

**THE CONTINUOUS REDOX FRACTIONATION SEQUENCE AMONG
ORDINARY CHONDRITES**

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A plausible though still controversial interpretation of ordinary chondrite compositional data is that these three closely related groups represent segments of a continuous fractionation sequence (CFS) involving redox state and siderophile abundances [1,2]. The intergroup trends are clear: the degree of oxidation, as measured by the distribution of Fe between oxidized and reduced phases, increases as the siderophile abundance decreases. Proponents of the CFS model suggest that the same trends are also observed within the groups if experimental errors are low enough to permit resolution of the much smaller intragroup fractionations.

To test the CFS and other models regarding the nebular agglomeration of ordinary chondrites we have studied a set of 65 ordinary chondrites: 23 H, 23 L, 15 LL, 1 H/L (Tieschitz), 3 L/LL (Albareto, Bjurböle, Qidong). Our data set includes replicate neutron activation determinations of 25 elements and electron microprobe studies of kamacite and olivine compositions. Alternate wafers were used for neutron activation and thin section preparation.

A working model of the redox fractionation is that ordinary chondrites agglomerated from the same (or very similar) components, but that the mix of components varied, probably with increasing distance from the Sun; support for this picture comes from studies of highly unequilibrated chondrites which show similar distributions of phase compositions in all groups. One component (perhaps mainly matrix) was superoxidized (henceforth oxidized), and another (probably coarse common metal) was superreduced (henceforth reduced). The oxidation state preserved in equilibrated chondrites reflects equilibration of the system during metamorphism.

If we assume that the abundance of the oxidized component was proportional to the amount of Mg, then a plot of FeO/MgO vs. Co/MgO or Ni/MgO should be linear, with a slope that reflects the reducing capacity of the metal component. Our data yield arrays that are straight except for a minor upturn in the most oxidized LL chondrites (the latter may require a slightly more oxidized matrix in LL). If we assume that the Ni content of the common metal component is ~100 mg/g, the slopes imply that 1 mole of common metal is able to reduce 1 mole of FeO to Fe. If the reducing agent in the metal is C and its oxidized product is CO, this picture requires that ~1 mole of C be associated with 1 mole of metal. If the reducing agent is metallic Si that is oxidized to SiO₂, then 0.5 mole of reduced

Si was associated with 1 mole of metal. These C/Fe and Si/Fe ratios are surprisingly large. If this picture is correct, we would expect to find more evidence for these reduced phases in highly unequilibrated chondrites such as Semarkona. The alternative is that differences in degree of oxidation of Fe-bearing phases were already largely established in the nebula.

On a Urey-Craig diagram, bulk chemical $Fe_{met} + Fe_{sul}$ is plotted against Fe_{oxid} . In the past, relationships among the ordinary chondrite groups have been obscured by errors in the determination of Fe_{met} , which caused the data to scatter along lines of constant Fe_{total}/Si . We have searched for superior bulk chemical data by requiring the bulk $FeO/(FeO + MgO)$ to agree with values obtained by electron microprobe. We found that type-4 and type-5 ordinary chondrite data by E. Jarosewich consistently pass this test, and when plotted on a Urey-Craig diagram show intragroup trends that follow a continuous fractionation sequence trend through the centroids of the groups.

Several recent papers have discussed the possibility that members of an ordinary chondrite group may have originated on two different parent bodies. If our picture is correct that the continuous-fractionation sequence reflects formation at a range of distances from the Sun, then differences in the mean redox state and siderophile abundance should be sought among the putative subgroups of chondrites.

References

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- [2] Müller O., Baedeker P.A. and Wasson J.T. *Geochim. Cosmochim. Acta* 35, 1121 (1971).