TRACING WATER IN SEMARKONA – A SIMS AND EBSD STUDY OF MAGNETITE

S. P. Alpert1,2,*, D. S. Ebel1,2, J. Barosch3, N. T. Kita1. 1Dept. of Earth and Planetary Sci., American Museum of Natural History, New York, NY 10024, USA. 2Earth and Environmental Sci., CUNY Graduate Center, New York, NY 10016, USA. 3Department of Geoscience, University of Wisconsin-Madison, Madison, WI 53706, USA.

*salpert@amnh.org

Introduction: Determining the timing, source, and products of aqueous alteration of meteorites allows for a better understanding of the distribution of water in the Solar System. Semarkona, classified as a type 3.00 LL ordinary chondrite fall, shows various types of evidence for fluid alteration [e.g., 1–5], particularly abundant magnetite. Based on the variation within δ18O values, the oxidant for magnetite formation is thought to have been a limited reservoir on the LL parent body [3]. Previous work by [6] showed that opaque assemblages (OAs) in the matrix all exhibit magnetite rims, but not all OAs in chondrules contain magnetite. Historically, the petrographic context for magnetite grains (in matrix, OAs, chondrule interiors, or chondrule rims) has not been well documented. Additionally, the effect of magnetite crystal orientation on secondary ion mass spectrometry (SIMS) analyses was not well-understood until more recently [8]. This suggests that more precise analyses should be conducted to better constrain the δ18O and Δ17O values of magnetite in Semarkona. Preliminary observations by [7] indicated that magnetite rims are composed of large, stress-free, single-crystal grains. Magnetite grains have been interpreted to form by in situ replacement of Fe,Ni metal.

We combine additional electron backscatter diffraction (EBSD) analyses with SIMS to better understand the relationships among magnetite grains in Semarkona and decipher their origin.

Methods: A section of Semarkona (AMNH #4128-5) was prepared for SIMS and EBSD using methods described in [6]. Additionally, samples were ion milled using a Hitachi IM4000 in two steps: first 20 minutes using 3 kV / 1 kV, second 30 minutes using 1.5 kV / 1 kV acceleration and discharge voltages respectively. EBSD was conducted on a FEG SEM at the Metropolitan Museum of Art (NY) using an Oxford Nordlys system with a 70° tilt angle, 25 kV accelerating voltage, 300 μm aperture, 25 Pa of pressure, and variable step size. Data reduction was carried out in Aztec Crystal software. SIMS δ18O isotope analyses were conducted on the WiscSIMS Cameca IMS 1280 using multicollection Faraday cups [9]. A 3 kV primary Cs+ ion accelerating voltage [8] was used to reduce crystal orientation effects. With the 0.5 nA primary ion intensity (10 μm diameter), the external reproducibility of δ18O and Δ17O were 1.5% and 1% (2SD), respectively, from the analyses of randomly orientated magnetite standard grains.

Results: Magnetite EBSD results show that grain size increases with distance from the core of each OA (Fig. 1). EBSD also shows that magnetite rims are generally separated from the core of the OA by an area of low band contrast. Magnetite grain size varies from sub-micron at the edge of the low band contrast zone to up to ~50 μm where they are in contact with the matrix. Kernel average misorientation (KAM) shows that magnetite grains are largely free of deformation/defects. SIMS measurements of 17 magnetite grains on the rims of 3 OAs in the matrix of Semarkona were conducted. Preliminary results show that the grains have an average Δ17O of ~4.5% (range: ~5.5 – 3.9%) and a δ18O average of ~2.2% (range: ~0.3 – 3.2%); indistinguishable within analytical uncertainties. Preliminary evaluation shows no resolvable difference in O isotope ratios according to the location of the measurement within the grain, the size of the grain, or distance of the grain from the core of its respective OA.

Discussion: The homogeneity of the δ18O and Δ17O values, despite being from multiple OAs separated by at least 1 cm, suggests an identical oxidant (water source) for all magnetite grains within Semarkona. The lack of deformation observed in all magnetite grains, and lack of defects in larger grains, indicates that grains are unlikely to have formed by topotactic replacement of Fe,Ni metal. Therefore, based on our isotopic and petrographic observations, we propose that the most likely formation mechanism for magnetite grains observed on the rims of OAs in Semarkona is via in situ precipitation as a result of parent body aqueous alteration.


Fig. 1A – Example of EBSD IPF plus band contrast for magnetite on OA rim in Semarkona (4128-5-m8). 1B – EBSD KAM map of same area.