PETROLOGY OF FeO-POOR, PORPHYRITIC PYROXENE CHONDRULES IN THE
SEMARKONA ORDINARY CHONDRITE. Rhian H. Jones, Institute of Meteoritics, University
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A suite of porphyritic pyroxene-rich chondrules in the unequilibrated ordinary chondrite,
Semarkona (LL3.0) has been examined in order to interpret their conditions of formation.
Classification of these chondrules may be made based on their textural properties [1,2], which
correlate well with their compositional properties. Types IAB and IB chondrules are porphyritic
olivine pyroxene (POP) chondrules that are generally FeO-poor, with mean Fs lying in the range
2-10 mole% in low-Ca pyroxene. These two textural types, which form a continuous series of
textural and compositional properties, have been examined in detail as part of a systematic study
of Semarkona chondrules.

General description. Types IAB and IB chondrules are usually well rounded, with diameters
approximately 0.3-1.0 mm. They contain phenocrysts of low-Ca pyroxene and olivine, and
small, rounded olivine grains are observed poikilitically enclosed in low-Ca pyroxene. Low-Ca
pyroxene grains are commonly rimmed with discontinuous overgrowths of augite. Mesostasis is
not very abundant (<10 vol%), and is usually glassy with fine microcrystallites. Minor amounts
of Fe,Ni metal are present as round blebs throughout the chondrule.

Low-Ca pyroxene. Low-Ca pyroxene phenocrysts are euhedral and tabular, and show multiple
twinning characteristic of unequilibrated chondrites. Mean FeO and CaO contents are plotted in
the accompanying abstract [2]. Mean minor element contents of individual chondrules lie in the
ranges TiO2 = 0.03-0.08, Al2O3 = 0.2-0.7, Cr2O3 = 0.5-0.8, MnO = 0.1-0.4, CaO = 0.1-0.3 wt%.
FeO and minor element contents show little or no overall zoning from cores to edges of grains.
However, a common feature exhibited in these pyroxenes is a faint lamellar zoning or banding
observed in back-scattered electron images (BSEI). The zoning consists of dark and light bands,
with widths of individual lamellae varying between 1-20 μm. Microprobe traverses
perpendicular to the lamellae show compositional variations that may be correlated with the
zoning (Fig. 1). However, the observed variations between light and dark bands are only of the
order of 0.3 wt% FeO, and statistical variations during microprobe analysis cannot be ruled out.
The banding is parallel, and similar in width, to the observed multiple twinning, but it is not
possible to determine whether twin planes and edges of bands are coincident. This zoning
feature is similar to that described in partially equilibrated chondrites (types 3.4-4), where it has
been attributed to diffusion of Fe during metamorphism [3,4]. Such an origin can be ruled out
in Semarkona, in which virtually no Fe-Mg diffusion related to metamorphism has occurred.
In support of this argument, no diffusion of Fe is observed along grain boundaries and cracks of
olivine grains in the same chondrules as the banding is observed. The zoning must therefore be
a primary feature, probably resulting from disequilibrium oscillatory zoning during chondrule
formation. It is likely to be the precursor of the zoning in partly equilibrated chondrites, and
appears to become more pronounced in appearance during metamorphism [3].

Ca-rich pyroxene. Ca-rich pyroxene (augite) occurs as thin rims on low-Ca pyroxene grains, up
to 20 μm in width. It is rich in Al2O3 and TiO2: means for individual chondrules range up to 18
wt% CaO, 11 wt% Al2O3 and 1 wt% TiO2. Compositions are similar to those reported by [5].
TiO2, Al2O3 and CaO are strongly correlated and are generally zoned with increasing oxide
contents towards the outer edges of grains. FeO contents of augites are generally higher than
those of corresponding low-Ca pyroxenes (up to 4 mole% higher - see Fig. 2). Augites are not
zoned in FeO. In general, there is a sharp interface between low-Ca and Ca-rich crystals.
However, rarely a narrow intermediate zone is observed in BSEI which is probably pigeonite.

Olive. Olivine is present as two distinct occurrences: as larger (typically 150 μm), euhedral,
equant phenocrysts (type IAB chondrules), and as smaller (typically 25 μm), rounded grains
poikilitically enclosed in low-Ca pyroxene. Olivine and low-Ca pyroxene compositions from
individual chondrules have similar Fe/(Fe+Mg) ratios, plotting close to a 1:1 line on a plot of
Fs/Fa (Fig. 2). In some type IAB chondrules with higher FeO contents, FeO contents of
poikilitic olivines are significantly higher than FeO contents of phenocrysts (Fig. 2). This is an
indication of considerable disequilibrium during chondrule formation, and suggests that olivine

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phenocrysts crystallized before low-Ca pyroxene. The poikilitic texture has been reproduced experimentally at cooling rates of 100 °C/hr, from starting material in which no olivine is present [6]. Mean minor element contents of olivine from individual chondrules lie in the ranges: MnO = 0.2-0.5, CaO = 0.07-0.14, Cr₂O₃ = 0.4-0.7 wt%. Al₂O₃ and TiO₂ contents are generally below microprobe detection limits. In more FeO-rich chondrules olivine is normally zoned with increasing FeO towards the edges of grains which can be observed in BSEI.

Mesostasis. Microprobe analyses of mesostases show that it is rich in SiO₂ (55-70 wt%), Al₂O₃ (12-20 wt%), CaO (1-12 wt%) and Na₂O (1-7 wt%). FeO contents are in the range 1-10 wt%.

Relic grains. Two of the chondrules studied contain "dusty" relic olivine grains. These are large (200 μm) olivine grains with abundant metal incorporated, and are very similar to dusty grains that have been described previously [7,8]. However, their CaO contents are not unusually low, as has been noted previously, and are similar to those of host chondrule olivines (0.1 wt% CaO). In both cases, the relic olivines have FeO contents higher than host chondrule olivines (2 and 4 wt% FeO higher). In a third chondrule an unusual type of relic grain is observed which appears to be a relic barred olivine grain. The barred olivine is enclosed by both glass and low-Ca pyroxene and is more FeO-rich than olivine phenocrysts in the same chondrule.

Summary. Types IAB and IB porphyritic olivine chondrules are complex assemblages of disequilibrium phases, consistent with rapid cooling during chondrule formation. Faint, banded zoning in low-Ca pyroxene is likely to be a feature of rapid disequilibrium growth, and is probably the precursor of similar, but more pronounced, zoning in partly equilibrated chondrites. A more detailed interpretation of the results discussed will enable the formation conditions of these chondrules to be better understood.


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