PETROLOGIC SIMILARITIES AMONG CHONDRULES IN H, LL, CO, CM AND E CHONDRITES.
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If, as we believe, the constituents of all chondrites share common origins (1), there should be petrologic similarities between chondrules in the various chondrite groups. Dodd (2) and others, however, maintain that chondrules in ordinary and carbonaceous chondrites have different textures, compositions and origins. McSween (3,4) has identified chondrule types in CO and CV chondrites that have very different bulk FeO concentrations, but studies of ordinary chondrites have not found such large compositional differences among the usual chondrule types (5). CM, CO and CV chondrites also differ from the least metamorphosed H-L-LL3 chondrites in having a much higher proportion of Fe-poor olivines (Fa 1-5 mole %).

Results. We analyzed olivines and low-Ca pyroxene for Fe, Mg, Si and Ca in 174 chondrules (both droplet and irregular varieties) in Semarkona (LL3), Tieschitz (H3), Kainsaz and Lancé (CO3), Murray (CM2) and Qingzhen (EH3). Porphyritic-olivine and metal-rich chondrules and those containing pyroxene poikilitically enclosing olivine were preferentially selected prior to analysis. [Metal-rich (6,7) and poikilitic-pyroxene (8) chondrules in some LL3 chondrites tend to contain forsteritic olivine.] In Murray, where chondrules are more sparse, chondrule fragments were also included. Fig. 1 shows means of 4-8 olivine analyses in each of the selected chondrules in 5 chondrites. Two chondrule populations can be discerned in each chondrite: those with low FeO concentrations (Fa 1-8), which show an inverse correlation between mean FeO and CaO concentrations in olivine, and those with Fa 10-50 which tend to show a positive correlation.

a) Low-FeO, porphyritic-olivine (PO) chondrules. Most of McSween's type I chondrules belong to this category (3,4). Metal-rich ones tend to be irregular and contain olivine with higher CaO and lower FeO concentrations. Metallic Fe,Ni blebs contain 0.1-1 wt.% Cr, Si, and P (3,6,9). Metal-poor ones may resemble high-FeO PO chondrules except that they are usually more spherical, have a clear glass mesostasis and sometimes have small amounts of low-Ca pyroxene poikilitically enclosing olivine on the edges. Olivine contains 0.3-5 mole% Fa and may be euhedral or granular.

b) Poikilitic-pyroxene chondrules. These contain 1-10 vol.% rounded olivine crystals (Fa 0-9; Fa <0.05-0.4 in Qingzhen) enclosed by low-Ca pyroxene, usually twinned clinopyroxene, (Fs 0.6-6, Fs 0.13-1.3 in Qingzhen). Olivine phenocrysts may also occupy the chondrule core. Pyroxene phenocrysts are common in H-LL chondrules but tend not to be separated by mesostasis in CO-CM chondrules.

c) High-FeO, porphyritic-olivine chondrules. These correspond to McSween's type II chondrules (3,4). Although some are spherical most are irregular and have larger euhedral olivine phenocrysts than low-FeO PO chondrules. Mesostases are commonly brown and translucent in transmitted light. Olivine crystals tend to be strongly zoned, with Fe and, generally, Ca enriched in rims. Pyroxene and metallic Fe,Ni are usually absent though pyroxene may form in mesostases. High- and low-FeO chondrules can be distinguished petrographically with >90% confidence.

Discussion

a) We have identified three categories of chondrules, each with characteristic mineral compositions and textures, that are common to H, LL, CO and CM chondrites. High- and low-FeO porphyritic-olivine chondrules tend to have different properties and may have formed in different environments. Chondrules with high concentrations of CaO in forsteritic olivine (>0.3%)do not have high bulk CaO concentrations; crystallization at high temperatures may be responsible.

b) Mineral compositions in analysed chondrules do not seem to have been affected by metamorphism of chondrules or chondrites. Edge enrichments of Fe and Ca in olivine from high-FeO PO chondrules appear to be igneous in origin, not metamorphic (10). Olivine phenocrysts and chadacrysts in poikilitic-pyroxene chondrules tend to have similar compositions, despite very different diffusion rates in the enclosing glass and pyroxene.

c) Many low-FeO PO chondrules have too little pyroxene to have formed by reduction of normal matrix material rich in Fa40-50 olivine (11). They may have formed from more reduced material like Kakangari matrix.

d) Low-FeO chondrules are more reduced in Murray (0.5-2% Fa) and Semarkona (0.3-7% Fa) than in Lancé and Kainsaz (1-9% Fa) and Tieschitz (2-8% Fa). High-FeO chondrules appear to be more reduced in ordinary chondrites (usually 10-30% Fa) than in carbonaceous chondrites (usually 20-50% Fa).

e) The proportion of low-FeO chondrules varies among different chondrule groups: 20-30% in the least metamorphosed H-LL chondrites (21), 90% in the CO group (3) and 60-90% in CM (Fig. 1 and ref. 12). Olivine compositions in CI chondrites (13) closely resemble those in Fig. 1, suggesting that 50% of CI chondrules had low FeO. We attribute these differences to sorting of chondrules and their precursor materials.

f) E chondrites lack porphyritic-olivine chondrules although olivine is abundant in Kakangari (Fa 3-5), Pontlyfni (Fa 1), and other reduced chondrites (14). This may also be a result of sorting of chondrules and their precursors.

g) Some magnesian 'aggregates' in CM chondrites (e.g., Fig. 2 of ref. 15) have mineral textures and compositions like chondrules in CO and ordinary chondrites that are round and have obvious igneous textures; these aggregates should also be called 'chondrules'. Isolated olivine crystals in CM chondrites have similar CaO-FeO distributions (16,17) to those of chondrules and chondrule fragments in Murray (Fig. 1) suggesting that the crystals formed by crystallization in chondrules (18,19,22), and not by condensation from a nebula (15,20).

Conclusions. Despite some differences in the proportions and compositions of these varieties of chondrules in H, LL, CO, CM and E chondrites, there are enough similarities to suggest that chondrules in all these groups share similar origins.

References: 1) E.R.D. Scott et al. (1982) Lunar Planet. Sci. XIII, 704. 2) R.T. Dodd (1981) Meteorites, A petrologic-chemical synthesis. Cambridge Univ. Press. 3) H.Y. McSween Jr. (1977) GCA 41, 477. 4) H.Y. McSween, Jr (1977) GCA 41, 1777. 5) G.E. Lux et al. (1981) GCA 45, 675. 6) E.R. Rambaldi and J.T. Wasson (1981) GCA 45, 1001. 8) Our unpublished data. 9) L. Grossman et al. (1979). Science 206, 449. 10) R.T. Dodd (1971) Contrib. Mineral. Petrol. 31, 201. 11) E.R.D. Scott et al. (1982) Conf. on Chondrules and their Origins, LPI Contrib. 493, 54. 12) J.A. Wood (1967) GCA 31, 2095. 13) J.F. Kerridge and J.D. Macdougall (1976) EPSL 29, 341. 14) A.L. Graham et al. (1977) Mineral Mag. 41, 201. 15) E. Olsen and L. Grossman (1978) EPSL 41, 111. 16) K. Fredriksson and K. Keil (1964) Meteoritics 2, 201. 17) R. Hutchison and R.F. Symes (1972) Meteoritics 7, 23. 18) H.Y. McSween Jr. (1977) GCA 41, 411. 19) S.M. Richardson and H.Y. McSween Jr. (1978) EPSL 37, 485. 20) L. Grossman and E. Olsen (1974) GCA 38, 173. 21) G.R. Huss et al. (1981) GCA 45, 33. 22) H. Nagahara and I. Kushiro (1982) Lunar Planet. Sci. XIII, 562.

Fig. 1. Mean compositions of olivine in 164 chondrules in type 2 and 3 chondrites.