MODAL ANALYSIS OF FINE GRAINED RIMS IN PRIMITIVE CO3 CARBONACEOUS CHONDRITE METEORITES BY LOW VOLTAGE SEM/EDS

E. Bonato[1] and T. Salge[2],
[1] Institute of Planetary Research, German Aerospace Centre (DLR), Rutherdforstraße 2, 12489 Berlin, Germany,
[2] Natural History Museum, Imaging and Analysis Centre, Cromwell Road, London SW7 5BD, Great Britain.

The estimation of modal mineralogy is commonly obtained by point counting of thin sections, image analysis, quantitative X-ray diffraction, or automated mineralogy analysers. Here, we describe an alternative approach that is based on chemical modelling using hyperspectral imaging techniques for scanning electron microscopy (SEM) and energy-dispersive spectrometry (EDS) [1, 2]. We will demonstrate that applying low voltage SEM/EDS to chemical phase mapping can be used to quantify the area fraction of mineral phases in complex matrixes of carbonaceous chondrites at sub-micrometre spatial resolution.

Carbonaceous chondrites are amongst the most primitive extra-terrestrial materials available for study and can be used to understand the formation and evolution of the solar system, as they preserve components that formed and evolved in the protoplanetary disk. They consist of chondrules, calcium-aluminium-rich inclusions (CAIs) and amoeboid olivine aggregates (AOAs) set within a matrix of fine-grained (<1 µm) components including amorphous and crystalline silicates, metal, Fe-sulphides and oxides. The matrix in CO3 chondrites can be divided into two components (Fig. 1A): inter-chondrule matrix, and distinct fine-grained rims (FGRs) of material that envelope and are in direct contact with the chondrules, AOAs and CAIs. While the inter-chondrule matrix in Northwest Africa 7892 (BM.2016, M5) has been well characterised [3, 4], the FGRs in CO chondrites have received much less attention. A major outstanding question, therefore, is the relationship between the inter-chondrule matrix and the FGRs.

Here, we focused our attention on the study of a FGR in NWA 7892, a CO3.05. Analysis made use of a high-sensitivity, annular, four channel silicon drift detector fitted to a field emission SEM. A low accelerating voltage of 6 kV has been applied to decrease the excitation volume of emitted X-rays to the sub-micrometre scale. A probe current of 216 pA resulted in an input count rate of ~84 kcps. A hyperspectral imaging data set, that provides complete EDS spectra for each pixel of the SEM micrograph, was acquired for the area (18 x 15 µm) shown in Fig. 1B at a pixel resolution of 25 nm for 89 minutes, resulting in an average impulse statistic of ~881 impulses per pixel spectrum. Matrix components were identified in the backscattered electron micrograph (Fig. 1B) and EDS net intensity maps (e.g., Fig. 1C). The composition of the areas shown in Fig. 1B was used to detect similar spectra in the data set by consideration of the net intensities of the X-ray line families (O K, Fe L, Ni L, Zn L, Na K, Mg K, Al K, Si Kα, Ca Kα). The chemical phase map (Fig. 1D) shows that matrix components down to ~100 nm in size can be detected and their model content can be quantified by low voltage SEM/EDS at 6 kV, whereas substantially smaller grains would require EDS using transmission electron microscopy.

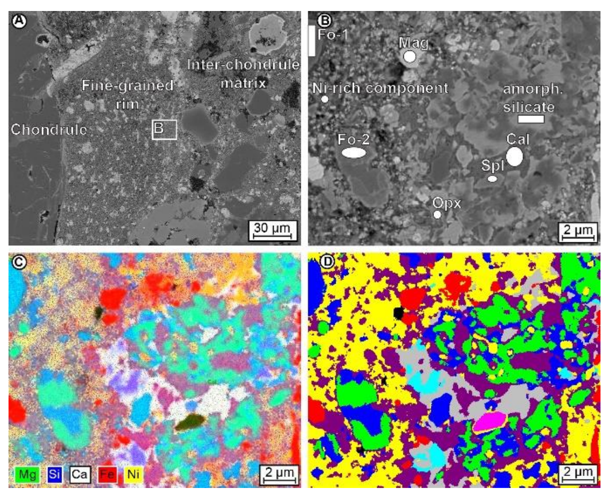

Fig. 1 A) Backscattered electron (BSE) micrograph showing a fine-grained rim (FGR) between a chondrule (left) and the inter-chondrule matrix (right). **B)** BSE micrograph of the analysed area. White, black outlined areas show regions that were used to detect similar spectra and obtain the modal abundance by chemical phase mapping. Mag: magnetite; Fo: forsterite; Cal: calcite; Opx: orthopyroxene; Spl: spinel. **C)** Composite net intensity map of magnesium, silicon, calcium, iron, and nickel. **D)** Result of chemical phase analysis showing the distribution of a Ni-rich component (28.1 %, yellow), amorphous silicate (27.6 %, violet), forsterite-1 (15.4 %, blue), forsterite-2 (14.5 %, green), calcite (7.5 %, grey), magnetite (4.2 %, red), orthopyroxene (1.8 %, turquoise), spinel (0.6 %, pink). An unassigned phase (0.3 %, black) can be observed at areas with pore space.

Acknowledgments: This research received support from the EUROPLANET Project https://www.europlanet-society.org/europlanet-2024-ri/ which is financed by the European Union's Horizon 2020 research and innovation programme under grant agreement No 871149. The authors would like to thank the NHM Meteorite Collections for the samples.

References: [1] Salge T. et al. (2019) *Meteorit. Planet. Sci.* 54 2334–2356; [2] Prevec S. A. et al. (2021) *Canad. Mineral.* 59, 1305-1338; [3] Bonato E. et al. (2018) *49thLPSC*, Abstract #1917; [4] Bonato E. et al. (2019) *50thLPSC*, Abstract #3047.