SPECIATION OF IRON AS A MONITOR OF OXIDATION, REDUCTION AND SULFIDATION IN ENSTATITE AND ORDINARY CHONDRITES.

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Introduction: It has long been recognized that enstatite chondrites (ECs) formed in a nebular setting characterized by low oxygen fugacities [e.g., 1-3]. Reducing conditions account for several mineralogical features of ECs, including: high MgO/(FeO+MgO) of pyroxene and olivine; the occurrence of typically lithophile elements (e.g., Ca, K, Mg, Mn,…) in sulfide minerals; and Fe,Ni-metal with dissolved Si. In this project, we address sulfidation and reduction as independent processes leading to the formation of enstatite chondrites.

Mass balance reacting system. We use "reaction space" (a linear algebraic approach [4,5]) to constrain reactions that may cause changes in mode of major minerals in chondrites. Transfers of mass between the main groups of minerals--silicates, metals, and sulfides--can be described by: $(Mg,Fe)SiO_3 + 0.5\ S_2 = (Mg,Fe)S + SiO_2 + 0.5\ O_2$; $FeSiO_3 = Fe^0 + SiO_2 + 0.5\ O_2$ [6]. To a first order, relative progress on these reactions can be estimated from the distribution of iron among silicates, metals and sulfides.

Analytical Methods: We determined mineral compositions and modes to estimate speciation of Fe in polished thin sections of St. Marks (EH5); Lewis Cliff [LEW] 88180 (EH5); Northwest Africa [NWA] 974 (E6); Mt. Tazerzait [Mt. Taz] (L5); and Bensour (LL6). Equilibrated samples were used because they have homogeneous mineral compositions. Obviously, mineral modes and compositions in these rocks reflect parent-body metamorphic conditions, but these conditions are related to the nebular settings where parent bodies formed. Compositions of pyroxene, olivine (where present), Fe,Ni-metal and troilite were analyzed using a JEOL JXA-8900 electron microprobe (EPMA) at Waseda University. The same EPMA was used to prepare elemental maps (step sizes 8-12 μm). Digital maps of individual elements were opened as layers in graphics software, and grids were overlain on the maps. The mineral present at each grid node was identified manually by inspection of elemental maps.

Speciation of Fe. The main Fe-bearing minerals consist of Fe,Ni-metal, troilite, olivine and pyroxene. Other Fe-bearing minerals are present but relatively minor. Modes and mineral compositions were combined with molar volumes to determine speciation of Fe among troilite, metal, and silicates.

Results: In the ordinary chondrites, 86% (Mt. Taz) to 93% (Bensour) of Fe occurs in silicates. The ECs have only 2-4% Fe as silicate. The two EHs have similar distributions of Fe, with ~26% in metal and ~70% in sulfide. NWA 974 has a higher proportion of Fe as metal (33%). Mt. Taz is both sulfidized and reduced relative to Bensour; the ECs are both sulfidized and reduced relative to the OCs. These results suggest that sulfidation and reduction to metal were linked processes in the solar nebula--probably by removal of oxygen from chondrite-reacting systems

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