

ELECTRON BACKSCATTER DIFFRACTION STUDY OF MAGNETITE IN ORDINARY CHONDRITE OPAQUE ASSEMBLAGES

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Introduction: Formation of Fe-oxides associated with opaque assemblages (OAs) in the matrix of unequilibrated ordinary chondrites (UOCs) has been previously attributed to two processes: secondary aqueous alteration of Fe,Ni metals on the parent body (e.g. [1, 2]) or direct nebular condensation (e.g. [3, 4]). Rims (likely shells) of magnetite surrounding matrix-hosted OAs in Semarkona (LL 3.00) were interpreted to have formed via condensation from a gas of increasing fO_2 based on the large, euhedral nature of the grains and their petrographic association with sulfides [3]. Electron backscatter diffraction (EBSD) is a powerful tool for characterization of crystal growth modes and can be used to distinguish between epitaxial growth and topotactic replacement of a phase [5]. EBSD can also be used to determine the grain stress/strain history by internal misorientation of a grain, as visualized in grain reference orientation deviation (GROD) maps [6]. We have used EBSD to observe both growth patterns and deformation of magnetite grains in rims surrounding matrix OAs in Semarkona to determine whether they are consistent with growth in free space, or represent secondary replacement of an initial Fe,Ni metal phase.

Methods: Samples were polished as in [7] but with diamond suspensions instead of Al_2O_3 . Initial WDS stage maps were collected with 10 elements and 1 μm /pixel resolution, as described in [3]. EBSD was conducted on an FEI Helios G3 dual-beam FIB-SEM equipped with an Oxford Aztec EBSD system, at the Naval Research Laboratory. Data were acquired at a 70° tilt angle, 20 KeV accelerating voltage, and a step size of 0.3 μm . Data reduction was completed using Aztec Crystal software.

Results: The inverse pole figure (IPF) map (Fig. 1A) of an example rim shows that the magnetite is a single crystal (orange) with a twin (green). Minor twins (turquoise) within the larger crystal follow natural fractures. The GROD map (Fig. 1B) shows only minor low angle ($< 5^\circ$) progressive plastic deformation near grain boundaries with no evidence of recovery.

Discussion: Single-crystal growth of magnetite supports the hypothesis of [3] that grains condensed on the surface of OAs and were not formed by replacement of exiting Fe,Ni metal in a parent asteroid. Replacement would have resulted in multiple subgrains of *different* orientations, similar to those observed during hematite replacement of magnetite [5]. This conclusion is further supported by the GROD map which shows no indication of mineral replacement reactions. Thus, we conclude that magnetite grains on OAs in Semarkona were formed by gas-grain interaction (condensation) in the nebula, prior to parent-body accretion.

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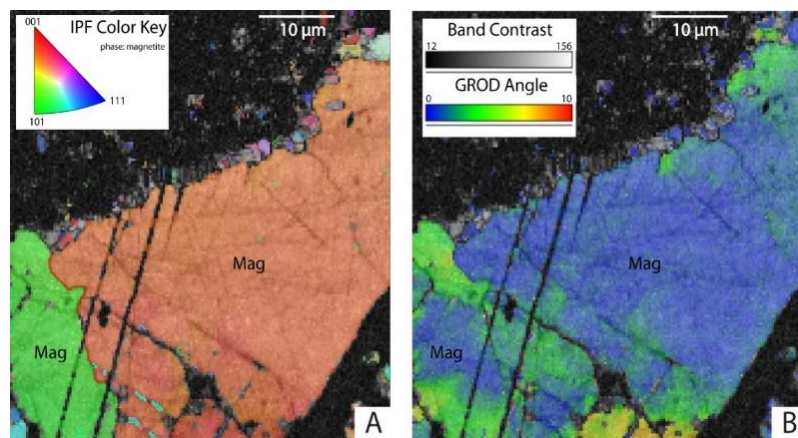


Fig. 1 (A) IPF map and **(B)** GROD map results from a magnetite grain on the exterior of a matrix OA (to upper left).