

CHONDRULE COMPOSITIONS AND THE ACCRETION OF CHONDRITES, L. L. Wilkening, Department of Planetary Sciences and Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721.

Hypothesis. The similarity of compositions of chondrules from H, L, and LL unequilibrated chondrites and the fact that chondrules comprise 65-85% of the volume of chondrites means that the entire burden for the distinctive characteristics of the various chondrite groups is due to the matrix, the material between chondrules, especially the metal and sulfide contained therein. This in turn implies that the differences among chondrite groups are due to the relative efficiency of the accretion of chondrules, metal/sulfide and fine-grained matrix. Differences among petrographic types (3,4,5) are due to heating that accompanied accretion or followed thereafter. The equilibration of chondrules with matrix including metal and sulfide then resulted in the distinctive bulk compositions and chondrule compositions found in equilibrated ordinary chondrites. The reasoning behind these points is explained below.

Background. This hypothesis is basically a modification of the two-component model of Larimer and Anders (1967). Observations of the abundances of volatile elements in the different classes of chondrites led Larimer and Anders (1967) to postulate the two-component model of chondrite formation in which the chondrites are a mixture of two types of material: a low-temperature component consisting of matrix and a high-temperature component consisting of chondrules and metal grains. According to this hypothesis the high-temperature component was formed by the heating and devolatilization of small amounts (less than 10% of the total) of the low-temperature component. Chondrites were then formed by the mixing of various proportions of the two components with preferential accretion of chondrules necessary to account for their high abundance in chondrites. The main difference emphasized here is that the high-temperature metal has become intimately associated with the sulfide and the volatile-rich matrix in an additional stage of mixing.

Volatiles. There has been considerable argument about whether the data on chondrule compositions support the view that volatiles are contained in the matrix. The problem is that although there have been many studies of chondrule compositions [See Gooding et al. (1980) for a complete list of references.] made by neutron activation analysis and electron microprobe techniques, very few studies included volatile elements other than Na and K and occasionally Au. Na is not depleted in chondrules. In fact some chondrules contain a few weight per cent Na in an Na-Al-Si-rich glass. This is an unsolved puzzle. Gold is also strongly siderophile so there is always an ambiguity in determining the cause of its depletion. More recent studies of chondrule compositions, which have included a larger number of volatile trace elements (Grossman et al., 1979; Grossman and Wasson, 1982; Wilkening et al., 1982; Boynton et al., 1982), showed volatile elements such as Zn, Br, As, Sb, Se, and Cd are depleted in Chainpur chondrules relative to the whole rock by factors of a few to 20. Simple mass balance requires the matrix to be considerably enriched in volatiles.

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Wilkening, L. L.

Siderophiles. The depletion of siderophiles in chondrules is well documented. Petrographic observations of chondrules show that they are very depleted in metal relative to the matrix of chondrites (where the matrix is defined to be all material interstitial to chondrules). A summary of the various mechanisms of metal/silicate fractionation can be found in Grossman (1982). Some call for fractionation of the precursor material; others call for fractionation during the liquid droplet phase of chondrule formation. Iron and the other siderophiles were certainly present, although at least iron was in an oxidized state, in the unfractionated, low-temperature component postulated by Larimer and Anders and in the fine-grained, silicate matrix precursor suggested by Scott et al. (1982). This means that in addition to heating, reduction would have had to occur. The important point for our discussion is that chondrules in all groups of unequilibrated chondrites are all depleted in metal with minor variations on a chondrule-to-chondrule basis.

Uniformity of Chondrule Compositions. The gross uniformity of chondrule compositions is supported by a substantial body of data showing that chondrules from the various chemical groups of unequilibrated ordinary chondrites form a compositionally similar suite of objects. Most recently, Gooding et al. (1980) showed that geometric means of elemental abundances in chondrules from Tieschitz (H3), Hallingeborg (L3), Chainpur and Semarkona (LL3) are virtually indistinguishable with a few very minor exceptions. Onuma et al. (1982) showed that isotopic compositions of chondrules from unequilibrated H, L, and LL chondrites lie along a mixing line and do not correspond to the field defined by their chemical group. They concluded that chondrules from all iron groups formed from a common precursor. The only significant difference among the H, L, and LL chondrules may be in the iron-contents of their pyroxenes and olivines, but because these minerals are strongly zoned this is very difficult to determine. Early calculations (e.g. Dodd and Van Schmus, 1965) of mean fayalite and ferrosilite contents of olivine and pyroxene in unequilibrated chondrites showed a fair amount of scatter for petrographic type 3, but strong clusterings for type 4. Iron contents of individual chondrules in unequilibrated chondrites showed complete overlap between L and H groups in a study by de Gasparis et al. (1975). All of the data show chondrules in unequilibrated chondrites to be remarkably similar in composition regardless of their host meteorite group.

Conclusion. Chondrules, metal and sulfide grains, and volatile-rich matrix were the accretionary building blocks from which chondrites were assembled. In order to understand the differences among chondrite groups we will have to work harder at learning about the process(es) of accretion.

References. Boynton et al., Abs. LPI Chondrule Conf.(1982); deGasparis et al., Meteoritics 10, 390(1975); Dodd & Van Schmus, JGR 70, 3801(1965); Gooding et al., EPSL 50, 171(1980); Grossman, J., et al., GRL 6, 597 (1979); Grossman, J., Abs. LPI Chondrule Conf. (1982); Grossman & Wasson, GCA 46, 1081(1982); Larimer & Anders, GCA 31, 1239(1967); Onuma et al., Abs. LPI Chondrule Conf.(1982); Scott et al., Abs. LPI Chondrule Conf.(1982).