COMPOSITIONAL STUDY OF CHONDRULES FROM THE HIGHLY UN-EQUILIBRATED (LL3.0) SEMARKONA CHONDRITE. Jeffrey N. Grossman and John T. Wasson, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90024, USA.

The record of chondrule formation is best preserved in the least equilibrated chondrites. Criteria are now available to assign subtype number (precise to about ±1) to type -3 chondrites; 9 corresponds to the most and 0 to the least equilibrated (Sears et al., 1980). We had previously studied by chemical and petrographic techniques the chondrules in the Chainpur (LL3.4) chondrite (Grossman et al., 1979; Grossman, 1980). We here report preliminary results of a similar study of the less equilibrated Semarkona chondrite.

There is increasing evidence that chondrites did not form by direct condensation of liquids, or by the melting of fine-grained CI-chondrite like materials (Grossman et al., 1979; Gooding et al., 1980a). Rather, compositional variations among chondrules suggest that they are remelted mixtures of heterogeneous precursor grains. These new results support and clarify our conclusions based on the Chainpur data, viz. that chondrules formed by melting of precursor material consisting of several distinct, identifiable components. The new data also support previous evidence indicating that the precursor Fe-Ni was relatively uniform in composition, and that some chondrules experienced volatile loss.

Siderophiles and chalcophiles
In both Chainpur and Semarkona, the siderophiles (Fe, Co, Ni, As, Os, Ir, and Au) intercorrelate strongly. Chalcophile Se also correlates with siderophile elements. These elements are generally depleted in chondrules relative to whole rock. Relative siderophile and Se abundances are similar in each chondrule. This uniformity implies that random samples of nebular metal having masses of <50 μg (and sometimes <5 μg) showed little variation in composition. Data from Chainpur indicated that the metal also contained most of the Ge, but little Ga. Variations in the Ir/Ni ratio in Chainpur chondrules showed that much of the Ir may not be in the main metallic component, a conclusion reached for whole rock ordinary chondrites on the basis of studies of magnetically separated fractions (Chou et al., 1973; Rambaldi, 1977). Further support is provided by our data on Semarkona chondrules; preliminary data showed that Os correlates with Ir, but is fractionated from Ni to a still greater degree.

Moderately volatile lithophiles
In Chainpur chondrules, Na, K, and Ga intercorrelate. Ga data is not yet available for Semarkona, but Na correlates strongly with K. In chondrules from both chondrites, Mn correlates weakly with Na and K; in general, the only chondrules having low Mn contents are those that are particularly depleted in Na and K. Na, K, Ga, and, to a lesser extent, Mn represent a moderately volatile, mainly lithophile chondrule component. This should not
be thought of as a "feldspar" component, since the feldspar-forming elements Ca and Al are not correlated with Na and K. We cannot determine whether this component reflects the composition of chondrule precursor material, or results from the partial loss of volatiles during chondrule melting. Probably, both factors are involved, with the latter dominating in those chondrules depleted in Mn.

**Refractory lithophiles**

The refractory lithophile elements Al, Ca, Sc, rare-earth elements (REE), and Hf intercorrelate in both Chainpur and Semarkona chondrules. FeO/(FeO + MgO) ratios measured in Chainpur chondrule silicates anticorrelate with refractories. Refractories are inversely related to whole chondrule Fe/(Fe + Mg) ratios in Semarkona; we will determine this ratio in mafic silicates later. Refractories vary independently from other elements, with the exception of weak correlations with V and Mg. Since refractories were not present in the gas phase when chondrules formed, chondrule precursor materials must have included a refractory lithophile component. The grain size of this precursor component had to be large compared to other precursor components, since it incorporated minimal amounts of oxidized Fe at low temperatures (Grossman et al., 1979). Correlation statistics indicate that V was mainly in the refractory lithophile component, while Mg was partially in that component.

Gooding et al. (1980b) reported that chondrules from unequilibrated chondrites have oxygen isotopic compositions lying along a slope-1 mixing line running through the ordinary chondrite groups on a 3-isotope plot. They further reported a correlation between $\delta^{18}O$ and bulk (CaO + Al₂O₃)/MgO ratio as well as with Fe/(Fe + Mg) in mafic silicates. It seems likely that their $^{18}O$ rich component is identical to our refractory lithophile component.

**Other components**

Most of the mass of a chondrule is Si and O. Silicon and most of the O condensed from the solar nebula at a lower temperature than elements in the refractory lithophile component, and at higher temperatures than elements in the moderately volatile lithophile component. Chromium, Mn, and Mg are the lithophiles condensing near the Si condensation temperature. In Semarkona, Cr and, neglecting a few chondrules slowing volatile loss, Mn show strong anticorrelations with elements in the metal/sulfide component. This shows that they are contained in another "major silicate" component which is nearly constant in composition, and large in amount. These anticorrelations are the result of dilution of this silicate component by metal and sulfide. Weaker anticorrelations are found between siderophiles and Mg and V. Mg, and, to a lesser extent, V are partly contained in this Cr- and Mn-bearing silicate component. No correlations exist between major silicates and refractories; since the refractory elements are in a minor component, it produces no resolvable dilution effect.
CHONDRULES FROM THE SEMARKONA CHONDRITE

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Conclusions

The chemical components of chondrules provide information about the kinds of materials available during chondrule formation, and about the nature of the chondrule forming event. Chondrules formed by mixing random amounts of precursor grains, including 1) nonrefractory metal of uniform composition; 2) Fe-poor refractory-lithophile grains; 3) Cr-, Mn-, and Mg-bearing "major silicate" material; and, possibly, 4) Na-, K-, and Ga-rich grains. Superposed on the trends generated by mixing these components is the occasional evidence of volatile loss.

References: