

Reduction, oxidation and sulfidation in ordinary, enstatite and R chondrites based on speciation of iron

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Speciation of iron plays the pivotal role in distinguishing the H, L, LL groups of ordinary (O) chondrites and O vs. enstatite (E) and R chondrites [1,2]. The variations in Fe-bearing minerals among these chondrite groups reflect variable physical conditions from different locations and times in the inner solar nebula. Most previous work has focused on speciation of Fe between silicates and metals as an indicator of oxygen vs. reduction [e.g., 1,2]. This project considers the role of sulfidation as well as reduction and oxidation in chondrite-forming regions of the solar nebula.

This approach depends on determining the speciation of Fe between silicates, metallic minerals and sulfides (mostly troilite). Data set (1) is based on modes and mineral compositions from thin sections of H, L, LL, E and R chondrites. These include: Bensour (LL6, fall); Mt. Tazerzite (L5, fall); Tamdakht (H5, fall); St. Marks (EH5, fall); Lewis Cliff 88180 (EH5, find); Northwest Africa 974 (E6, find); Northwest Africa 753 (R3, find). Meteorite falls and type 5 and 6 chondrites were emphasized in order to minimize heterogeneity of mineral compositions and effects of terrestrial weathering. In Data (1), modes were determined from manual counting of grids overlain on elemental maps, and mineral compositions were determined using a JEOL JXA-8900 electron microprobe at Waseda University. Data set (2) is based on whole-rock wet chemical analyses conducted and compiled by E. Jarosewich [3,4]. We used falls for LL (n = 17), L (n = 57) and H (n = 31) and all of the E (1 fall, 3 finds) chondrites from the Jarosewich compilation. Data set (3) is based on similar whole-rock analyses conducted by H. Haramura of NIPR and compiled by Yanai and Kojima [5]. This data set consists of Antarctic finds (59 LL, 158 L, 162 H, 6 E).

This project also requires an understanding of reactions that transfer Fe between the silicate, sulfide and metal subsystems within whole-rock reacting systems of O, E and R chondrites. A reaction space [6,7] approach was used to identify the main reactions that change mineral abundances in these rocks: (R1) $\text{NaAlSi}_3\text{O}_8 = \text{NaAlSi}_2\text{O}_6 + \text{SiO}_2$; (r2) $\text{Mg}_2\text{SiO}_4 + \text{SiO}_2 = 2\text{MgSiO}_3$; (R3) $\text{FeSiO}_3 = \text{Fe-metal} + \text{SiO}_2 + 0.5\text{O}_2$; (R4) $\text{FeSiO}_3 + 0.5\text{S}_2 = \text{FeS} + \text{SiO}_2 + 0.5\text{O}_2$. R1 does not appear to be important in most chondrites. R2 is very important as it describes variations in abundance of olivine vs. pyroxene, but this reaction occurs entirely within the silicate subsystem. Reduction of Fe occurs with progress on R3, so forward progress on R3 can be estimated from the ratio of metallic Fe to all Fe, and can be used as a monitor of reduction. Likewise, forward progress on R4 can be used as a monitor of sulfidation. In this framework, if $R_3 = 1$, all Fe occurs as Fe-metal; if $R_4 = 1$, all Fe occurs as Fe-sulfide; if $R_3 = R_4 = 0$, all Fe occurs as FeO in silicates.

The three data sets all show a wide range of reduction and little variation in sulfidation for O chondrites (R_3 from 0 to 0.7; $R_4 \sim 0.2$). E chondrites appear to be more reduced and sulfidized (R_3 from 0.7 to 0.8; R_4 from 0.2 to 0.3). The R chondrite of this study is oxidized and somewhat sulfidized ($R_3 = 0$; $R_4 \sim 0.3$). Most deviations from these patterns occur in Data (3) and are probably due to terrestrial weathering. Results suggest that an oxidant (or reductant) was independent of sulfur fugacities in the regions where ordinary chondrites formed.

[1] van Schmus W.R. and Wood J.A. (1967) *GCA* 31: 747-765. [2] Weisberg M.K. (2006) in Lauretta D.S. and McSween H.Y. Jr. (editors) *Meteorites and the Early Solar System II*, p. 19-52. [3] Jarosewich E. (1990) *MaPS* 31: 323-337. [4] Jarosewich E. (2006) *MaPS* 41: 1381-1382. [5] Yanai K. and Kojima H. (1995) *Catalog of the Antarctic Meteorites*, National Institute of Polar Research, 230 p. [6] Thompson J.B. Jr. et al. (1982) *J. Petrol.* 23: 1-27. [7] Fagan T.J. and Day H.W. (1997) *Geology* 25: 395-398.

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