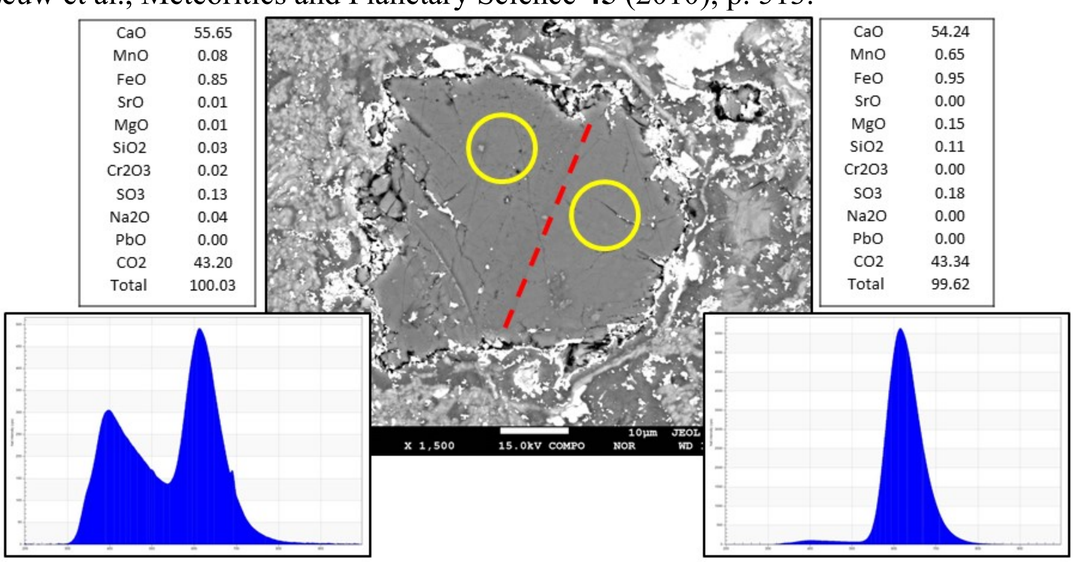

Figure 1. Back-scatter electron image of a carbonate grain in meteorite MET 01070. The grain is possibly twinned, showing slight variations in brightness between the left and right hand sides (the boundary is marked by the dashed red line). Compositionally, both halves are similar (although the right half contains more MnO), but show a marked difference in their CL spectra. CL spectra scale goes from 200nm to 1000nm.

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